GARTEUR

ANNUAL REPORT 2016

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

GARTEUR ANNUAL REPORT 2016

Contents

1 INTRODUCTION

GARTEUR was established in 1973 to facilitate research and technology (R&T) collaboration in aeronautics between European countries. It represents a unique forum, providing the only framework for civil and military R&T collaboration across Europe. Drawing upon leading R&T representatives from government departments, national research institutions and industry, GARTEUR addresses the challenges of aeronautics through its Groups of Responsables (GoRs) and Action Groups (AGs).

In January 2016 the United Kingdom assumed the biennial chairmanship of GARTEUR, succeeding France. The UK thanks France for its excellent chairmanship over the past three years. Administrative and strategic support to the UK chair has been provided by the UK Aerospace Technology Institute (ATI) – an organisation created by the UK government and aerospace industry in 2013 to create and implement a technology strategy for civil aerospace in the UK.

The UK chairmanship has focused on developing a strategic road-map for GARTEUR, providing a clear illustration of the past and present work of the Action Groups and providing guidance on future research projects. It proposes to bring research within GARTEUR in line with the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council for Aviation Research in Europe (ACARE), while still allowing scope for radical innovation and the low technology readiness level (TRL) research that lies at the heart of GARTEUR. In June 2016, GARTEUR took the initial steps towards this aim by holding a road-mapping session attended by GARTEUR Council members and the chairs of the Groups of Responsables. During the remainder of 2016 the road-map continued to develop and is expected to be ratified by the council in 2017.

The UK is grateful to its GARTEUR colleagues for their support and collaboration, in particular to those French, German, Swedish and Dutch colleagues who hosted GARTEUR meetings during 2016.

2 EXECUTIVE SUMMARY

This 2016 report summarises the main actions of the council and the scientific and technological progress made by the five GoRs. The report has been prepared by the executive committee for the 63rd council meeting that will be held on the 16th & 17th November 2017 in the UK.

Chapter 3 provides a summary of council activities, including the changes in chairmanship and membership, and information on the GARTEUR road-map. A list of colleagues receiving certificates in recognition of their services to GARTEUR is included, along with information on the GARTEUR website.

Chapter 4 reports on the European aeronautical R&T environment by highlighting the importance of Horizon 2020, Flightpath 2050 and the ACARE Strategic Research and Innovation Agenda (SRIA) to civil aviation. The close involvement of GARTEUR members with ACARE is also described. Developments in military aeronautical strategy within Europe are also discussed, with information provided on the European Defence Action Plan, the military perspective on the Single European Sky programme and the benefits that may be available to aeronautic development from EU-funded defence research.

GARTEUR scientific and technical activities are reported in chapter 5, with each of the five GoRs presenting a summary of their work during 2016. This document is accompanied by annexes presenting a more detailed account of GoR activities; these are available in electronic format from the GARTEUR website at http://www.garteur.org/index.html.

Chapter 6 provides two success stories which provide examples of the benefits of GARTEUR membership in facilitating excellent research.

Finally, the appendix includes various administrative details pertaining to the GARTEUR organisation and GoR activities.

3 GARTEUR COUNCIL

3.1 Chairmanship and membership

On 1st January 2016, the United Kingdom succeeded France as chair of GARTEUR. The UK chairmanship will last for two years, ending on 31st December 2017, when the chair is passed to Spain.

During 2016 the chairman of the council was Louis Barson 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. Due to career developments, Louis Barson stepped down in 2016 and is succeeded by Paul Griffiths, also of BEIS.

Two secretaries, Ioannis Goulos from Cranfield University and George Kwofie from Cranfield Aerospace, served GARTEUR sequentially during 2016.

Henk van Leeuwen of The Netherlands, retired from his position as a national delegate of the council after lengthy service. The remaining council members are unchanged since 2015. See appendix 1 for a full list of council, executive committee and GoR members.

3.2 GARTEUR meetings

GARTEUR council meetings and executive committee meetings are both biannual events. Prior to the council meetings the GoR chairs and executive committee members meet to discuss the scheduled topics for the council in detail and to prepare proposals for the council. The council meetings bring together the members of 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. During these meetings, each delegation provides an update on recent developments at national level in research and development in civil and military aeronautics. The multidisciplinary nature of the council meetings provides excellent opportunities for dynamic collaboration and an exchange of expertise and varied perspectives.

In 2016 the C60 meeting held in Paris, France on 17th and 18th March, was the first meeting of the UK chairmanship and was chaired by Louis Barson. Gratitude was expressed for the excellent chairmanship delivered by the French during the preceding years. Looking forward to the two-year British chairmanship, Mr Barson stated that the focus would be on improving the impact of GARTEUR through actioning road-mapping activities. Subsequently a dedicated road-mapping session was convened for the GoR chairs and council members during June of that year, to ensure that GARTEUR remains focused and committed to the major challenges being addressed by pan-European aerospace research and innovation.

During 2016 an executive committee meeting was held in Stockholm, Sweden on 13th September, as a precursor to the 61st council meeting held in Hamburg, Germany on 13th and 14th October. During the council meeting, the chair of GoR Aerodynamics, Harmen van der Ven, reported on the effectiveness of the June road-mapping session and led a discussion on the results and actions arising from the meeting. The GARTEUR road-map is discussed in detail in the following section.

The council meeting also provided an opportunity to host Sebastiano Fumero, head of the aviation unit at the European Commission directorate general for research and innovation. Dr Fumero discussed some of the significant issues the Commission is currently considering and the future of the next Framework Programme following Horizon 2020.

3.3 GARTEUR Road-map

With an aeronautical research and technology portfolio spanning more than 40 years, GARTEUR has delivered a wealth of leading-edge projects. Although mostly low TRL, the majority of current projects remain broadly guided by the targets set out in the ACARE Strategic Research and Innovation Agenda (SRIA), as well as defence drivers set out by the respective governments of the GARTEUR delegations. At the highest level, the purpose of the GARTEUR road-map is to permit a review of past and current GARTEUR activities, thus ensuring a common research goal within GARTEUR and alignment with wider European activities.

By giving visibility to past, current and potential future projects across the five GoRs, the chairs and members of the GoRs can systematically review the relevance of their action groups, exploratory groups or EU collaborations to the wider GARTEUR strategy, in addition to identifying links and interdependency between projects. The road-map enables them to identify collaboration opportunities both within and across the GoRs, and provides a way to measure impact against ACARE and defence targets.

By the end of 2016 the GoR chairs had completed most preliminary work with regards to road-mapping and are now in a strong position to consider the importance of this strategy to GARTEUR and the type of tools they need to facilitate its use.

Decisions on the long-term use of the road-map are scheduled to be made at the 62nd council meeting in March 2017.

3.4 GARTEUR website

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

For the use of the GoRs, the site is also used as a depository for minutes and other documents. During 2016 the website was regularly updated by the secretary.

3.5 GARTEUR certificates

In 2016 GARTEUR certificates were awarded to past members of the council, GoR chairs, industry points of contact (IPoCs), and secretaries, in recognition and appreciation of services rendered to GARTEUR.

France		
Anne-Laure Delot	GARTEUR secretary 2013 to 2015	ONERA
Odile Parnet	Member of GoR Helicopters	AIRBUS
Virginie Wiels	Chair of GoR Aviation Security	ONERA
Germany		
Philipp Krämer	Member of GoR Helicopters	AIRBUS
The Netherlands		
Henk van Leeuwen	Council member	NLR
Rob Ruigrok	Chair of GoR Flight Mechanics, Systems & Integration	NLR
Henri de Vries	Member of GoR Structures & Materials	NLR
Sweden		
Renaud Gutkin	Member of GoR Structures & Materials	SICOMP
UK		
Louis Barson	GARTEUR Council Chair for 2016	BEIS
Ioannis Goulos	GARTEUR secretary 2016	ATI
George Kwofie	GARTEUR secretary 2016	ATI
Mark White	Chair of GoR Helicopters	Liverpool University

Table 1 Awardees of GARTEUR Certificates

4 THE EUROPEAN AERONAUTICS RTD ENVIRONMENT

4.1 Civil aeronautics

Civil aeronautics research and technology development (RTD) in Europe is centred around the research calls associated with the EU Framework Programmes.

The current Framework Programme - Horizon 2020 - has been apportioned over €70 billion in grants, loans and incentives over seven years (2013-2020) for researchers, engineers and entrepreneurs and as the largest EU Framework Programme, it 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.

For aeronautics, Horizon 2020 provides funding aimed at resource efficient transport that respects the environment by making aircraft, vehicles and vessels cleaner and quieter. Horizon 2020 is also aimed at creating better mobility, less congestion and more safety and security.

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 environmental 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.

The purpose of volume 2 of the SRIA is to turn the high-level goals in Flightpath 2050 and Volume 1 into a series of specific and time-bound research and innovation objectives to guide the work of research and innovation teams across Europe.

Throughout 2016, the SRIA has been the subject of a review, in order to take into account developments that have happened since the document was last issued in 2004. Topics that have been identified as requiring modification include aviation security, the competitiveness of European manufacturing, the use of big data and an increasing focus on the inter-modality of transport. In addition, there is a desire to simplify the document and the revised document will be produced within the parameters of a simplified structure. The revision of Volume 1 was launched at the Paris Airshow in June 2017, with Volume 2 being updated later in 2017.

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 EC 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. 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 Clean Sky.

4.2 Military aeronautics

The European Defence Agency (EDA) is an intergovernmental agency of the Council of the European Union, comprising 28 members less Denmark and also including four non-EU member states through special administrative arrangements (EDA 2016b). Through close cooperation the EDA seeks to improve European defence through supporting the development of capabilities and nurturing technology and research to meet the future defence requirements and to promote defence interests in wider EU policies. The EDA operates at ministerial level and includes over 4000 national based experts collaborating on projects.

4.2.1 European Defence Action Plan

In September 2016 Jean-Claude Juncker, President of the European Commission called for the creation of a European Defence Fund as part of a new European Defence Action Plan, which was subsequently adopted by the European Commission (EDA 2016a). The fund will have two distinct structures known as windows, one focused on research into defence technologies and products and the other focused on financing the joint development of defence capabilities. The research and capability windows are expected to have budgets in the region of €90m until 2020 and €5bn per year respectively. The fund will aim to improve Europe's commitment to defence spending, in order to improve Europe's defence capabilities and also to strengthen the EU defence industry which is a major contributor to the European economy. In response to these developments the EDA is reviewing its engagement with industry and R&T.

4.2.2 Single European Sky Military Aviation Board

As Europe seeks to modernise its air traffic management with the Single European Sky (SES) programme, the EDA is ensuring that defence issues are strongly represented. The military have been likened to the largest airline in Europe with more than 11,000 aircraft currently stationed in Europe, contributing to more than 150,000 flights per year (EDA 2016c). To ensure the requirements of the military are represented, the EDA has established the SES Military Aviation Board (EDA 2016d). The Board held its first policy level meeting in May 2016, which brought together representatives from the participating Member States and yielded agreement on priorities regarding upcoming SES milestones from a military viewpoint.

4.2.3 European Union funded defence research

In 2016 the EDA became the conduit for the EU's pilot project to fund defence research. Having received 21 proposals from collaborators spanning 20 countries, the EDA awarded three grant agreements worth a total of €1.4m in October 2016 (EDA 2016a). Two of the awards are of particular interest to aeronautics, namely the 'Standardisation of Remotely Piloted Aircraft System (RPAS) Detect and Avoid (TRAWA)' which seeks to enable the widespread use of RPAS in non-segregated airspace in Europe through supporting the development of standards for the certification of detect and avoid solutions; and the 'Unmanned Heterogeneous Swarm of Sensor Platforms (EuroSWARM)' which expects to deliver a control and command architecture for autonomous and heterogeneous swarms of sensors, that may be applied to critical European and global challenges such as border control or surveillance-security. This pilot project is the first step in the EU's Preparatory Action on Common Security and Defence Policy Related Research, which has the ambition of developing a European Defence Research Programme (EDRP) as part of the EU's next Multiannual Financial Framework (2021-2027).

4.2.4 Air-to-Air Refuelling and Remotely Piloted Aircraft System programmes

Two new key capability programmes were established in 2016, both with strong aeronautical relevance (EDA 2016a). The Netherlands, a GARTEUR country, leads the Air-to-Air Refuelling (AAR) programming which seeks to tackle the European shortfall in suitable tanker aircraft. AAR is vital for air power protection and to sustain air combat operations. Since the Kosovo campaigns in 1999 it has been clear that Europe has relied heavily on American assets, with European tanker aircraft being too few and varying too greatly in types. Moving forward the European initiative is towards an increased AAR capacity with a reduced fragmentation of the fleet and compatibility with a wider range of air platforms, including near future RPAS. The second key capability programme with an aeronautical emphasis relates to the development of a European medium-altitude long endurance (MALE) RPAS that is to be operational by 2025. This objective is one of the five main RPAS field objectives being pursued by the EDA (EDA 2016e). The programme allows for a two year definition phase that is managed by OCCAR on behalf of GARTEUR countries France, Germany, Italy and Spain (OCCAR-EA 2016). The definition study is performed by three co-contractors: Airbus Defence and Space GmbH, Dassault Aviation and Leonardo S.p.a. The EDA is providing targeted support by facilitating the air traffic integration of the future systems and by establishing the RPAS Airworthiness Regulatory Framework. The framework encourages co-ordination between EU Member States and expects that common military airworthiness and certification requirements for military RPAS will be available by 2018, which would lead to the operation of military RPAS in non-segregated airspace.

5 SUMMARY OF GARTEUR TECHNICAL ACTIVITIES

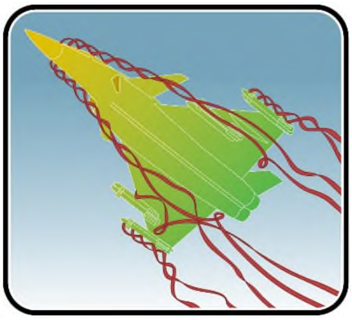
During 2016 the five GARTEUR Groups of Responsables continued to facilitate and deliver vital research in the field of aeronautics and the GARTEUR council had the pleasure of welcoming three new GoR chairs as the biennial rotation brought in new leadership. Herman van der Ven of the NLR succeeded Frank Ogilvie as chair of GoR Aerodynamics (AD), while Philippe Beaumier of ONERA replaced Mark White as chair of GoR Helicopter (HC) and Angela Vozella of CIRA replaced Virginie Wiels as chair of GoR Aviation Security (AS).

The GoRs are responsible for monitoring and encouraging the progress of action groups and exploratory groups. Such 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 will aid potential research consortiums by critically reviewing their proposed research objectives and methodologies. The GoRs will guide the embryonic research projects to remain 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.

In 2016 GoR AD had five action groups (AGs) and initiated four exploratory groups (EGs). Three of the five AGs have completed their technical activities and are mostly involved with the delivery of their final report. During 2016 GoR AD produced four conference papers and one book. The recently established GoR AS is considering the development of four new EGs and during 2016 placed particular emphasis on engaging industry in discussions on a shared approach to tackling the main research topics of this GoR. Six AGs and one EG were monitored by GoR HC with two of the AGs approaching their final stages of dissemination. During 2016 GoR HC AGs contributed to one journal article and fifteen conference papers. 2016 was a challenging year for GoR FM with budget reductions impacting on two EGs, preventing them from progressing onto action group status. However pilot papers explored the possibilities of future research in several topics. GoR SM continued to monitor the progress of two AGs and three EGs, with one of the EGs moving towards AG proposal.

A summary of the technical activities of GARTEUR is presented below; more detailed information on the research and administration relating to the GoRs can be found in the annexes to this report. An electronic copy of the annexes can be found on the GARTEUR website: http://www.garteur.org/index.html

5.1 Group of Responsables – Aerodynamics (AD)

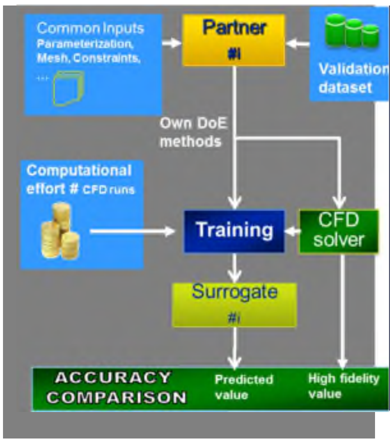


The GoR AD initiates and organises basic and applied research in aerodynamics. Whilst in general terms aerodynamics makes up the majority of the research done within the GoR, some work has a significant amount of multi-disciplinary content. This trend is driven by industrial interests, and the importance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

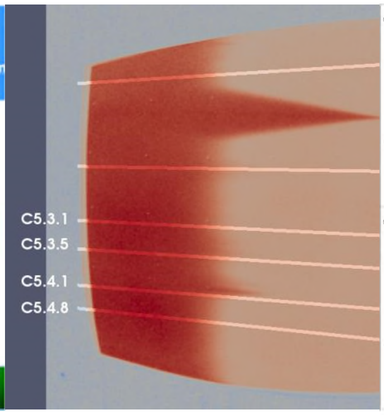
The current scope of the aerodynamic activities in the GoR covers the following:

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

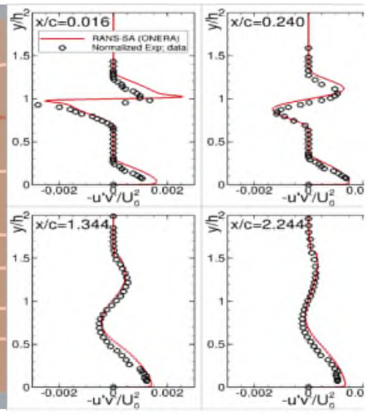
In all fields a synergy between experiments and simulations is aimed for.



Surrogate modelling flow chart (AG-52)

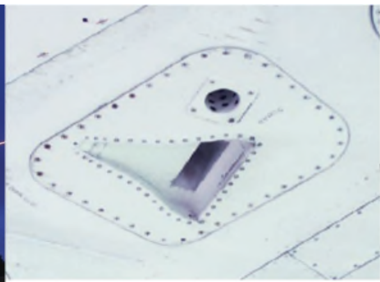


Temperature sensitive paint for transition detection (AG-53)

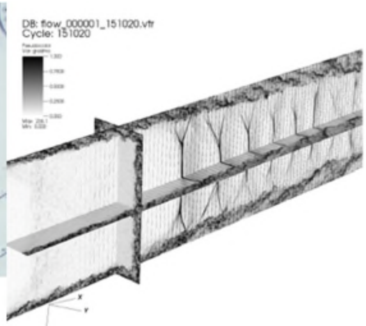


Validation of zonal method for co-flow of boundary layer and wake (AG-54)

Flare trajectory experiment (AG-55)



Secondary inlets and outlets (EG-73)



Supersonic air intakes (EG-75)

Figure 1 Illustration of the Group of Responsables Aerodynamics

In 2016, 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-52	*Surrogate-Based Global Optimization methods in aerodynamic design* To develop and assess optimization methods using low-fidelity models For shorter time-to-market of new aircraft
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 started:

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 light-weight 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

New topics which are under consideration are:

Vortical flows on transonic and supersonic slender configurations To understand and predict flow separation on slender configurations
Simulation of the flow in S-ducts To understand and predict the flow phenomena in curved inlets
Design of an experiment for the basic understanding of synthetic jets To design a detailed experiment for the flow inside and outside a synthetic jet in cross flow
Laminar bubbles To calibrate existing RANS turbulence models when laminar bubbles are present
Non-intrusive characterization of the laminar wing surface To develop measurement techniques to detect transition on naturally laminar wings in real flight

In 2016, the first steps have been taken in the development of research road maps which will be used to identify knowledge gaps.

The membership of GoR-AD in 2016 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
Per Weinerfelt	SAAB	Sweden
Torsten Berglind (till mid 2016)	FOI	Sweden
Magnus Tormalm (from mid 2016)	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
Chris Newbold	QinetiQ	United Kingdom

Table 2 Membership of GoR AD in 2016

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

AD/AG-52: SBGO methods for aerodynamic design

Action Group Chairpersons: Dr. E. Andrés (INTA) and Dr. E. Iuliano (CIRA)

Background

Surrogate-based global optimization methods (SBGO) can meet the requirement of performing a broad exploration of the design space, as they have the ability to work with noisy objective functions without assumptions on continuity and with a high potential to find the optimum of complex problems. However, global optimization methods involve a vast number of evaluations even for a small number of design variables. As each evaluation requires a CFD complete analysis, this would make the method unfeasible, in terms of computational cost. Therefore, there has been a **raising interest in surrogate modeling** which promises to provide sufficiently accurate solution of complex problems with reduced computational efforts.

Main work focused on the assessment of different surrogate modeling techniques for fast computation of the fitness function and the evaluation of SBGO strategies for the shape design of the selected configurations..

Specific challenges: Deal with the "curse of dimensionality", off-line and on-line model validation strategies, proper error metrics for comparison, efficient DoE techniques for optimal selection of training points towards validation error mitigation, reduction of the design space, improvement of surrogate accuracy at fixed computational budget, and variable fidelity models.

Aerodynamic applications: Aerodynamic shape optimization problems in an early stage. "Best practice" guidelines for the industrial use of SBGO methods

Partners: Research, academic organizations and industries: INTA, CIRA, AIRBUS-Military, Brno University of Technology, FOI, ONERA, SAAB, University of Alcala and University of Surrey.

Programme/Objectives

Main objectives: To analyze the feasibility and possible contributions of SBGO methods in an early phase of the aerodynamic design, where the design space will be broadly analyzed to get the optimum solution

Project duration: 3 years (2013-2016)

Work plan: The work in AG52 is divided into three tasks. Task 1 and 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3.

AG52 Work Breakdown Structure

- **Task 1 Basic configurations**: To make comparatively studies of partners' simulations to highlight the benefits and drawbacks of different SBGO methods
- **Task 2 Industrial-relevant configurations**: To validate the experience gained from T1 in designing industrial-relevant configurations
- **Task 3 "Best Practice" Guidelines**: To give a clear statement about the possibilities and restrictions in using SBGO methods. To facilitate their **use in aeronautic industries**

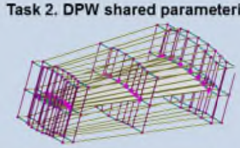
Two test cases are defined in Task 1:
TC 1.1 RAE2822 airfoil
Design points: DP1 M=0.734, Re=6.5x106, AoA=2.65º. DP2 M=0.754, Re=6.2x10^6, AoA=2.65º
Objetive: maximize C_L/C_D

TC 1.2 DPW-W1 wing
Design points: DP1: M=0.76, C_L=0.5, Re=5x10^6, DP2: M=0.78, C_L=0.5, Re=5x10^6, DP3: M=0.20 and C_L^{max} (optima) >= C_L^{max} (original). Objetive: Minimize C_D with constant C_L

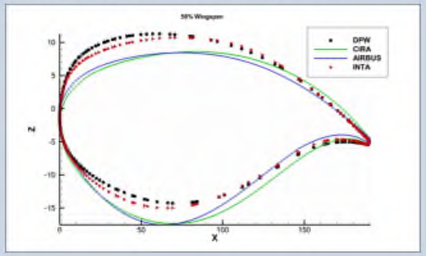
Task 1.2 Surrogate models comparison

	Mean OF (TAU, MSES, ZEN 3 levels)	Mean OF (only TAU and ZEN fine)
RAE 2822 baseline	1	1
CIRA-POD	0.6223	0.6266
CIRA-EGO	0.6208	0.6236
INTA/UAH	0.6243	0.6211
ONERA	0.6494	0.6498
UNIS	0.6367	0.6338
VUT	0.6969	0.7063

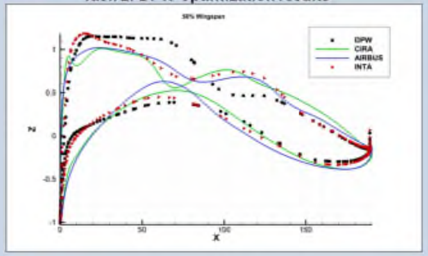
Task 2. DPW shared parameterization



In order to minimize the sources of discrepancies and allow a fair comparison between surrogates, the **geometry parameterization**, the **computational grids** (unstructured and structured) and the **surface deformation algorithm** are **shared** between all partners.



Task 2. DPW optimization results



Results

- Assessment of SBGO methods investigated by AG members in terms of their respective advantages and disadvantages for the application to the aerodynamic shape design, by means of cross comparisons of solutions.

Partial reports delivered:
- PR01: RAE2822 definition and common geometry parameterization
- PR02: DPW-W1 definition and common geometry parameterization
- PR03: Strategy for surrogate validation in aerodynamic shape optimization
- PR04: CFD cross-analysis
- PR05: Summary of task 1 results
- Final AG52 report (to be delivered)

Current Status:
This group has finished. Main activities are summarized here:
- Common data (parameterization, grids and surface mesh deformation) for all TCs of Task1 were made available for surrogate model validation and optimization comparison:
- Common meshes for all the test cases
- Geometry parameterization for all the defined test cases
- Surface deformation tool and volume mesh deformation tool executable
- NURBS parameterization parser
- Tutorials for the common tools
- A website has been created for dissemination: www.ag52.blogspot.com
- A CFD cross-analysis to identify the error sources of using different CFD solvers was performed.
- Results on task 1 (surrogate validation and rae2822 optimization) have been provided
- Results on task 2 (opt of the dpw) have been provided by CIRA, AIRBUS and INTA.
- Participation and organization of Special Sessions at EUROGEN 2013, ECCOMAS 2014, EUROGEN 2015 and ECCOMAS 2016.
- Organization of the EUROGEN 2017 in progress (eurogen2017.etsiae.upm.es/)

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

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

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

Background

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

Programme

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

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

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

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

The Outcomes

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

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

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

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

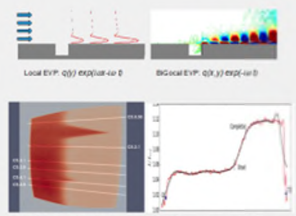
KTH have completed highly accurate simulations of the leading-edge acoustic receptivity, showing pervious results overestimating the receptivity coefficient. KTH has also performed direct numerical simulations of the interaction of acoustic waves with roughness-induced crossflow vortices, corresponding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

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

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

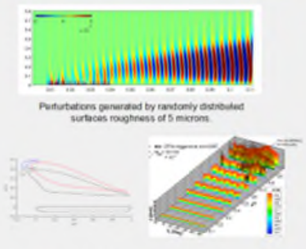
Gap Analysis

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



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

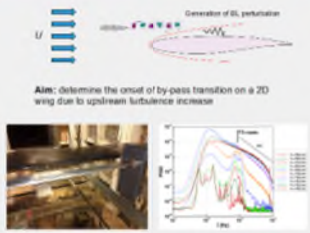
Receptivity model development



Perturbations generated by randomly distributed surfaces roughness of 5 microns.

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

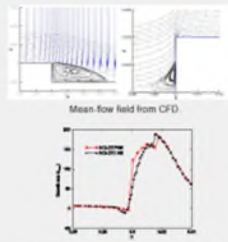
Receptivity & transition experiment



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

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

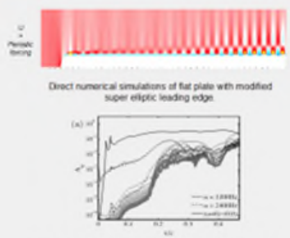
Backward/Forward-facing step



Mean-flow field from CFD.

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

Leading-edge acoustic receptivity



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

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

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

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
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AD/AG-54: RaLESin

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

Action Group Chairman: Dr 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, ZUAS

Programme/Objectives

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

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

Task 1: Non-zonal modelling methods

(Task Leader: **NLR**)

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

TC M1 Spatially developing mixing layer

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

TC O1 Backward-facing step flow

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

Task 2: Zonal modelling methods

(Task Leader: **UniMan**)

For models with the location of RANS-LES interface prescribed, Including embedded LES. Two TCs are defined.

TC M2 Spatially developing boundary layer

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

TC O2 NASA hump flow

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

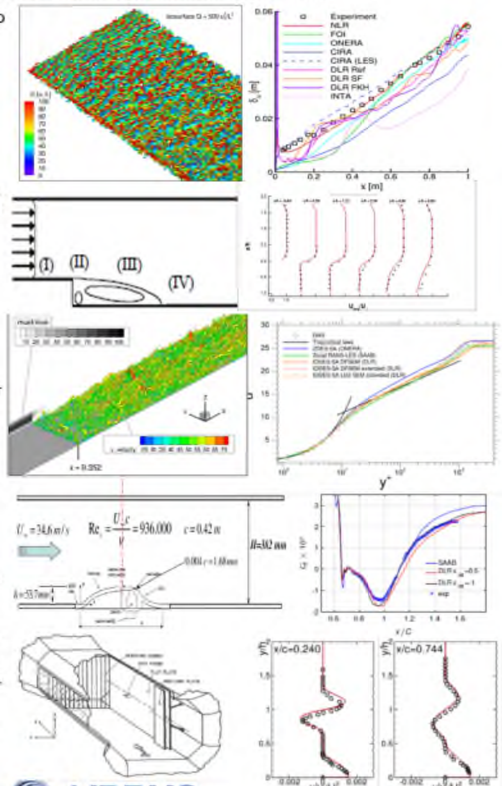
Task 3: Modelling assessment

(Task Leader: **Airbus-Innovations** (EADS-IW))

Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.

TC M3 Co-flow of BL and wake

Re = 2.4x10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.



Results

- Further evaluation of existing hybrid RANS-LES methods of zonal and non-zonal modelling in computations of 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 three 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 progressing on, among others, using stochastic backscatter model plus temporal and spatial correlation, velocity-gradient-based energy backscatter, vorticity-based length scale and other verified hybrid length scale.
- 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 collected 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 preliminary cross plotting.
- The 1st and 2nd progress meetings were held in Oct. 2014, Oct. 2015 & Nov. 2016, respectively.

AIRBUS AIRBUS GROUP CIRA DLR FOI INTA nlr SAAB ONERA MANCHESTER 1824 The University of Manchester zh aw TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

5.2 Group of Responsables – Aviation Security (AS)

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 RPAS.

Four research themes have been identified and four corresponding exploratory groups are under consideration:

- AS/EG-1 (Cybersecurity): Towards an Information Security Management System for the aviation sector;
- AS/EG-2 (CBE): Enhancing airport security against CBE threats;
- AS/EG-3 (Dazzling): Detection of threatening laser radiation on aircrafts or helicopters for future protection of pilots;
- AS/EG-4 (RPAS): Analysis of new threats posed by malevolent use of Unmanned Aerial Systems (UAS) and/or Remote Piloted Aircraft Systems (RPAS). Threat mapping.

GoR activities

The main activity in 2016 was engaging with industry to identify their priorities in these domains, the analysis of other similar initiatives in aviation security, and the definition of a shared approach. A preparatory meeting was held by WebEx in February 2016, enabling the list of participating industries and the approach to be finalised. The GoR has presented its work both to EASA and Eurocontrol, and various GoR members are also involved in ACARE working group 4 (safety and security), enabling the GoR to fit in around existing initiatives and avoid duplication of effort.

Industrial partners who have expressed interest in the GoR include:

- GE aviation
- Airbus Group
- Airbus Defence and Space
- CS
- Selex ES Finmeccanica
- Rhode Schwarz
- BAE systems
- Gifas

A one-day meeting was organized on April 21st 2016 at ONERA in Toulouse to present the GoR and discuss potential collaborations. The meeting focussed on the following topics:

- GARTEUR and AS GoR;
- Cybersecurity;
- Malevolent use of RPAS;
- Industrial interests and activities; and
- Discussion and planned actions.

The presentation on cybersecurity was given by René Wiegers and Angela Vozella.

Security, and specifically cybersecurity, is spread over different domains and it is necessary to capitalize on existing knowledge and experience. Though cybersecurity is a large domain, there are specificities for aviation: certification brings specific constraints; aircraft are specific entities where a pilot is in charge; the international nature of aviation (which can be an issue with respect to IT rules). The GoR should address these specificities.

Assessing risk: avionics has a history of closed systems; the current move to openness is not accompanied by a sufficient awareness of security issues. A first necessary step is thus a total risk assessment of the aviation system life cycle and its different, potentially conflicting, challenges e.g. safety, security, performance, competitiveness. A potential difficulty is that companies are very protective about security issues, and it may be difficult to share information. The right starting point is to share needs, vision, and methodologies. However, security, like safety, represents a European priority and there are benefits and opportunities in cooperation also at precompetitive level (such as for example the UK avionics industry working group). There is also a need to share an acceptable level of the likelihood of threats (as is done for safety).

Contribution to SRIA: the update of SRIA represents a chance for GARTEUR to contribute, validating and complementing the issues raised in ACARE working group 4. The existing links and interrelations among people involved in the different groups within aviation security will avoid duplication of effort and enable a more efficient process.

The following provides a summary of industrial interests and activities collected during the meeting:

Finmeccanica

- GAMMA (SESAR) initiative in cybersecurity
- Participation in the European cybersecurity PPP platform
- ATP platform on safety and security in definition (not only aviation)

CS BOREADES project: civilian drone neutraliser system for critical infrastructures - Topics of interest:

- security supervision on board and on ground
- Communication security ground/board (post-quantic, long term, new generation of cryptography)
- Security standards (exchange format, cyber joint common exchange picture)

BAE Systems:

- Risk assessment
- Security assurance
- Security management systems
- Maintaining security over life of the aircraft

Airbus Group:

- CBE detection for on-board security
- Dazzling
- MalURPAS: future threats (not only current threats)
- Cybersecurity: main upcoming revolution is SWIM (SESAR). Long term perspective is necessary too.

Rohde Schwarz:

- Military and civil (secure communications – air traffic control)
- ICONAV project (with DLR)
- A/G communication systems
- Member of Eurocontrol Security sub-group, will ask for permission to disseminate information and make the link between the two groups

Presentation on MalURPAS (Francisco Munoz Sanz): National directives have been published (Italy in September 2015 for example), they should be taken into account by the GoR. Large scope but the GoR should focus on more specific topics:

- Control link
- Future threats: swarm of UAVs, UAVs with auto navigation system
- Increase the ability of RPAS to be safer (sensing capabilities, visual detection technologies)
- Coordinate with FM GoR to profit from GARTEUR multidisciplinary aspect

Main results concern:

- Agreement on the need to target critical aviation assets, and more specifically aircraft security
- Vulnerability of aircraft against small UAVs (2-10kg).
- Specific issues around engines

Need for risk assessment to properly characterize the specific risks for RPAS (security or safety) and the related scenarios.

Detailed conclusions & decisions for 2017

A global picture of all aspects of aviation security in Europe (including the relevant spective expertise domain) is required in order to set up processes for cooperative working avoiding, duplication, and allowing effectiveness and efficiency.

In this context, the proposed themes, integrated with the interests expressed by the industries involved, should be aligned with the updated SRIA. Specific actions:

SRIA update:

AS GoR will contribute to the SRIA update. Angela Vozella will distribute the current SRIA draft and transfer Garteur AS considerations to WG4.

Cybersecurity: an EG could be launched on risk assessment. René Wiegers will explore this possibility. The objective of this EG would be to see if we could have enough information to define an AG on this topic.

MalURPAS: NLR and CIRA to define a point of contact. ONERA to involve people from the ANGELAS project. Think about defining an EG on vulnerability of aircraft against small UAVs (2-10kg).

Airport security not very present at European level now, Alberto Bianchi (Finmeccanica) will prepare a discussion on this subject for the next meeting.

In June 2016, GARTEUR organized a road-mapping meeting to position GARTEUR work with respect to ACARE SRIA and to define road-maps for each GoR. Concerning AS GOR the road-maps for each of the previous themes include:

Cybersecurity - Towards an information management system for aviation

- Identification of cyber vulnerability for all critical aviation assets
- Identification and development of mitigation actions for cyber attacks
- Integration and continuous risk data collection and analysis

CBE - enhancing airport security against CBE threats

- Verification and evaluation of protection performance for security

Malevolent use of RPAS

- Characterization of threats and possible impact
- Study of the effect of small drone impact on aircraft

During council meeting 61 the GoR was requested to provide more details of specific low TRL research with collaborative potential that could be carried out.

Angela Vozella participated in a consultation by EG to identify research priorities supporting the themes proposed by the GoR.

As well as aligning the GoR with the updated SRIA, some GoR members participated in a further working group launched within EREA (Association of European Research Establishments in Aeronautics), *EREA Security for Aviation Working group* (ES4AWG), to identify common security research priorities. This enables the issues to be worked on in both groups (GARTEUR and ES4AWG) to be harmonised.

6 years rolling Plan for AS/EGs

No	Theme	Topic	2012	2013	2014	2015	2016	2017
AS/EG-1	Cybersecurity	- Towards an Information Security Management System for the aviation sector						
AS/EG-2	CBE	- Enhancing airport security against CBE threat						
AS/EG-3	Dazzling	- Detection of threatening laser radiation on aircraft or helicopters for future protection of pilots						
AS/EG-4	Malevolent use of RPAS	- Analysis of new threats posed by malevolent use of Unmanned Aerial Systems (UAS) and/or Remote Piloted Aircraft Systems (RPAS) - Threat mapping						

Active | Closed
Extended | Inactive

In 2017 the first meeting will take place in July.

Virginie Wiels
Chairman (2014-2016)
Group of Responsables Aviation Security

Chairmanship

Virginie Wiels has been chair for two years, but the current vice-chair Ingmar Ehrenpfordt has informed the GoR that she would not be able to take over the chairmanship due to a disengagement from DLR.

For 2017 the chairman role has been assigned to CIRA (Angela Vozella).

GoR membership 2016

Chairman			
Ms Virginie Wiels	ONERA	France	Virginie.Wiels@onera.fr
Vice-Chairman			
Mr. Ingmar Ehrenpfordt	DLR	Germany	Ingmar.Ehrenpfordt@dlr.de
Members			
Mr. Bernd Eberle	Fraunhofer	Germany	Bernd.Eberle@iosb.fraunhofer.de
Mr. Anders Eriksson	FOI	Sweden	e.Anders.Eriksson@foi.se
Mr. Francisco Munoz Sanz	INTA	Spain	mugnozsf@inta.es
Ms. Angela Vozella	CIRA	Italy	A.Vozella@cira.it
Mr. René Wiegers	NLR	Netherlands	Rene.Wiegers@nlr.nl

Table 3 Membership of GoR AS in 2016

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

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; and
- Scientific and technical expertise for air systems certification and regulatory aspects.

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

GOR activities

In 2016, activities were limited. As identified already in 2015, budget reductions have prevented new ideas from growing and Exploratory Groups from transitioning to Action Groups. The GoR management activity was also reduced due to changes at NLR.

Two Exploratory Groups were identified in 2015, but are not yet active:

- FM/EG-28 “Non-linear flexible civil aircraft control methods evaluation benchmark”;
- FM/EG-29 “Trajectory V&V Methods: formal, automatic control and geometric methods”.

FM/EG-28, has been scheduled to start after several changes in participation and limited budget of interested parties.

FM/EG-29 showed progress but has not yet finalized a starting paper.

New topics were discussed at the GoR meeting and pilot papers identified on several topics, Electric RPAS, Smart RPAS swarms and Upset Condition Detection as well as RPAS as validation flight test platform.

As in 2015, there were no Action Groups active.

Management issues

The GoR met only once during 2016. The EGs were discussed and new topics identified. At the meeting industry and research organizations were present but since only one meeting was held the yearly participation was limited.

Future plans

During 2017 the GoR will continue efforts to establish new EGs and transition EGs into AGs. Changes at NLR resulted in an untimely departure of the previous GoR chair and the change in chair delayed the postponed GoR activities which will be taken up in the second half of 2017.

Managed and foreseen GOR activities

The following meeting was held during 2016:

- 105th GoR(FM) meeting at NLR, Amsterdam, The Netherlands, 5 April 2016;

Eight national representatives and IPOCs attended the meetings during 2016. The estimated effort associated with these activities amounts to 1/2 man-month (10 man-days) in total and the associated travel and subsistence costs are roughly 5 k€.

The following meetings are planned for 2017:

- 106th GoR(FM) meeting TBD.

Martin Hagström: Chairman (March 2017 - March 2019)
Group of Responsables
Flight Mechanics, Systems and Integration

GoR membership

2016 membership of the Group of Responsables Flight Mechanics, Systems and Integration

Chairman			
Mr. Rob Ruigrok	NLR	The Netherlands	ruigrok@nlr.nl
Vice-Chairman			
Mr. Martin Hagström	FOI	Sweden	martin.hagstrom@foi.se
Members			
Mr. Leopoldo Verde	CIRA	Italy	l.verde@cira.it
Mr. Philippe Mouyon	ONERA	France	philippe.mouyon@onera.fr
TBD	INTA	Spain	
Mr. Emmanuel Cortet	Airbus	France	Emmanuel.CORTET@airbus.com
Mr. Bernd Korn	DLR	Germany	Bernd.Korn@dlr.de
Industrial Points of Contact			
Mr. Laurent Goerig	Dassault	France	laurent.goerig@dassault-aviation.com
Mr. Francisco Asensio	Airbus Military	Spain	Francisco.Asensio@military.airbus.com
Mr. Martin Hanel	Cassidian	Germany	Martin.Hanel@cassidian.com
TBD	SAAB	Sweden	

Table 4 Membership of GoR FM in 2016

Status of action groups and exploratory groups

Action Groups (AG) - None.

Exploratory Groups (EG) - Two Exploratory Groups have continued to be in discussion in 2016:

- FM/EG-28 “Non-linear flexible civil aircraft control methods evaluation benchmark”;
- FM/EG-29 “Trajectory V&V Methods: formal, automatic control and geometric methods”.

Within FM/EG-28, which was defined and started in 2013, there were difficulties and changes in participation and limited budget of interested parties. It has been rescheduled to start.

FM/EG-29 showed some progress in 2016.

Future topics

Pilot paper discussed and proposed: Electric RPAS, Smart RPAS swarms and Upset Condition Detection, Prevention and Mitigation (depending on outcome of Future Sky Proposal), RPAS as validation flight test platform and Verifyable adaptive robust control.

Action group reports

No FM Action Groups were active in 2016.

5.4 Group of Responsables – Helicopters (HC)

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 context of 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 campaigns
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines)
- Increase security, safety
    - Security studies, UAVs, advanced technologies for surveillance, rescue and recovery
    - Flight mechanics, flight procedures, human factors, new commands and control technologies
    - Increase crashworthiness, ballistic protection
- Integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations)
- Tackle environmental issues:
    - Greening, pollution
    - Noise (external, internal)
- Progress in pioneering: breakthrough capabilities

Technical disciplines include, but are not limited to: aerodynamics; 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 2 Illustrations of the Groups of Responsables Helicopters

List of Action Groups being monitored by GoR-HC

HC/AG-19 "Methods for Improvement of Structural Dynamic Finite Element Models Using In-Flight Test Data" was started in May 2010 with a three year duration. This AG was extended up to the end of 2016, and the final report was issued in February 2017.

HC/AG-20 "Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction" started in October 2012. The activities in 2016 were focused on the dissemination of the results, and the final report was issued in January 2017.

HC/AG-21 "Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity" was launched in April 2013. The 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.

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. Most of the experimental activities were completed in 2016 and the numerical simulations have been continued. It is expected that HC/AG-22 will close as scheduled at the end of 2017.

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. The University of Glasgow has joined this AG due to the movement of one of the AG members, Professor G Barakos, to that University. A 15-month extension up to the end of 2018 was asked during the C62 Council meeting to complete the activities and propose several publications.

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 three 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 is planned for September/October 2017.

List of Exploratory Groups

HC/EG-29 "Intelligent Lifeing & HUMS" was launched in 2011, and started in April 2013. The exploratory group has not produced its report in 2016 and is expected to conclude its activities in 2017.

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 is 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 helicopters 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
- Man-machine interface requirements for cockpit operations

Table of GoR HC membership

Membership of the Group of Responsables Helicopters (2016):

Chairman			
Mark White	Uni. of Liverpool	United Kingdom	mdw@liverpool.ac.uk
Vice-Chairman			
Philippe Beaumier	ONERA	France	beaumier@onera.fr
Members			
Odile Parnet	Airbus Helicopters	France	odile.parnet@airbus.com
Antonio Antifora	Leonardo	Italy	antonio.antifora@leonardocompagny.com
Philipp Krämer	Airbus Helicopters	Germany	Philipp.Kraemer@airbus.com
Klausdieter Pahlke	DLR	Germany	klausdieter.pahlke@dlr.de
Joost Hakkaart	NLR	The Netherlands	Joost.hakkaart@nlr.nl
Lorenzo Notarnicola	CIRA	Italy	l.notarnicola@cira.it
Observer			
Richard Markiewicz	Dstl	United Kingdom	rhmarkiewicz@mail.dstl.gov.uk

Table 5 Membership of GoR HC in 2016

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
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HC/AG-19: Improvement of Structural Dynamic FEM using In-flight Test Data

Action Group Chairman: Hans van Tongeren (Hans.van.Tongeren@nlr.nl)

Interest of the research

AG-19 investigates methods to improve the structural dynamic representation of a helicopter fuselage.

Background

The issue of vibration in helicopters is of major concern to operators in terms of the maintenance burden and the impact on whole life costs. Operators are demanding smooth ride vehicles as a discriminator of vehicle quality, which requires close attention to the vehicle dynamics.

Good mathematical models are the starting point for low vibration vehicles. The ability to faithfully simulate and optimize vehicle response, structural modifications, vehicle updates, the addition of stores and equipment is the key to producing a low vibration helicopter. However, there are many issues affecting the creation of an accurate model and it is clear that much research is needed to further that understanding.

A recent GARTEUR Action Group, HC/AG-14, concluded that helicopter dynamic models are still deficient in their capability to predict airframe vibration. The AG looked at the methods for improving the model correlation with modal test data along with the suitability of existing shake test methods.

Among others, the following recommendations were made for continued research:

- Study effects of configuration changes in the structure. How significant are these effects? How can uncertainties be handled in the context of an FE model. What is the influence of flight loads.
- The helicopter structure tested in HC/AG-14 was suspended in the laboratory. However, this is not the operational environment where there are very significant mass, inertia and gyroscopic effects from the rotor systems. Could in-flight measurements be made? What are the benefits?

Other recommendations with respect to ground vibration testing are considered in the closely related GARTEUR Action Group HC/AG-18.

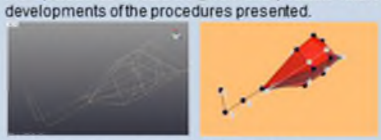
Programme/Objectives

Objectives

The main purpose of this AG is to explore methods and procedures for improving finite element models through the use of in-flight dynamic data. For the foreseeable future it is expected that validated finite element models will be the major tool for improving the dynamic characteristics of the helicopter structural design. It is therefore of great importance to all participants that the procedure of validating and updating helicopter finite element models with such in-flight data is robust, rigorous and effective in delivering the best finite element model.

The members will present further developments of methods used to update the finite element model whether automated, manual or both. Advantages and disadvantages of the approaches should be given and possible future developments of the procedures for localizing the areas of the models causing the discrepancies and for improving the updating process presented.The members will present developments of methods for the prediction of the effect of configuration changes on FRF behaviour. These can be based on a finite element model. Advantages and disadvantages of the approaches should be given and possible future developments of the procedures presented.

Finally the group shall assess the methodology with respect to evaluating vibration measurements from flight tests where effects of aerodynamic and rotating machinery affect the vehicle response. The objective is to extract modal parameters from in-flight measured data. Advantages and disadvantages of the approaches should be given and possible future developments of the procedures presented.



Traditional analysis versus OMA analysis

Available flight test data

Three sources of flight test data are available to the action group:

A flight test programme on an attack helicopter resulted in vibration response measurements on the stub wings for a wide range of manoeuvres and store configurations. A Full Aircraft GVT on RNLAF attack helicopter was conducted by Agusta Westland Ltd (with NLR assistance) on 5-7 March 2012.

The department of mechanical and aerospace engineering of "La Sapienza" University has a model helicopter at it disposal. Flight tests have been conducted with this helicopter. A finite element model is available. Ground vibration tests have been conducted. The advantage of this helicopter is that it is available for additional ground vibration and flight tests.

The third data set is based on LMS flight test data for Polish Helicopter

Results

The project should result in a review of various methods to process acceleration (or other) time signals. Sine inputs from rotating components in the flying helicopter dominate the response signals and obscure the structural responses related to structural vibration modes. The methods should separate the rotating component contributions from the structural vibration content. The updated finite element models will be used to predict in flight vibration responses of existing and new store configurations. This may reduce the amount of flight testing required to validate new store configurations. This is beneficial to both operators and manufacturers. This could involve coupling the structure model to simulation models that predict the main and tail rotor hub excitation levels.

So far, available experimental flight test data for validation purposes has been analyzed to update the related FE models. For the attack helicopter, model mass and construction of the complete helicopter model is finished. The GVT on a Dutch Attack helicopter was used to update the complete helicopter model. The flight test data will be used to further improve this model.

Members of the HC/AG-19 group are:

Nima Ameri	Bristol University
Giuliano Cappotelli	Sapienza University Rome
Johnathan Cooper	Bristol University
	previously Liverpool University
David Ewins	Bristol University
Cristinel Mares	Brunell University
Bart Peeters	LMS
Hans van Tongeren	NLR
Trevor Walton	Agusta Westland Ltd

GARTEUR Responsable:

Joost Hakkaart NLR

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HC/AG-20: Simulation methods and experimental methods for new solutions for internal noise reduction

Action Group Chairman: Frank Simon (frank.simon@onera.fr)

Interest of the research

AG-20 investigates methods to reduce the cabin noise of a helicopter.

Background

Since several years, aeronautical industries have wished to improve internal acoustic comfort. It is particularly true within the cabin of a helicopter where the passenger is in very close proximity to disturbing sources that contribute to interior noise: main and tail rotors, engines, main gearbox (tonal noise) and aerodynamic turbulence (broadband noise).

Nevertheless, to reduce global mass, the trim panels in cabin are generally provided with a core in Nomex honeycomb and external layers in composite fibres. This light assembly is not subjected to high static force and must just assure a sufficient stiffness not to be damaged during the helicopter life. Each material satisfies specific tests to be certified: behavior in high temperature, with humidity... To use these components can worsen the internal acoustic comfort because their behaviour is essentially due to mass effect.

It appears that conventional passive systems (trim panels, passive anti-resonance isolation systems as well as classical vibration absorbers and pendulum absorbers) are still the main way to control the acoustic of the cabin whereas active systems (active vibration and noise control) are not completely reliable or applicable (problems of robustness or time convergence of algorithms – often reduction in some area but increase outside – high added mass and electrical power – difficult identification of optimal locations for actuators and sensors).

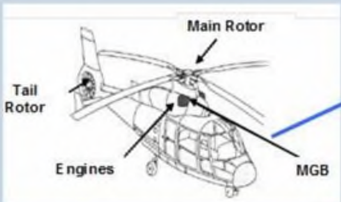
Programme/Objectives

Objectives

HC/EG-28, about internal noise and associated passive acoustic solutions (soundproofing, e.g. 1cm-thick trim panels designed for optimizing the absorption or the transmission loss), development of a vibro-acoustic model of the cabin (SEA coupled with FEM), human factors (subjective annoyance, speech intelligibility)" brought to launch the HC/AG20.

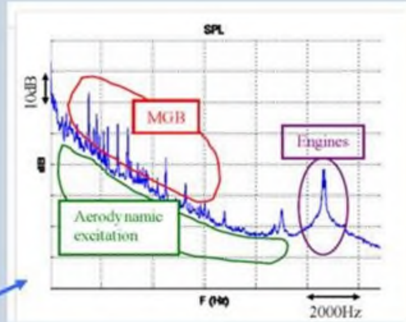
The HC/EG-28 conclusions listed the following needs:

1) to improve quality of absorption of materials with absorbing fillings or foam material tuned to control specific frequency bands
2) to design composite trim panels with industrial requirements and simulate acoustic performances of treatments after integration in cabin
3) to develop reliable vibro-acoustic "methodologies" to reproduce the interior noise levels in large frequency range by combined numerical models/ experimental data
4) to estimate mechanical power sources and contribution of vibration panels radiating in cabin (Structure-borne transmission of energy from gearbox and engines through helicopter frame to the trim panels)
5) to take into account "subjective or human annoyance" in specific frequencies
6) to study influence of noise on the communication between pilot and crews (problem of speech intelligibility)



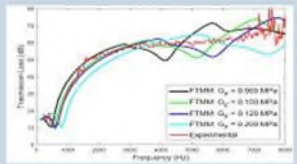
The activities in the new HC/AG-20 constitute the conclusion of HC/EG-28 and explore the points 2 to 4:

- applying 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
- applying 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 also to apply sound source localization methods as beamforming or holography.



Results

The AG results in a benchmark of the appropriateness of tools for complex configurations (multiple anisotropic layers with various mechanical characteristics) and applies complementary passive and active concepts for composite trim panels.



Panel 2: Simulations Polimi / expérimentation Onera

Members of the HC/AG-20 group are:

F. Simon	ONERA
A. Grosso	MICROFLOWN
T. Haasse	DLR
R. Wijntjes	NLR
Gian Luca Ghiringhelli	Politecnico di Milano

GARTEUR Responsable:
Ph. Beaumier ONERA

Microflown Technologies – Charting sound fields · NLR · ONERA THE FRENCH AEROSPACE LAB · DLR · POLITECNICO MILANO

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HC/AG-21: Rotorcraft Simulation Fidelity Assessment: Predicted And Perceived Measures Of Fidelity

Action Group Chairman: Mark White (mdw@liv.ac.uk)

Interest of the research

AG-21 aims at quantifying the perception of a of a rotorcraft simulator fidelity.

Background

The qualification of rotorcraft flight simulators is undertaken using the new framework detailed in "Certification Specifications for Helicopter Flight Simulation Training Devices CS-FSTD(H). This document contains a number of component fidelity requirements, flight loop data matching tolerances (i.e. Qualification Test Guide) and some brief guidance material on the requirements for the final subjective assessment of a simulator in order for it to be qualified to a certain Level.

The work from a previous GARTEUR activity, HC/AG-12, "Validation Criteria for helicopter real-time simulation models", indicated that there were a number of shortcomings in the current civil simulator standards, namely the tolerances contained within JAR-FSTD H (predecessor to CS-FSTD(H)) have no supporting evidence for their definition and there is not a systematic approach identified for overall fidelity assessment.

HC/EG-30, (Simulation Fidelity) examined the state of play of current research and industrial practice and recommended a focussed activity for a future Action Group to examine critical aspects of simulator fidelity and fitness for purpose, e.g. the flight model tuning process, metrics and tolerances, integrating predicted and perceived fidelity. The GARTEUR work highlighted the need for the evaluation of overall fidelity of the integrated system of pilot and machine and is driver for the new GARTEUR activity in this area.

Programme/Objectives

Objectives

Helicopter simulation training device qualification is a complex activity, requiring a large number of resources. In order to effectively address some of the key challenges identified previously a work programme has been developed in order to enhance current simulator qualification standards.

The principal objective of the Action Group is to gain a better understanding of the various components that contribute to the definition and perception of rotorcraft simulation fidelity. This may subsequently result in the development of new criteria for fidelity assessment. This activity would require an examination of the influence of the flight loop tolerances on predicted fidelity assessment together with an investigation of the role of simulator cueing on subjective or perceived fidelity assessment.

The research outcomes will be in the form of new metrics which would define rotorcraft simulation fidelity boundaries together with guidelines for the subjective fidelity assessment process.

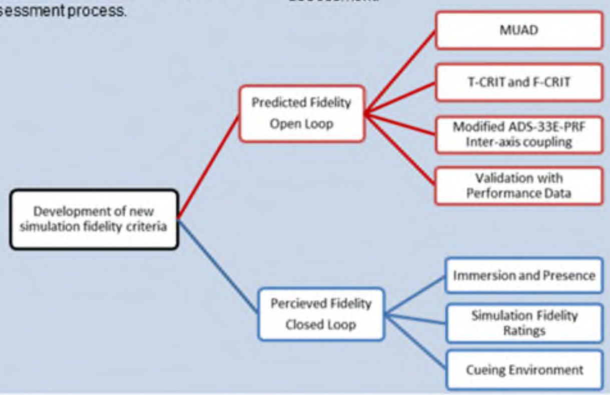
The work programme has two strands:

Predicted Fidelity assessment using off-line flight models with a range of standard control inputs

Perceived Fidelity assessment using ground-based pilot-in the-loop simulations at partners' own facilities.

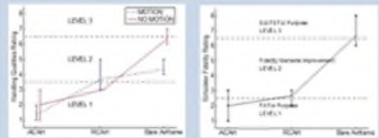
Specific areas of interest for helicopter flight simulation device fidelity include:

1. An investigation of validation techniques for the definition of predicted or flight loop fidelity
2. Definition of new criteria for predicted fidelity assessment
3. Definition of new rotorcraft flight test manoeuvres to be used during the subjective evaluation of a simulator
4. An investigation of the effect cueing on the subjective assessment of fidelity
5. Development of metrics for subjectively perceived fidelity
6. Development of an overall methodology for fidelity assessment.



Results

Flight simulator tests have shown that the Simulation Fidelity Rating (SFR) Scale is a useful tool for measuring fidelity in the absence of objective tests. It has been used to demonstrate that simulator fidelity motion cueing requirements are not only task based, but are also dependent on the handling qualities of the aircraft being flown. Immersion questionnaires have been developed to subjectively assess the fidelity experienced by users are currently being used in simulation fidelity trials.



Handling Qualities and Simulator Fidelity Ratings awarded for the Hover Task.

Members of the HC/AG-21 group are:

M White	University of Liverpool
G.Meyer	University of Liverpool
M. Pavel	TuDelft
O. Stroosma	TuDelft
J. vd Vorst	NLR
C. Seehof	DLR
F. Cuzieux	ONERA
B. Berberian	ONERA
M. Theophanides	CAE
S. Richard	Thales

GARTEUR Responsable:

J. Haakkart	NLR

UNIVERSITY OF LIVERPOOL THALES TUDelft Delft University of Technology CAE NLR ONERA THE FRENCH AEROSPACE LAB DLR

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HC/AG-22: Forces on Obstacles in Rotor Wake

Action Group Chairman: Antonio Visingardi (a.visingardi@cira.it)

Interest of the research

AG-22 investigates methods to better understand and predict the obstacles-rotorcrafts relative influence.

Background

Helicopters are routinely employed in missions within "confined areas", regions where the flight of the helicopter is limited in some direction by terrain or by the presence of obstructions, natural or manmade. Rescue operations, emergency medical services, ship-based rotorcraft operations are some examples of near-ground and near-obstacle operations.

The wind conditions, the distance and the height of the helicopter from the obstacles and the ground are the main factors due to which the wake generated by the obstacle in the vicinity of the ground may result in: high compensatory workload for the pilot; degradation of the handling qualities and performance of the aircraft; unsteady forces on the structure of the surrounding obstacles. These forces are of aerodynamic nature and arise from the interaction between the wake induced by the rotor and the airflow around the obstacles.

A helicopter sling load is another, however particular, case of obstacle subject to forces produced by its interaction with the rotor wake. Once airborne a sling load comes under the influence of aerodynamic forces and moments associated with its size, shape, mass, and transport speed. The instabilities that can arise from these forces affect the rotorcraft and/or the load itself and their avoidance is therefore crucial not only for safety reasons, but also when a controlled attitude of the load is required.

Several publications address the problem of the helicopter ground effect in confined areas, the majority of them concerning investigations of the helicopter-ship interactional problem. Nevertheless, references of the evaluation of forces acting on obstacles in rotor wake are scarce. Likewise, there are few experimental databases for the validation of numerical methodologies, their accessibility is uncertain, and do not provide force measurements on obstacle surfaces.

Programme/Objectives

The principal objective of HC-AG22 is then to promote activities which could contribute to fill these gaps. This will be accomplished by investigating, both numerically and experimentally:

- the effects of the confined area geometry on a hovering helicopter rotor from the standpoints of both the phenomenological understanding of the interactional process and the evaluation of the forces acting on surrounding obstacles;
- the downwash and its influence on the forces acting on a load, loose or sling, at low to high separation distances from the rotor disc.

The project, started in November 2014, has a duration of three years during which the following activities are carried out:

- application and possible improvement of computational tools for the study of helicopter rotor wake interactions with obstacles;
- set-up and performance of cost-effective wind tunnel test campaigns aimed at producing a valuable experimental database for the validation of the numerical methodologies applied;
- final validation of the numerical methodologies.

The know-how acquired by the HC/AG-17 about the wake modelling in the presence of ground obstacles, was capitalized and sets-up the basis for this new research activity.

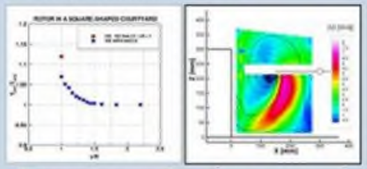
The work programme is structured in four work packages:

- WP0 – Management & Dissemination: fulfilment of all the obligations concerning the project management and the dissemination of the results;
- WP1 – Preliminary Computations & Code Enhancements: preparation phase during which partners are involved in literature review and preliminary computational activities;
- WP2 – Wind Tunnel Test Campaigns: performance of the following four wind tunnel test campaigns:
  1. HOGE/HIGE rotor with a loose/sling load (CIRA);
  2. HIGE rotor in proximity to a square-shaped obstacle (ONERA);
  3. HIGE rotor in proximity to an obstacle in wind-on conditions (PoliMi);
  4. HIGE rotor in proximity to an obstacle in wind-off conditions (Univ. Glasgow).
- WP3 – Final Validation of Codes: final validation of the numerical tools proposed by partners.

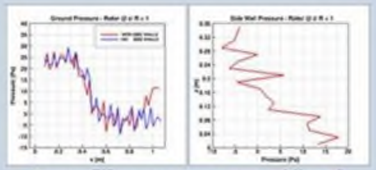
Results

Each experiment covers different aspects of the rotor wake/obstacle interaction. There is a strong collaboration in experimental tests between POLIMI and UOG (exchange of personnel). The cuboid obstacle is put at disposal by DLR.

- The thrust of a helicopter rotor hovering above an obstacle is increased wrt both an OGE and IGE rotor. The thrust of a rotor hovering aside of or surrounded by obstacles is increased wrt to an OGE rotor but is reduced wrt a IGE rotor. The reason lies in the wake recirculation induced by the side walls of the obstacle;
- The ground pressure is the highest below the rotor. It reduces gradually away from the rotor but increases again in the vicinity of a side wall. The side wall pressure is positive about the ground/side wall corner but becomes negative at higher z because of the wake recirculation.



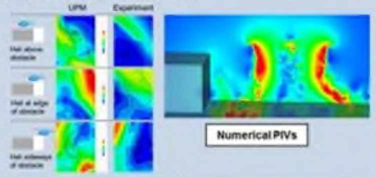
Thrust increase in IGE — Wake recirculation



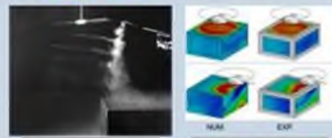
Pressure distribution on a square-shaped obstacle

Solvers ranging from Flight Mechanics-based to Navier Stokes are employed.

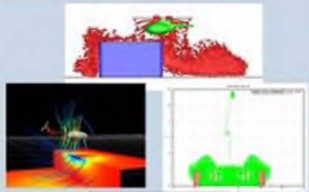
- The rotor-obstacle interactional process requires lengthy calculations to reach a converged solution (> 15 revs.);
- Inviscid potential methods require a specific modelling of the wake-obstacle interaction and the inclusion of viscous effects.



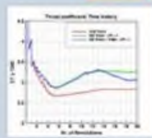
Numerical PIVs



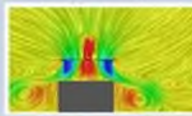
Flow visualization — On-obstacle pressures



Wake-obstacle interactions



Thrust time history



Instantaneous streamlines

Members of the HC/AG-22 group:

A. Visingardi, F. De Gregorio	CIRA
T. Schwarz	DLR
R. Bakker	NLR
S. Voutsinas	NTUA
Q. Gallas, R. Boisard	ONERA
G. Gibertini	Politecnico di Milano
G. Barakos, R. Green	University of Glasgow

GARTEUR Responsable:

K. Pahlke	DLR

CIRA DLR nlr ONERA THE FRENCH AEROSPACE LAB University of Glasgow

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

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

Interest of the research

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

Background

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

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

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

Programme/Objectives

Objectives

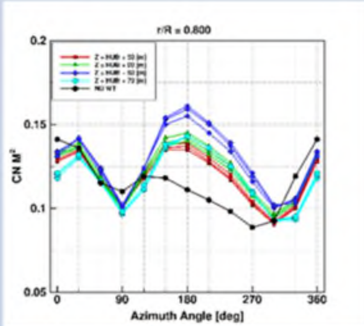
Despite the amount of literature on both wind turbine wakes and helicopter – fixed wing tip vortex encounters, not much research has been done on the interactions of wind turbine wakes and helicopter flight.
The aim of the Action Group is to set up a team of researchers from universities and research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

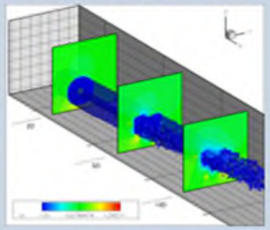
Programme

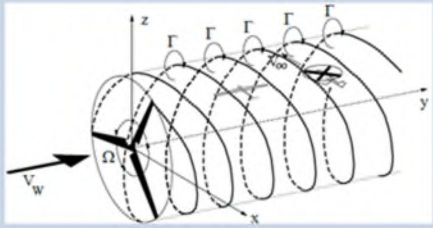
The programme consists of 5 work packages

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

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







Results

- A reference wind turbine (NREL5), a reference helicopter (BO105, and a set of test cases to be studied has been selected
- An overview of wind turbine wake characteristics, methods and tools has been prepared. Both analytical, computational and experimental data has been collected.
- Computed wind turbine wake velocity fields using a variety of CFD tools and with different methodologies have been prepared and are available to the partners to use for helicopter-wake encounter simulations.
- Evaluating the effect of the WT wake on a helicopter rotor entering the WT wake effects have been evaluated in terms of hub loads (thrust, torque) and roll, pitch and yaw moment coefficients of the rotorcraft.
- Computations of a helicopter-wake encounters and the resulting attitude rates.
- Preparations have been made for the implementation of a wind turbine wake and a helicopter for use in a full-scale simulator.
- Study for the definition of objective criteria to assess handling qualities in a wind turbine wake has been conducted.

Members of the HC/AG-23 group are:

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

GARTEUR Responsable:

J. Hakkaart	NLR

UNIVERSITY OF LIVERPOOL · TU Delft · TECHNISCHE UNIVERSITÄT MÜNCHEN · NLR · ONERA · CIRA · DLR

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

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

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

Interest of the research

AG-24 investigates how the helicopter rotor noise propagates in presence of the fuselage.

Background

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

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

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

Programme/Objectives

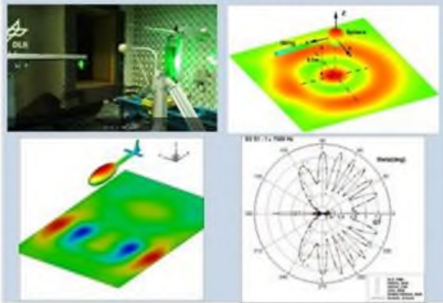
Objectives

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

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

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

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



The work programme is structured in three work packages:

➢ WP 1: Simulation on the acoustic scattering effect

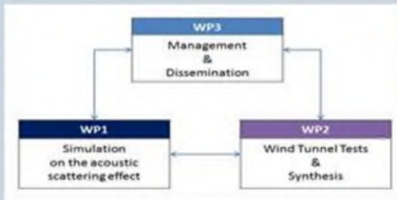
- Code adaptation & prediction
- Code validation & improvement of prediction tools
- Evaluation of noise scattering of various components using validated codes

➢ WP 2: Wind Tunnel Tests & Synthesis

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

➢ WP 3: Management & Dissemination

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



Results

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

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

1. Description of available analytical, experiment test cases including database completed and distributed;
2. Specifications on the common simulation for the sphere scattering defined and the results of sphere simulation completed and compared. In addition the comparison results published in ERF 2016;
3. The Sphere scattering tests composed of 3 spheres, two support systems, and two noise sources were conducted and the results published in ERF 2016;
4. The generic helicopter and model tail rotor were manufactured; tests for generic helicopter with three different sources will be made in Sep. 2017;
5. Specifications on the test for the GARTEUR helicopter scattering defined;
6. The abstract related to the group activities in terms of the simulations and experiments is accept for AHS 2017;
7. 4 publications and 7 reports were produced

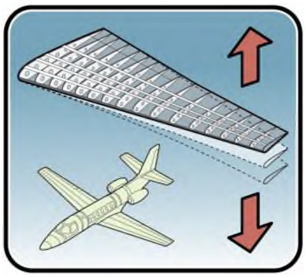
Members of the HC/AG-24 group are:
(only contact persons are listed here)

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

GARTEUR Responsable:
K. Pahlke DLR

CIRA Centro Italiano Ricerche Aerospaziali — Marine Technology Research Institute INSEAN — DLR — NLR — ONERA THE FRENCH AEROSPACE LAB — POLITECNICO MILANO — ROMA TRE UNIVERSITÀ DEGLI STUDI

5.5 Group of Responsables – Structures and Materials (SM)



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;
- Additive layer manufacturing.

Material properties of components produced with additive manufacturing technologies, especially fatigue properties, are a key issue for most applications. The Exploratory Group 43 will build up knowledge, skills and corresponding demonstrator products in the field of metal AM processes and materials in order to support manufacturing industry and increase its competitiveness.

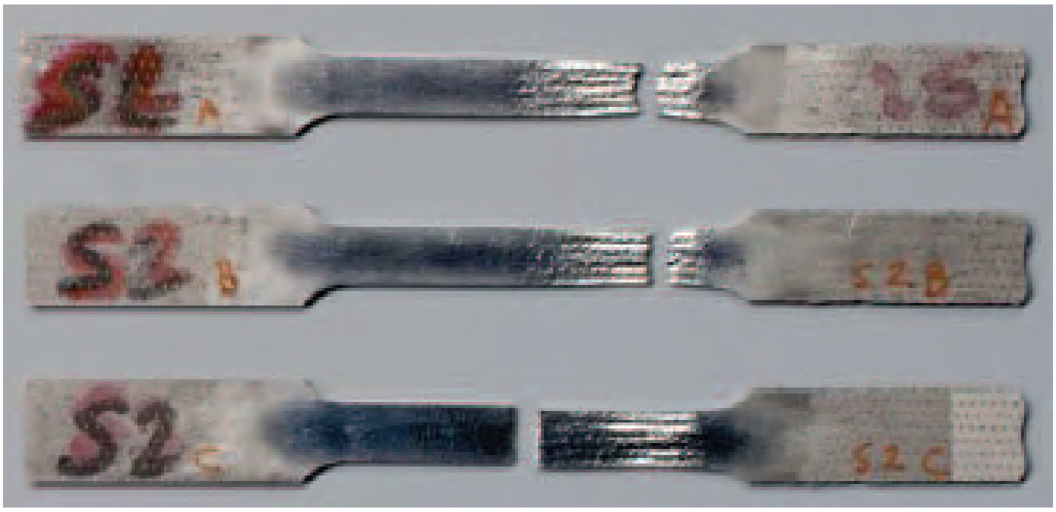


Figure 3: Illustrations of the Group of Responsables "Structures and Materials"

During 2016 GoR - SM monitored the following Action Groups:

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

For these two Action Groups one-page summary posters are included on the following pages.

The situation regarding Exploratory Groups and new topics under review was as follows at the end of 2016:

- GoR - SM Exploratory Groups:
    - SM/EG-39: Design for high-velocity impact on realistic structures. EG 39 has been put on hold until Imperial College secure the necessary funding to manage the project.
    - SM/EG-42: Bonded and bolted joints. This EG was initiated by FOI and was formally started at the GoR autumn meeting 2013. Due to recent reorganisations, FOI will not be able to manage or even participate in the AG. Based on the member feedback a reorientation of the EG with a

focus on bonded joints is to be discussed. A new partner who will take over the management of the EG is sought. Currently EG-42 is on hold.

- SM/EG-43: Development of additive layer manufacturing for aerospace applications. This EG was formally started at the GoR autumn 2014 meeting and the first EG-43 meeting was held on 10th April 2015. An AG proposal is under preparation.

- New Topics: The following topics for future Exploratory Groups are under discussion:
    - Multi-functional Materials with a focus on improving the electrical conductivity and structural health monitoring (SHM);
    - Multi-scale dynamics of joints: modelling and testing;
    - New Methodologies for thermal-mechanical design of supersonic and hypersonic vehicles;
    - Composite fire behaviour;
    - Structural uncertainties;
    - Aeroelasticity and aero-servo-elasticity; and
    - Thin ply laminates

The membership of GoR-SM in 2015 is presented in the table below.

Chairman		
Peter Wierach	DLR	Germany
Vice-Chairman		
vacant		
Members		
Domenico Tescione (from May 2015 on)	CIRA	Italy
Aniello Riccio[1]	Univ. II Naples	Italy
Bert Thuis	NLR	The Netherlands
Javier Sanmilan	INTA	Spain
Tomas Ireman	SAAB	Sweden
Joakim Schön	FOI	Sweden
Jean-Pierre Grisval	ONERA	France
Industrial Points of Contact		
Caroline Petiot	Airbus AGI	France
Matthias Jessrang	Airbus	Germany
Roland Lang	Airbus DS	Germany
Massimo Riccio	Alenia	Italy
Luc Hootsmans	Fokker	The Netherlands
Angel Barrio Cárdaba	Airbus DS	Spain
Hans Ansell	SAAB	Sweden
Dr. Robin Olsson	SICOMP	Sweden
Andy Foreman	Qinetiq	United Kingdom

[1] Associate Members

Table 6 Membership GoR-SM in 2016

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
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SM/AG-35: Fatigue and Damage Tolerance Assessment of Hybrid Structures

Action Group Chairman: Jaap Laméris
(jaap.lameris@nlr.nl)

Background

A major challenge in the fatigue analysis and subsequent fatigue testing of hybrid structures originates from the differences in deriving fatigue spectra for metal and composites and incorporation of required environmental load factors for composites. Specifically, the following aspects can be addressed:

1. Composite structure is sensitive to environmental conditions, metal parts usually are not. If it is decided not to perform fatigue- or residual strength tests under these conditions, which aspects should be taken into account via environmental factors on the applied loads?
2. Material scatter for composites is much larger than for metals; this is usually covered by a combination of a life factor and a load enhancement factor. However, to avoid non-linear behaviour of test set-up and too high stress levels in the metal parts a maximum overall load increase should be respected.
3. In general, damage growth in composite materials is most sensitive for compression-compression cycles, where metal fatigue initiation and crack growth are more sensitive to tension-compression and tension-tension cycles. A generic process for a load spectrum reduction technique covering both aspects should be discussed.
4. Spectrum truncation levels must be different for metals and composites. Where composites experience high damage from high peak loads, metals will experience crack retardation after application of a severe load condition.

Since metals are most sensitive to fatigue damage, it is often chosen to relax one or some of the aspects from the list above for the composite fatigue justification. However, since operational strain levels in new composite designs, using improved material systems, constantly increase, the validity of this approach will be limited in the near future.

Programme/Objectives

Objectives
The main objectives are listed below:

- Validation of the basic assumptions for any applied spectrum manipulation techniques;
- Examination of the capabilities and benefits of a probabilistic approach;
- Determination of the optimum way to account for thermal loads in a non-thermo test set-up;

leading to a joint 'best practice' approach for testing of hybrid airframe structural components.

Task 1 Determination of a Test Spectrum
A benchmark will be defined that will address as much aspects of fatigue and damage tolerance testing/justification as possible, for both the metal and composite structures, for both bolted and bonded joints. The benchmark spectrum will be equivalent to known definitions such as FALSTAFF (fighter wing) or TWIST (transport wing), modified for application to hybrid structure. Testing will be done on hybrid coupons and, if possible on more complex components, addressing all phases of static, fatigue and damage tolerance certification, using a number of derived spectra in order to investigate effects on fatigue and damage tolerance behaviour.
Phase 1 Benchmark definition
Phase 2 Spectrum development
Phase 3 Validation of assumptions

Task 2: Probabilistic approach
Application of probabilistic analyses in combination with virtual testing techniques can be used to incorporate scatter in material properties, loading, etc. The most important scatter sources (model parameters) will first be identified by means of a probabilistic sensitivity analysis. The probabilistic methods will then be applied on a failure model to determine the scatter in derived properties, from which allowable values can be obtained. In case of sufficient correlation with experimental data, the probabilistic simulation model allows for (extensive) virtual testing, reducing the number of tests required in a fatigue material qualification program.

Task 3: Environmental influences
As one of the most important effects of the environment on a hybrid structure, thermally induced interface loads due to the differences in coefficient of elongation between metals and carbon composites come in addition to the 'mechanical' loads. In non-thermo fatigue testing, it is a challenge to apply these loads mechanically.
Phase 1 Identification of the thermal stress condition
Phase 2 Impact on fatigue life
Phase 3 Testing

Results

The AG should results in establishing a joint 'best practice' approach for full scale fatigue testing of hybrid airframe structural components.

The second progress meeting was held at DLR on 19-05-2014 in Cologne and the third progress meeting was at Fokker Aerostructures at Papendrecht on 12-11-2014. SAAB hosted the fourth progress meeting on 22-09-2015 in Lynkoping. In June 2016 the fifth progress meeting was held at the NLR premises in Amsterdam. The next project meeting is planned for Jan/Feb 2017

Task 1: Determination of a test spectrum
A conceptual definition of a specimen geometry was proposed by Fokker/NLR in order to be able to observe the behaviour of the test specimen with respect to the various (conflicting) requirements associated with a hybrid (metal-CFRP) fatigue test. The first part of the work of Fokker/NLR on 3 test approaches (application of probabilistic analyses in combination with virtual testing techniques) has been completed and reporting is almost completed. The second part concerns validation by testing and is planned for 2017

Task 2: Probabilistic approach
The DLR contribution on a probabilistic approach is ongoing. The work on hybrid joints (metal/composite) is in the testing phase. A PhD student is currently working on the completion of this task.

Task 3: Environmental influences
The work of FOI/SAAB on uni- and biaxial loading of bolted joints (SAAB simulation, FOI testing) has been finished except for the reporting which is planned for 2017.

6 GARTEUR SUCCESS STORIES AND LINKS TO OTHER EUROPEAN PROGRAMMES

This chapter provides two examples of GARTEUR success stories, in addition to illustrations of the connections between European projects and GARTEUR AGs.

6.1 GARTEUR success stories

GARTEUR Action Groups, AD AG52 and SM AG33 represent two success stories from 2016. Both groups demonstrate the highly innovative research and broad European collaborations that are typical of GARTEUR AGs. While AD AG52 investigated optimization methods for non-conventional aerodynamic designs, SM AG33 provided valuable contributions to the European project ECOMISE in their search for a new production system for thermoset composite manufacturing and post-processing.

6.1.1 GoR AD AG52: Surrogate-Based Global Optimization Methods in Aerodynamic Design

Motivation and objectives

Surrogate-based Global Optimization (SBGO) methods have a high potential to find the global optimum, even in noisy environments, independently from the initial configuration, at a relatively low cost. This makes the methods ideally suited for the search of non-conventional designs.

The objective of this Action Group was to investigate and analyse the feasibility and possible contributions of SBGO methods in an early phase of the aerodynamic design.

Collaboration and dissemination

The main success of the group is demonstrated in its dissemination activities. Partners have presented their SBGO results in ECCOMAS, EUROGEN and EUCASS, and specific Mini-symposiums on Surrogate-based optimization methods were organised at ECCOMAS 2014 and 2016, and EUROGEN 2015 and 2017. A total of 14 papers were published during the group’s duration. It has allowed opening the group research to the rest of the community in this topic, and, in addition, it has been an incentive for the involved researchers.

The group was chaired by Esther Andres (INTA) with a very intensive support from the vice-chair, Emiliano Iuliano (CIRA). The close collaboration within the group allowed detailed validations and cross-comparisons.

Brief summary of results

First, the surrogate models are validated by comparing surrogate model results with full-blown CFD results (see Figure 4). The next step is to compare the different SBGO approaches. As shown in the left part of Figure 5, the optimization process combines surrogate and CFD models to evaluate the design. Best results are achieved by the adaptive Kriging and SVMr optimization approaches in RAE2822 and inviscid wing from the Drag Prediction Workshop (DPW). In the case of the DPW wing in viscous conditions, Kriging-based and High Order SVD-based approaches showed the best performance (see the right part of Figure 5).

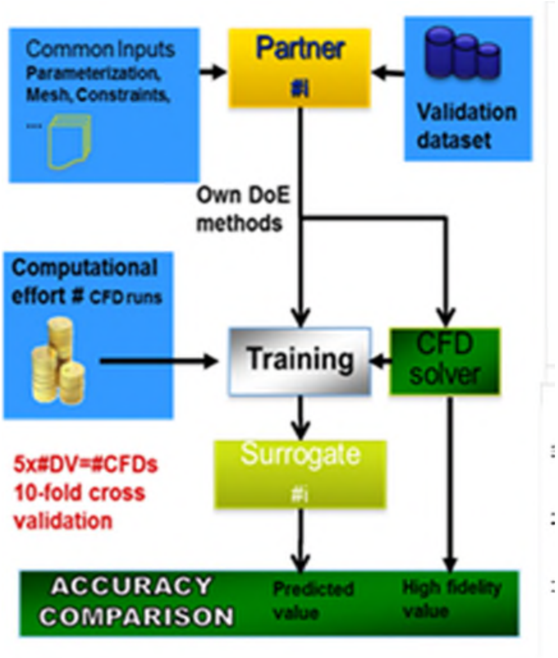
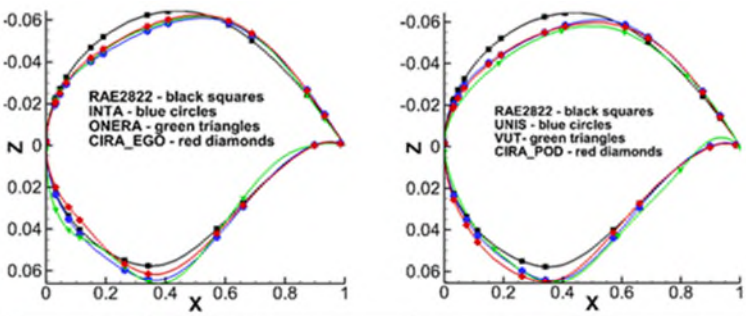


Figure 4 Surrogate models validation strategy (common inputs and dataset were used for surrogate validation). A 10-fold cross validation strategy has been applied, limiting the number of CFD runs to five times the number of design variables in the optimization problem



	Mean OF (TAU, MSES, ZEN 3 levels)	Mean OF (only TAU and ZEN fine)
Baseline	1	1
CIRA-POD	0.6223	0.6266
CIRA-EGO	0.6208	0.6236
INTA/UAH	0.6243	0.6211
ONERA	0.6494	0.6498
UNIS	0.6367	0.6338
VUT	0.6969	0.7063

Figure 5 Flowchart of the SBGO comparison process (left) and optimization results for the RAE2822 test case(right).The flowchart shows how the comparison of the optimization results was performed and the table displays the mean objective function computed with different solvers (TAU, MSES and ZEN)

Final report

All the details on AG52 results are provided in the final report, to which the following people contributed: Esther Andrés, Daniel González, Mario Martin (INTA), Emiliano

Iuliano, Davide Cinquegrana (CIRA), Gerald Carrier, Jacques Peter, Didier Bally (ONERA), Olivier Amoignon (FOI), Petr Dvorak (VUT), David Funes (AIRBUS-Defense and Space), Per Weinerfelt (SAAB), Leopoldo Carro, Sancho Salcedo (UAH), Yaochu Jin, John Doherty and Handing Wang (UNIS).

Conclusions and next steps

The group has reached its objectives: the partners have gained a better understanding and improved capabilities of SBGO techniques and their application to aerodynamic shape optimization.

With the acquired knowledge and capabilities, most of partners are interested in continuing their research on the potential application of surrogate modelling approaches for uncertainty quantification and robust design. It will be discussed if an exploratory group is created for a collaborative research on these topics and, in this way, outputs from related European projects, such as UMRIDA (Uncertainty Management for Robust Industrial Design in Aeronautics) and UTOPIAE (Uncertainty Treatment and Optimisation in Aerospace Engineering) will be taken into account in order to complement their activities.

6.1.2 GoR SM AG33: RTM Material Properties During Curing

The SM AG33 played an important role in the initialization of the EC project “ECOMIZE”. The project was successfully completed in 2016. Besides the GARTEUR partners DLR and NLR additional industrial partners joined the consortium underlining the relevance of this research topic. In total 11 partners from 6 counties worked together from 2013 until 2016 to make this project a success.

Within current composite part development and manufacturing processes a disproportional high effort is implied in order to find optimal process parameters and to meet required qualities and tolerances of high performance light weight structures.

The ECOMISE project proposes a breakthrough production system to enable next generation of thermoset composite manufacturing and post-processing. Within this new approach high precision process techniques for advanced dry fiber placement (AFP), infiltration (RTI/ RTM) and curing will be developed in order to maximize process efficiency at reduced costs and production time due to less material consumption, higher reproducibility, less energy, less waste and less rework.

In detail, innovative online process monitoring systems, probabilistic process simulation methods as well as a new method for in-situ structural evaluation of resulting composite properties will be developed, followed by a new knowledge-based method for in-situ process adjustment with respect to initial structural requirements. In this novel way, the required structural performance of the final composite product can be linked and assured during every manufacturing step, yet serving qualification issues at the earliest stage. Advanced characterization and testing techniques will be utilized and tailored to evaluate the process efficiency for required product quality by focusing on process robustness and throughput rate. Hereupon, the reduced carbon footprint is evaluated during manufacturing and in-service.

The resulting economic benefits of the ECOMISE approach will be evaluated and demonstrated by pilot implementations for industrial use-cases, considering particularities for volume part (automotive), large part (aeronautic) and thick complex part (marine) productions. Here, a significant impact is expected for SME and industry end users and suppliers of composite structures as well as of facilitators providing measurement systems and software solutions.

The objectives for this project were to achieve higher utilization of composites with improved performance without cost increase and to ensure a decrease of raw materials, energy consumption and emission during manufacturing. Figure 6 compares the approach of state-of-the-art manufacturing process with the ECOMISE process.

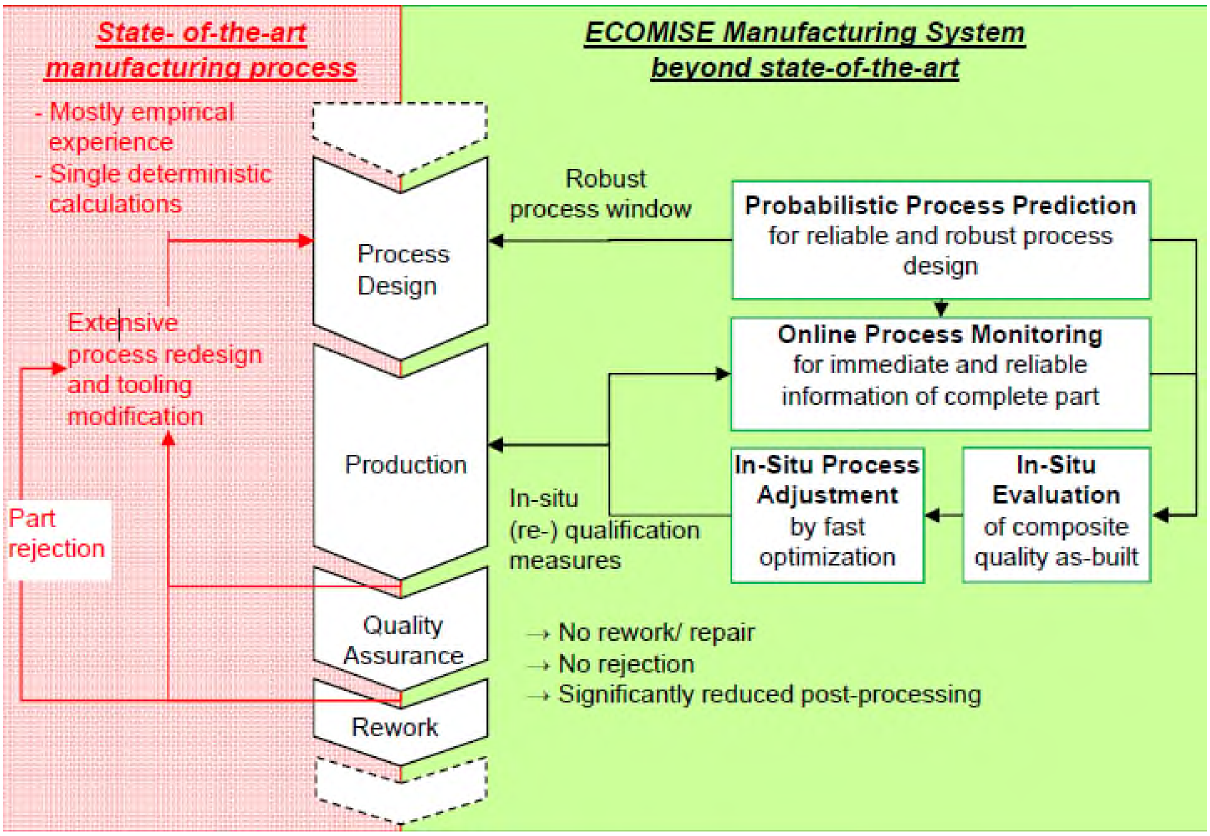


Figure 6 The ECOMISE manufacturing process

6.2 Links with other European Programmes

GARTEUR projects have had strong links with EU Framework projects for over three decades. As GARTEUR does not provide financial support for their projects it is necessary for the GoRs to investigate funding opportunities from the EU or other sources as illustrated in Figure 7 below.

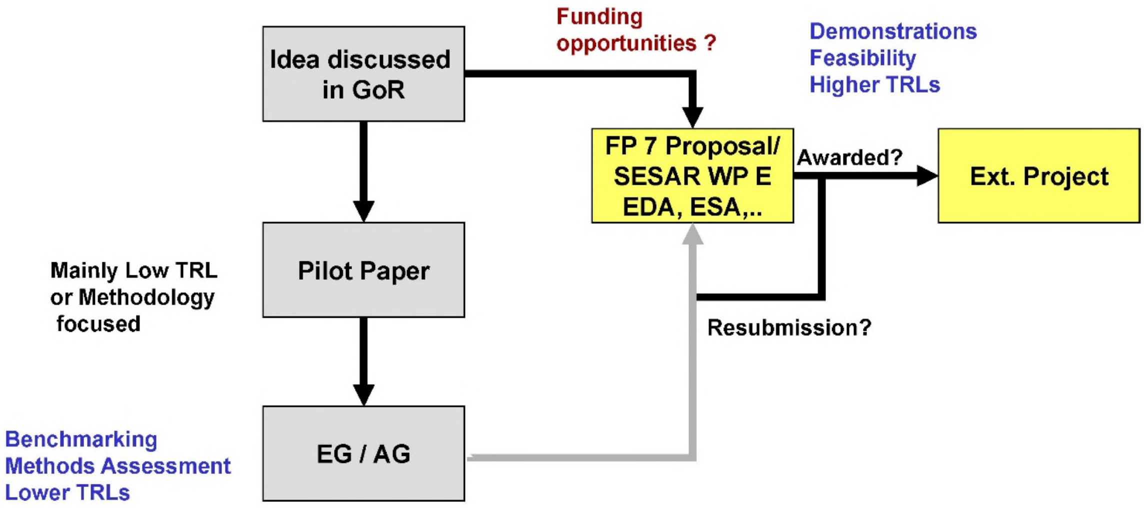


Figure 7 Illustration of how links are established between GARTEUR and other European programmes

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 8 to 10 are additional illustrations of the links between GARTEUR Action Groups and EU projects, as provided by GoR Aerodynamics and GoR Helicopters.

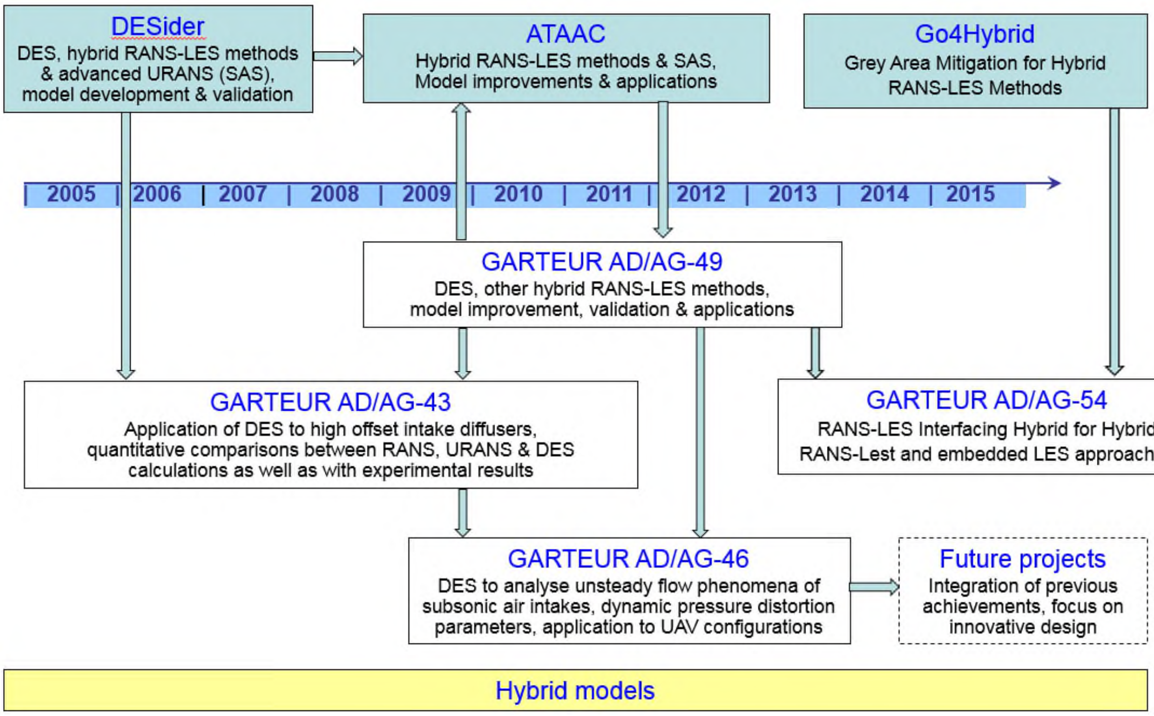
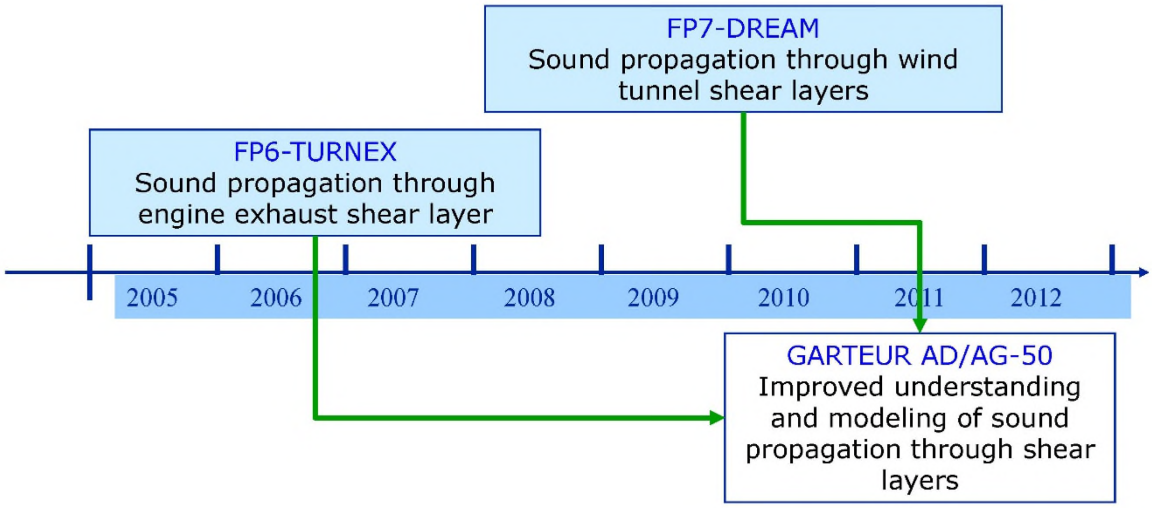


Figure 8 Links between EU-projects/proposals and GARTEUR AD/AG-43, AD/AG-46, AD/AG-49 and AD/AG-54



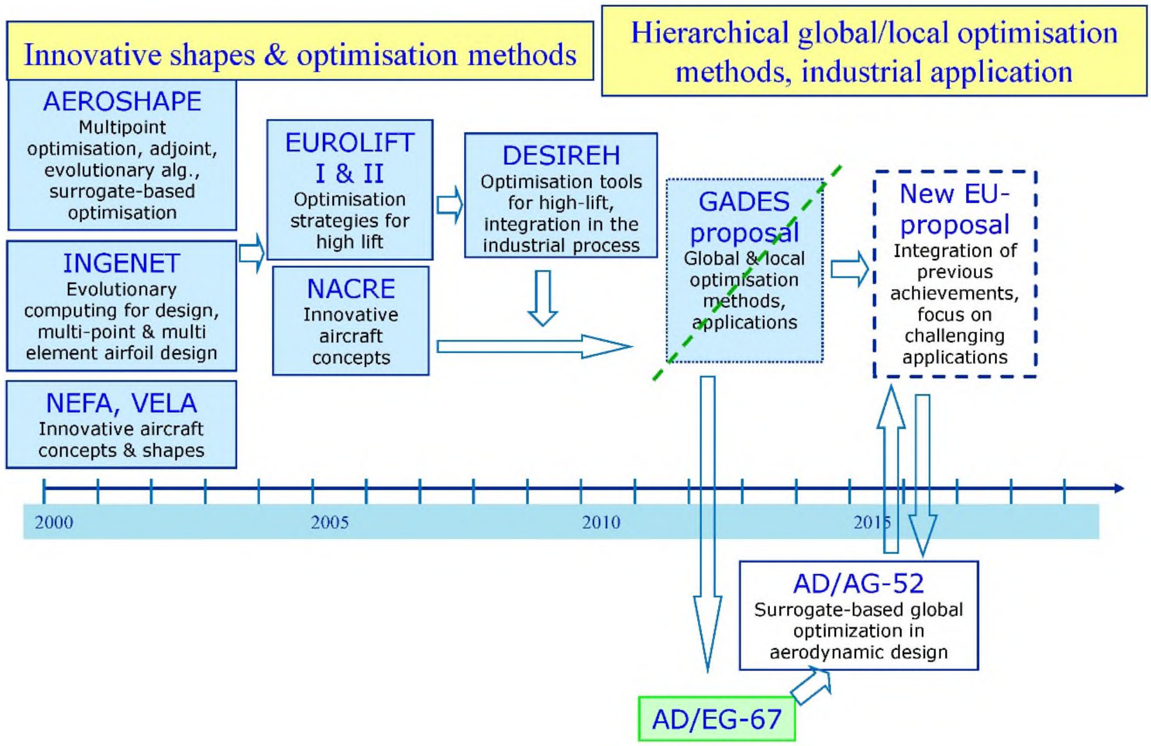


Figure 9 Links between EU-projects/proposals and GARTEUR AD/AG-50 and AD/AG-52

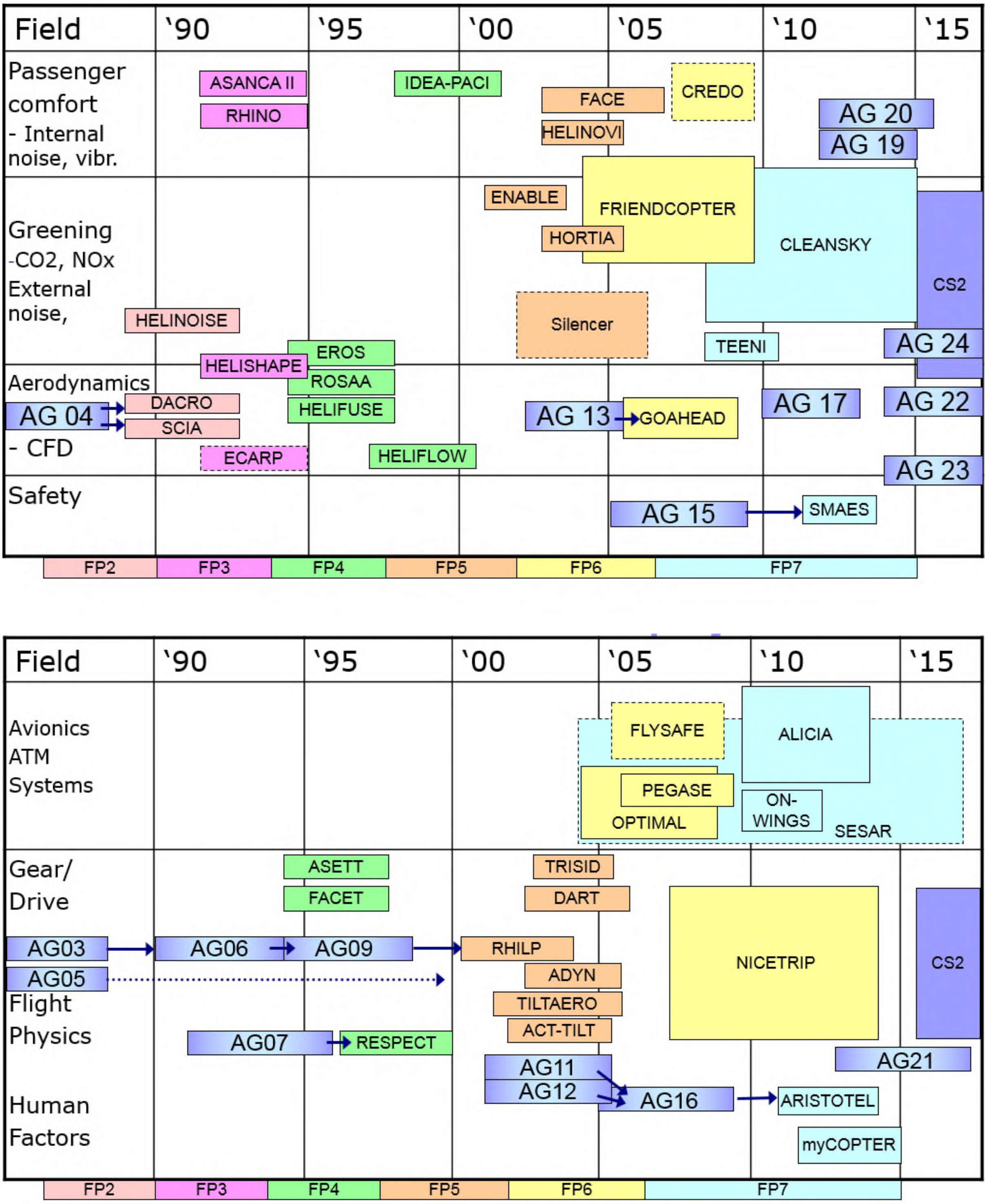


Figure 10 Relation between HC/AGs and EU projects

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8 LIST OF TABLES AND FIGURES

9 APPENDIX

9.1 Appendix 1 GARTEUR Organisation

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

Updated 20th December 2016

GARTEUR ORGANISATION

GARTEUR Chair Country 2016-2017: United Kingdom
Council Chair: Mr. Louis Barson, UK

XC Chair: Mr. Malcolm Scott, UK
Secretary: Mr. George Kwofie, UK

GARTEUR COUNCIL

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XC Member	O. Vasseur	F. König	L. Paparone	K. Wijnberg	F. Muñoz Sanz	E. Bernhardsdotter	M. Scott
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GROUPS OF RESPONSABLES

Aerodynamics (AD)	Aviation Security (AS)	Flight Mechanics, Systems & Integration (FM)	Helicopters (HC)	Structures & Materials (SM)
GoR AD members	**GoR AS members**	**GoR FM members**	**GoR HC members**	**GoR SM members**
H. van der Ven NL (chair 2016-17)	**A. Vozella IT chair 2017-18**	**R.C.J. Ruigrok** NL chair 03/2015 - 2016	**P. Beaumier FR chair 2017-18**	**P. Wierach** DE chair 2016-17
F. Monge Gómez ES (vice-chair)	V. Wiels FR chair 2014-16	B. Korn DE	M. White UK chair 2015-16	J.P. Grisval FR (chair 2014-15)
F. Ogilvie UK (chair 2014-15)	I. Ehrenpfordt DE	L. Verde IT	L. Notarnicola IT (chair 2013-14)	T. Ireman SE (chair 2011-13)
T. Berglind SE (chair 2012-13)	B. Eberle DE	M. Hagström SE	J. Hakkaart NL	D. Tescione IT
E. Coustols FR	F. Muñoz Sanz ES	P. Mouyon FR	K. Pahlke DE	J. Sanmilan ES
G. Mingione IT	A. Eriksson SE	E. Cortet FR	A. Antifora IT	J. Schön SE
K. Richter DE	R. Wiegers NL		P. Krämer DE	H. de Vries NL
G. Schrauf DE			O. Parnet FR	A. Riccio IT (Associated member)
P. Weinerfelt SE			R.-H. Markiewicz UK	B. Thuis NL
Industrial Points of Contacts	**Industrial Points of Contacts**	**Industrial Points of Contacts**	**Industrial Points of Contacts**	**Industrial Points of Contacts**
T. Berens DE		F. Asensio-Nieto ES		H. Ansell SE
L.P. Ruiz-Calavera ES	AS IPoCs will be included very soon	L. Goerig FR	HC IPoCs included above	A. Barrio Cardaba ES
N. Ceresola IT		M. Hanel DE		L. Hootsmans NL
M. Mallet FR		TBD SE		R. Lang DE
D. Pagan FR				R. Gutkin SE
N. Wood UK				C. Petiot FR
C. Newbold UK				A. Foreman UK
				M. Jessrang DE
				R. Olsson SE
				M. Riccio IT

9.2 Appendix 2 Overview of GARTEUR Technical Activities

The tables below show the rolling plans for GoR AD, HC and SM.

GoR AD

Number	Topic	2013	2014	2015	2016	2017	2018
AD/AG-51	Lamiminar-Turbulent Transition in Hypersonic flows						
AD/AG-52	Surrogate-based Global optimisation methods in preliminary designs						
AD/AG-53	Receptivity and Transition prediction						
AD/AG-54	RANS-LES Interfacing Hybrid for Hybrid RANS-LES and embedded LES approaches	EG69 ➔					
AD/AG-55	Countermeasures Aerodynamics		EG71 ➔				
AD/EG-70	Plasma aerodynamics						
AD/EG-72	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations						
AD/EG-73	Secondary Inlets and Exhausts for ventilation						
AD/EG-74	Integration of innovative nozzle concepts with thrust vectoring						
AD/EG-75	Supersonic air intakes						

GoR HC

Number	Topic	2013	2014	2015	2016	2017	2018
HC/AG19	Methods for Impr. of Struct. Modell. In-Flight Data						
HC/AG20	Simulation/Testing for design of passive noise absorption panels						
HC/AG21	Rotorcraft Simulation Fidelity Assessment						
HC/AG22	Forces on Obstacles in Rotor Wake	EG32 =>					
HC/AG23	Wind Turbine Wake and the effect on helicopters	EG32 =>					
HC/AG24	Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction		EG34 =>				
HC/EG28	Testing/Modell. for Internal Noise Investig.						
HC/EG29	HUMS						
HC/EG30	Simulation Fidelity	=> AG21					
HC/EG31	Conceptual design of Helicopters CoDHe		x				
HC/EG32	Forces on Obstacles in Rotor Wake		=> AG22				
HC/EG33	Wind Turbine Wake and the effect on helicopters		=> AG23				
HC/EG34	CFD based flow prediction for complete helicopters		x				
HC/EG35	Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction		=> AG24				

GoR SM

Number	Topic	2012	2013	2014	2015	2016	2017
SM/AG30	High Velocity impact				▲		
SM/AG33	RTM material properties during curing				▲		
SM/AG34	Damage repair in composite and metal structure						
SM/AG35	Fatigue and damage tolerance assessment of hybrid structure						
SM/AG39	Design for high velocity impact on realistic structure				➔ AG 36		
SM/AG42	Bonded and bolted joints						
SM/AG43	Additive Layer Manufacturing						

	Active		Extended		Closed		Inactive	▲	Finalisation of report

Table 7 GARTEUR Action and Exploratory Groups – 6 year rolling plan

In addition GoR FM initiated two EGs in 2015 which are currently on hold; FM/EG-28 “Non-linear flexible civil aircraft control methods evaluation benchmark” and FM/EG-29 “Trajectory V&V Methods: formal, automatic control and geometric methods”.

GoR AS are considering four EGs on the topics of Cybersecurity, CBE, Dazzling and RPAS.

9.3 Appendix 3 Participation in Action Groups by Nations/Organisations in 2016

Country	Participants	GoR (Number of Action Groups)			
		AD (5)	HC (6)	SM (2)	Total (13)
France	ONERA	4	5	0	9
	Industry	3	1	0	4
	Academia	1	0	0	1
Germany	DLR	3	5	2	10
	Industry	5	0	0	5
	Academia	3	1	0	4
Italy	CIRA / CNR	4	5	3	12
	Industry	0	2	1	3
	Academia	0	6	2	8
The Netherlands	NLR	2	6	5	13
	Industry	0	1	1	2
	Academia	0	2	0	2
Spain	INTA	2	0	1	3
	Industry	1	0	0	1
	Academia	0	0	0	0
Sweden	FOI	3	0	3	6
	Industry	2	0	3	5
	Academia	1	0	3	4
United Kingdom	ATI	0	0	0	0
	Industry	0	2	1	3
	Academia	3	9	1	13
Non-GARTEUR	National Research Establishments	0	0	0	0
	Industry	0	1	0	1
	Academia	3	2	2	7

GoR	AG number	Research Establishment	Industry	Academic Institutes	Total
AD	51	3	1	3	7
	52	4	2	3	9
	53	3	2	2	7
	54	6	3	3	12
	55	2	3	0	5
HC	19	1	3	3	7
	20	4	1	1	6
	21	3	3	2	8
	22	4	0	4	8
	23	4	0	6	10
	24	5	0	2	7
SM	34	5	3	4	12
	35	3	2	0	5

Table 8 Participation in Action Groups by organizations

9.4 Appendix 4 Resources deployed within Action Groups

GoR	AG	2013		2014		2015		2016		2017*		2018*	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	44	1	0										
	45	1	0										
	46	3	3	0	0								
	47	1	0	0	0								
	48	6	8	1	0								
	49	7	70										
	50	10	20										
	51	12	40	12	40	0	0	0	0				
	52	20	45	23	63	23	63	23	63				
	53	10	12	13	24	13	24	2	12				
	54			18	100	22	140	18	80	20	100	12	50
	55					16	24	18	24	16	24		
AD	TOTAL	71	198	67	227	74	251	61	179	36	124	12	50

GoR	AG	2012		2013		2014		2015		2016		2017	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	19	12	5	3	3	10		2		1		0	
	20	1	1	18	10	20	28	18	28	9	28	0	0
	21			15.5	0	14.5	10	6	10	4	8	0	0
	22							28	33	28	35	15	20
	23							18	1.6	17	1.3	18	0
	24							16.7	30.5	20.5	30.6	22	34
HC	TOTAL	13	6	36.5	13	44.5	38	88.7	103.1	79.5	102.9	55	54

GoR	AG	2012		2013		2014		2015		2016		2017	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	34	0	0	50	49	50	20	0	0	0	0	\	\
	35	1	1	10.5	16	11	41	10	35	10	35	\	\
SM	TOTAL	1	1	60.5	65	61	61	10	35	10	35	\	\

Table 9 Resources deployed within Action Groups: person-month and other costs in k€

9.5 Appendix 5 GARTEUR Reports

There were no GARTEUR technical reports completed in 2016. By the end of 2016 there were 162 reports available on the website and another 50 held by the secretariat as GARTEUR Limited. No GARTEUR Limited documents were declassified during 2016.

The 2015 Annual Report X/D 51, and the Annexes X/D 52 were published in May 2016.

9.6 Appendix 6 List of abbreviations

AAR: Air-to-Air Refuelling

ACARE: Advisory Council for Aviation Research and Innovation in Europe

AG: Action Group

ATI: Aerospace Technology Institute (UK)

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

CIRA: Italian Aerospace Research Centre

CNR: National Research Council (Italy)

DLR: German Aerospace Centre

EDA: European Defence Agency

EDRP: European Defence Research Programme

EG: Exploratory Group

EU: European Union

ETP: European Technology Platform

FOI: Swedish Defence Research Agency

GoR: Group of Responsables

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

INTA: National Institute of Aerospace Technology (Spain)

IPoC: Industrial Points of Contact

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

NLR: Netherlands Aerospace Centre

OCCAR: Organisation Conjointe de Coopération en matière d'ARmement

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

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

SRIA: Strategic Research & Innovation Agenda

TRL: Technology Readiness Level

XC: Executive Committee

For further information about GARTEUR please contact:
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