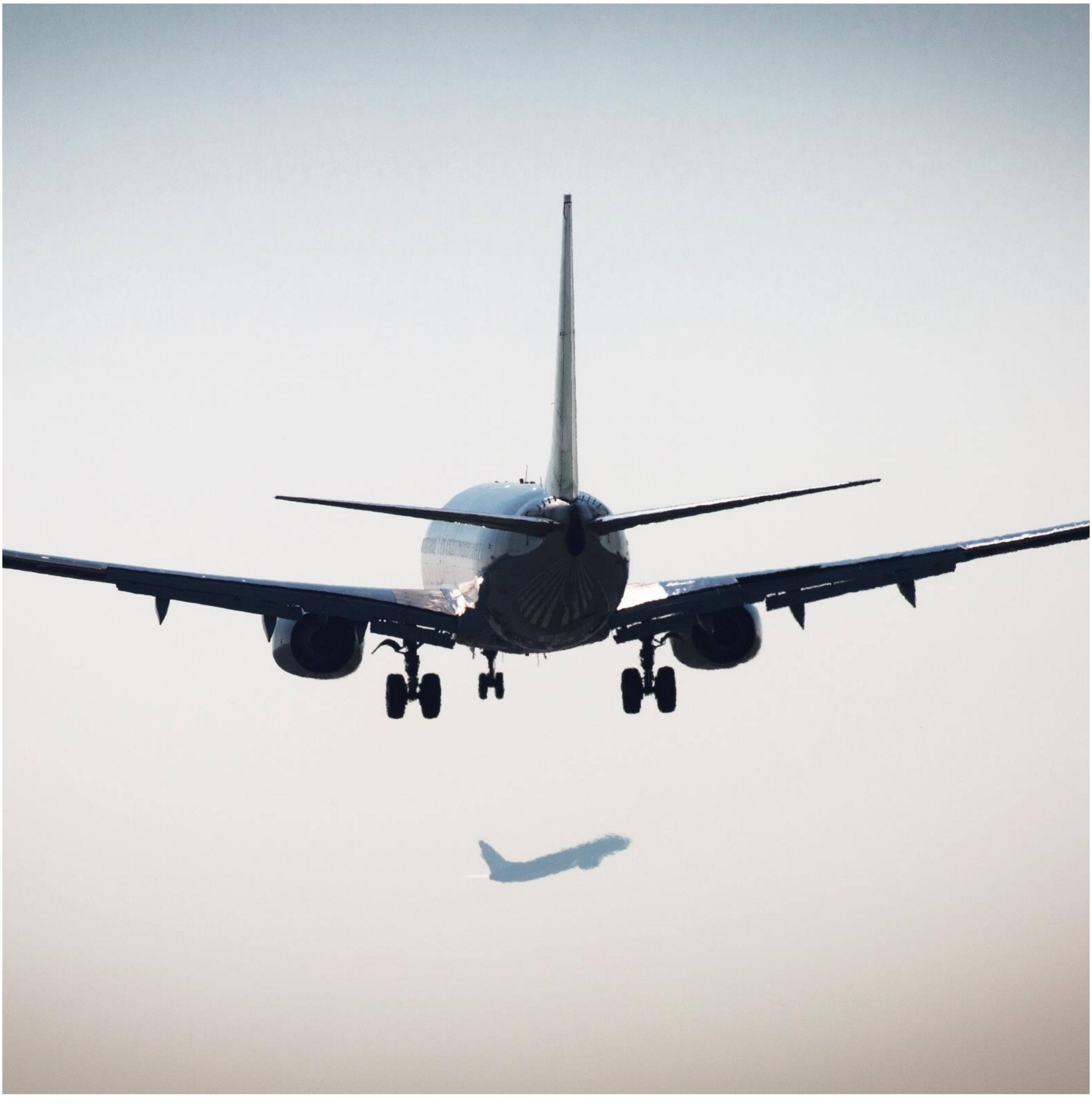
GARTEUR

ANNUAL REPORT 2020



GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

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GARTEUR ANNUAL REPORT 2020

GARTEUR aims at stimulating and co-ordinating co-operation between
Research Establishments and Industry in the areas of Aerodynamics,
Flight Mechanics, Systems and Integration, Helicopters and Structures & Materials.

Table of Contents

1. Introduction

Dear reader,

The year 2020 will be remembered as the year we as humanity learned a valuable lesson. The role aviation played in global travel and the resulting rapid spreading of a small viral organism will with no doubt be the subject of future studies. No other event since the collection of data on this topic has had this impact on aviation, tourism, trade and economy.

During taking over as chair begin 2020 we had different plans. Emerging technologies like AI, hypersonic and growing environmental concerns to name a few topics.

Quickly after the first lock-downs and travel restrictions we had to anticipate. As chair I have to state that I'm impressed by the work accomplished past year in these conditions by the XC and GoRs. Despite the restrictions on physical meetings we still managed to produce interesting research. I have to thank Kees Wijnberg as Chairman XC and our Secretary Ligeia Paletti for their continued effort to keep business within GARTEUR going.

GARTEUR was established with the goal to facilitate cooperation on aviation research and that means we have to keep looking forward. Opportunities like the European Defence Fund lay ahead. We proved that working in a virtual setting is possible, but human interaction profits if it's not by verbal communication alone.

This all reflects in our Annual Report of 2020, I wish that we can meet soon in physical form and wish you good reading.

LCOL Etiënne Nijenhuis

Chair GARTEUR 2020-2021

Dear GARTEUR Friends,

When taking over the GARTEUR Chairmanship at the end of 2019, who could have thought that 2020 would have been so much different than we anticipated?

We made plans, had some ideas about what to bring to GARTEUR during our Chairmanship...

COVID-19 hit all of us hard and also GARTEUR was impacted strongly by this. All of a sudden, physical meetings were not possible anymore and with an Organization that partly thrives on these meetings to boost activities, we found ourselves discussing how to keep the GARTEUR family together.

All of us were able to use online tools to reach out more and more, but it needed time and it was (and still is) not easy to do everything online. Nonetheless, we did our XC and Council meetings efficiently and, as XC, we supported the Council meetings the best we could.

As XC, we realized that we needed to support and push the Council more on open actions that were needed by the GoRs and thanks to Ligeia Paletti, GARTEUR Secretary, we even introduced, at the end of 2020, monthly meetings with the GoR heads and the XC to keep in touch.

When writing this, we are far in 2021 and things slowly seem to get better. Whether we can meet in person shortly, I do not know. I hope very soon, because GARTEUR needs that!

No, 2020 was not a year with optimal results, but certainly not a lost year either. So, enjoy reading this Annual Report which includes a lot of interesting research work done by the GoRs in 2020.

Kees Wijnberg

Chair XC GARTEUR 2020-2021

2. Executive summary

The GARTEUR Annual Report 2020 provides a summary of the main managerial actions of the Council, and the scientific and technological progress made by the five Groups of Responsables (GoRs). The GoRs constitute the main bodies for establishing research priorities in the technology areas covered by GARTEUR: aerodynamics, structures and materials, helicopters, flight mechanics and systems integration, and security.

Section 3 of this report provides a summary of the Council activities, including the changes in chairmanship and membership.

Section 4 reports on the European aeronautical R&T environment by highlighting the importance of European Collaborative Programs such as Horizon 2020 and Clean Aviation to civil aviation. Great steps have been taken to streamline aeronautical research in Europe, making use of several bodies within the European R&T environment (e.g. EREA and ACARE).

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

The GARTEUR scientific and technical activities are reported in section 5, with each of the five GoRs presenting a summary of their work during 2020.

3. GARTEUR Council

3.1 Chairmanship and membership

On the 1st of January 2020, the Netherlands succeeded Spain as chair of GARTEUR for a period of two years, ending on the 31st of December 2021.

During 2020 the Chairman of the Council was Lt. Col. Etienne Nijenhuis, from Directorate Operational Policy and Plans of the Dutch Ministry of Defence, with Kees Wijnberg, head of NLR's Flight Physics and Loads Department, as Chairman of the Executive Committee. Ligeia Paletti from NLR served as GARTEUR secretary during 2020.

3.2 GARTEUR council meetings

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

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

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

Meetings:

- XC164 – London (UK)
- C68 – Online
- XC165 – Online
- C69 – Online

3.2.1 XC164

The first XC meeting of 2020 was held in UK, hosted by ATI in its facilities in London on the 6th February. The primary purpose of the meeting was to make an overall review of the status of GARTEUR considering both technical and administrative / organization matter.

During November 2019 the handover for the chairmanship from Spain to the Netherlands was performed. The handover was performed successfully, explaining main operational and administrative aspects. The annual reports and the launch of the new website were the only actions still open to the Spain delegation.

The main topics discussed during this meeting were:

- The Netherlands approach towards a plan to develop a vision of the role of GARTEUR in the next 5 years and to implement concrete actions towards the GARTEUR Mission and Values, as defined in the Basic Documents;
- Progresses on the selection of research topics related to UAV for joint projects across GoRs.
- Implementation of GoR teamsites.

3.2.2 C68

The first Council meeting of 2020, C68, took place digitally, as consequence of travelling restrictions in place due to the COVID-19 pandemic, on April 1st. In that meeting Etienne Nijenhuis introduced the main themes of the chairmanship of the Netherlands for the period 2020-2021:

- Mission and vision of GARTEUR;
- Improve the visibility of GARTEUR and of its activities;
- Boost the engagement of academic and industrial partners.

During this meeting, the mission and vision of GARTEUR for the coming 5 years is being discussed.

Mario Verhagen presented the current status of the UAV overarching thematic. Possible topics and possible associations to the GARTEUR GoRs are discussed.

3.2.3 XC165

The XC165 meeting took place digitally on 22nd September 2020. The topics for discussion of XC165 were focused on three aspects:

- Impact of COVID-19 on GARTEUR;
- GARTEUR Vision and Action Plan;
- Improvements in the communication between Council, XC and GoRs.

The impact of the (national) measures to limit the spread of the COVID-19 pandemic on GARTEUR activities was topic of discussion.

Regarding the GARTEUR Vision and Action Plan, the XC members discussed about the GARTEUR Vision 2020-2025. The GARTEUR Vision is attached in Appendix A.

Regarding the need to improve the communication between Council, XC and GoRs, and the overall visibility of GARTEUR, it is discussed the need to shift the content of the communication from mainly technical to more related to impact of the research performed by the GoRs. This would enhance the communication potential towards external, industrial or government, research partners.

3.2.4 C69

The Council meeting C69 took place digitally on November 2nd and 3rd. During that meeting, the GARTEUR Vision was approved (see section 3.3.1) and, building on that vision, the positioning of GARTEUR with respect to the various European organisations was discussed. Another topic of discussion was the impact of COVID-19 on GARTEUR activities and how to ensure the functioning and communication of the GARTEUR participants.

Also, the presentation of the GARTEUR Award of excellence recipient "AD/AG52 SURROGATE-BASED GLOBAL OPTIMIZATION METHODS IN PRELIMINARY AERODYNAMIC DESIGN" was given by Esther Andres. The GARTEUR Award was delivered remotely by the Spain delegation.

3.3 Council initiatives

Following the Council initiatives detailed in 2019, the Netherlands chairmanship focused on developing the GARTEUR mission, vision and action plan.

A revision of the GARTEUR mission was deemed not necessary; the GARTEUR mission as detailed in the GARTEUR Basic Documents is still valid. Based on this mission and the GARTEUR principles, also included in the Basic Documents, the Netherlands delegation developed and presented a vision for the future of GARTEUR. Following discussions with the entire GARTEUR members, the GARTEUR vision was approved at C69 meeting. The full version of the GARTEUR vision is included in section 3.3.1.

The next step is to develop an Action Plan to support the GARTEUR mission and vision.

3.3.1 GARTEUR Vision 2020-2025

The European aviation and technology sector is currently confronted with various urgent internal and external mainstreams.

• We see developments in the field of Environment, where a.o. the Green Deal will pose quite a challenge on the aeronautical world.

• We see developments in the field of Defence and Security (e.g. cyber, UAVs, space), where recent activities of different states undermining security demand a strong and coordinated answer.

• And we see developments in the field of Mobility, where multi-modal transport and Urban Air Mobility are rising topics as possible answers to Urban Congestion.

These mainstreams are showing related challenges that can only be solved in a joint effort by multiple stakeholders from Academia, Research Institutes, Defence and Industry.

GARTEUR is the only collaboration platform that we as partners have and that:

- covers both Civilian and Military topics, at several managerial and TRL levels and that
- includes people from Academia, Research Institutes, Defence and Industry.

And considering GARTEUR Mission:

'...to mobilise, for the mutual benefit of the GARTEUR member countries, their scientific and technical skills, human resources and facilities in the field of aeronautical research and technology...'

we see that GARTEUR can provide added value for all partners, both in a coordinating role for collaborative research and at a technical level to jointly execute research not (yet) covered in other ways. And in terms of technical research, we see added value in the work done by the GoRs (our backbone) covering the above challenges in Environment, Defence and Security, and Mobility in a more and more integrated way (multi-disciplinary, integrated and multi-partner). With this integrated and collaborative approach, and focused on the mainstreams, GARTEUR provides additional knowledge to its partners that cannot be done by each partner individually.

In short, our Vision is that, for the next 5 years, GARTEUR will continue to actively focus on bringing added value to its network in a coordinating role for its research, as well as in executing technical research that adds value to all partners aiming at Environmental, Defence and Security, and Mobility topics

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.

During 2020 the website was regularly updated by the secretary.

For the use of the GoRs, DLR has arranged TeamSites, to be used as a repository for minutes and other documents. Those TeamSites are managed directly by the GoRs.

3.5 GARTEUR Certificates

In 2020 no certificates were issued.

4 The European aeronautics RTD environment

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

4.1 Civil aeronautics

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

Horizon 2020 is funding a considerable number of initiatives that will have a positive impact on Europe by unlocking innovation, providing the funds necessary to encourage and enable scientific and technological breakthroughs. Seen as a key driver of economic growth and job creation, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament Aeronautical RTD is funded through a specific Aviation programme within the Transport theme as a Societal Challenge and sets out to tackle some of the main environmental challenges attributed to the aeronautical industry including designing and producing cleaner and quieter aircraft, minimising the impact of transport on the environment. Another key focus of Horizon 2020 is aimed at creating better mobility, less congestion and more safety and security.

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

4.1.1 Strategic direction of European R&T

Since 2011, European Commission's Flightpath 2050 document outlines long-term goals associated with meeting society's needs for more efficient and environmentally friendly air transport, as well as maintaining global leadership for the European aerospace industry. It is therefore a crucial reference document for organisations in Europe and served as the basis for the research calls within Horizon 2020 and the research projects that GARTEUR chose to undertake over the last years.

In 2020 the development of the Clean Aviation JU began[1].

[1] Clean Aviation (clean-aviation.eu)

Europe needs to accelerate and enhance its efforts to achieve the ambitious goals set out in the Paris Agreement. The European Green Deal has been established as a cornerstone policy of the European Union, including the first European Climate law, which enshrines the 2050 climate neutrality objective in legislation. At the same time, the newly launched Industrial Strategy for Europe lays out in clear terms the importance of industrial leadership in making the transformation to a green and digital Europe fit for the future.

The aviation sector will need to contribute to these priorities and transform. Together with the European Union, European aviation has the power to lead the way toward a climate neutral aviation system and set new global standards for *safe, reliable, affordable and clean air transport*.

The journey to a climate neutral aviation system is well beyond the private sector's capability and capacity to invest alone. Equally, no single country in Europe has the financial, technological and industrial capability to affect the transformation. The European additionality is evident. An Institutionalised European Partnership for Clean Aviation under Horizon Europe constitutes the only approach that can pull together the resources and commitment and adequately reduce the industrial risk for transformative research and innovation. This approach will secure the long-term industrial commitments needed for long innovation cycles. It will ensure that research activities of industry are aligned with the Union's policy priorities. It will build Europe's leadership in innovation and technology, and deliver jobs and economic growth throughout the transition to a climate neutral Europe by 2050. It can offer future generations the promise of continued, affordable and equal access to air travel, and its social and economic benefits, and contribute to the UN's Sustainable Development Goals.

The new Partnership will build upon the important technological progress that has been made under the Clean Sky and Clean Sky 2 programmes. Support from the EU Institutions and European Member States will be essential in creating the conditions for impact, and in enabling synergies with other EU, national and regional research and innovation programmes.

The Clean Aviation Partnership's Strategic Research and Innovation Agenda [SRIA] sets out the way to achieve the overall vision, in terms of timescales and magnitude of impact. This integrated research roadmap includes the required upstream 'exploratory' research that is essential to finding tomorrow's pathways to mature technologies, ready to be incorporated into further new and disruptive innovations.

The Clean Aviation trajectory defines two clear horizons towards climate neutrality by 2050:

2030: *demonstrating and introducing low-emissions aircraft concepts exploiting the research results of Clean Aviation, making accelerated use of sustainable fuels and optimised 'green' operations, so these innovations can be offered to airlines and operators by 2030 for an entry into service [EIS] in the 2030-2035 timeframe;*

2050: *climate neutral aviation, by exploiting future technologies matured beyond the Clean Aviation phase coupled with full deployment of sustainable aviation fuels and alternative energy carriers.*

4.1.2 GARTEUR and ACARE

In addition to its responsibility for developing the SRIA, ACARE plays an integral role in advancing aviation innovation within Europe by developing policy positions on European aviation initiatives and working closely with European Commission officials to ensure that Horizon 2020 funding calls - as well as calls associated with the Clean Sky 2 and SESAR Joint Undertakings - are closely aligned with the SRIA.

Members of the GARTEUR Council are also heavily involved with ACARE and this ensures that GARTEUR's research interests are strategically aligned with the SRIA, ensuring that GARTEUR remains focused and committed to the major challenges being addressed by pan-European aerospace research and innovation. GARTEUR's representatives within ACARE have emphasised that the innovation life-cycle needs to have the right mix of projects at all levels; covering the early, critical part of the innovation pipeline as well as the 'market readiness' associated with high TRL projects.

4.1.3 GARTEUR and EREA

EREA is the Association of European Research Establishments in Aeronautics, whose members are Europe's most outstanding research centres in the field of aeronautics and air transport.

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

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

4.2 Military aeronautics

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

4.2.1 European Defence Agency

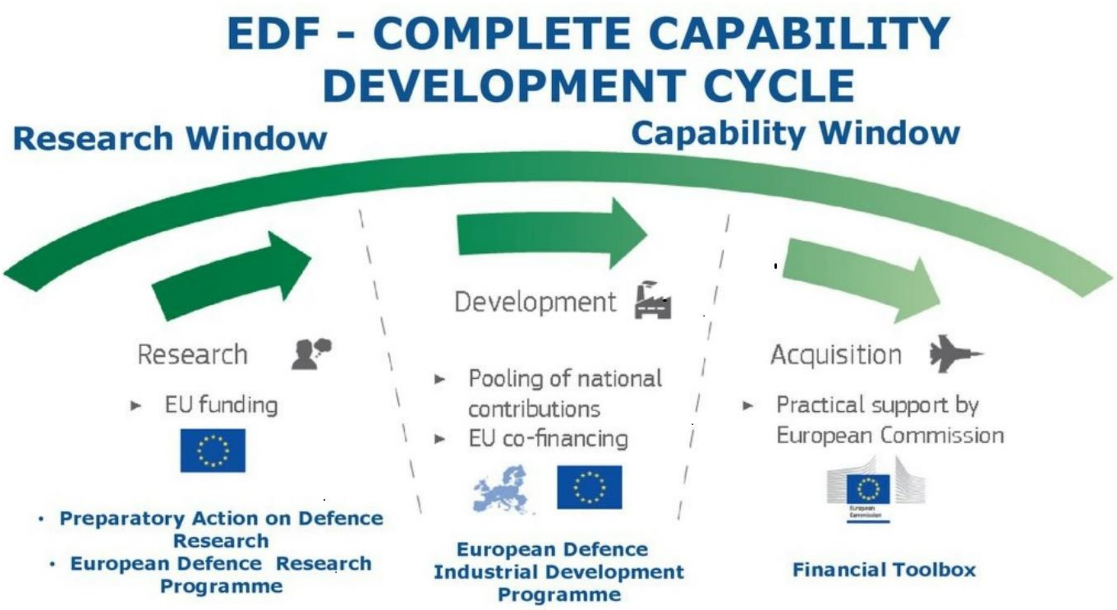
The European Defence Agency (EDA) is an intergovernmental agency of the Council of the European Union, comprising all EU members with the exception of Denmark and also including from non-EU member states, Norway, Switzerland, the Republic of Serbia, and Ukraine, through special administrative arrangements.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

4.2.2 European Union-funded defence research

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

The European defence fund supports collaborative defence research and development through consecutively programmes with limited duration and budget:

- The preparatory action on defence research (PADR, 2017-2019. The preparatory action on defence research provided grants for collaborative defence research with a budget of €90 million.
- The European defence industrial development programme (EDIDP, 2019-2020). The European defence industrial development programme offered co-financing for collaborative defence development projects with a budget of €345 million
- The European Defence Fund (EDF, 2021-2027) has been rewarded a total of 7 Bljrd programme funding by the European Committee.



5 Summary of GARTEUR technical activities

During 2020 the five GARTEUR Groups of Responsables (GoRs) continued to facilitate and deliver vital research in the field of aeronautics. The GoRs are responsible for monitoring and encouraging the progress of Action Groups (AGs) and Exploratory Groups (EGs). These groups are collaborations of researchers from national aerospace institutes, universities and industry. Although GARTEUR is not a source of funding, the GoRs constitute a powerful network and provide a unique forum for aeronautical research in Europe. The GoRs aid potential research consortia by critically reviewing their proposed research objectives and methodologies.

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

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

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

5.1 Group of Responsables – Aerodynamics (AD)

5.1.1 GoR-AD Overview

The GoR AD initiates and organises basic and applied aerodynamic research in the field of aeronautics. The current scope of activities covers the following areas:

- Aerodynamics;
- Aero-thermodynamics;
- Aero-acoustics;
- Aero-(servo-)elasticity;
- Aerodynamic shape optimization;
- Aerodynamics coupled to flight mechanics;
- Aerodynamics systems integration.

The activities aim to advance the collaborative aerodynamic research in Europe, combining both numerical and experimental research. Dedicated experiments are carried out using advanced experimental techniques and measurements methods in order to generate valuable data needed for the further understanding of basic flow physics, for the investigation of specific aerodynamic problems, and for the validation of numerical simulation tools in a number of areas. The computational activities comprise the further development of simulation and prediction tools of different classes of fidelity, the tool validation using experimental data, and also the application of these tools for the investigation of specific problems arising in aeronautical applications. The close collaboration of experimental and numerical activities is of great benefit and enables enhanced progress in aeronautical research.

Whilst the majority of the research activities focusses on mono-disciplinary aerodynamics, some of the work also has a significant amount of multi-disciplinary content. This trend is driven by industrial interests, and is likely to increase in the future.

Funding for GARTEUR activities is relatively small and, in general, is insufficient to fully support new research. In most cases therefore the AG activities are combined with activities funded through other routes, such as EU, NATO STO (Science and Technology Organisation) or national aeronautical research programmes.

Research initiated in GoR-AD programmes sometimes leads to an EU proposal or compliments concurrent EU program content. In addition, the content of GoR-AD activities can be cross sectorial in covering both civil and military interests.

5.1.2 GoR-AD Activities

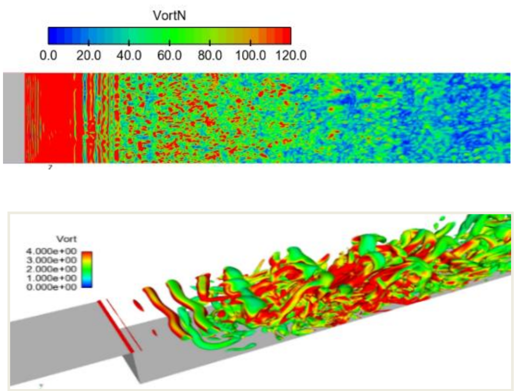
In 2020, one Action Group (AD/AG-54) was completed and four others were active (AD/AG-56, AD/AG-57, AD/AG-58, AD/AG-59). Two Exploratory Groups (AD/EG-77, AD/EG-78) were active. AD/EG-78 was transformed into an Action Group (AD/AG-60). Details about these groups can be found below.

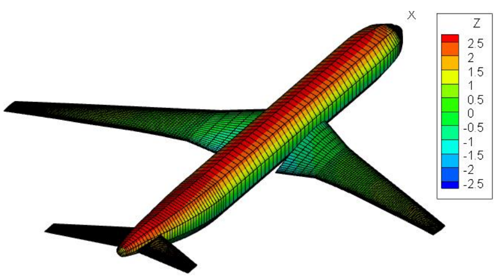
Regarding the interaction with the other GoRs, an example are the aero-servo-elastic simulations conducted in AD/AG-56. The chairs of the different GoRs interact during the Council meetings or meet in specific sessions dedicated to multi-disciplinary topics.

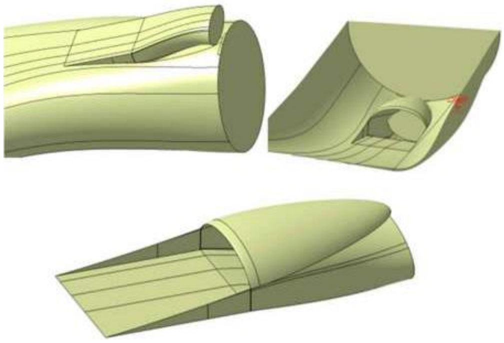
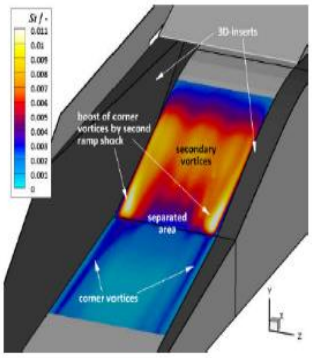
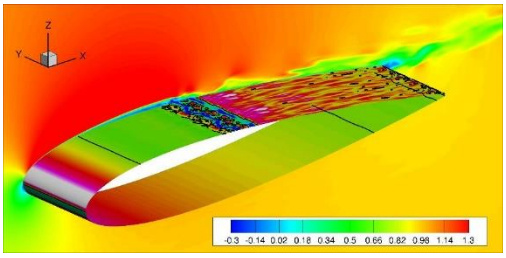
In 2020, several ideas for possible new Groups were on the table. Among those that have not yet resulted in an EG are: Natural Laminar Flow Monitoring, Morphing for Load Control, Convective Heat Transfer, Immersed Boundary Simulations, Hypersonic Flows, Thermal Management for Electric Propulsion, Corner Flows, Human Droplet Dispersion.

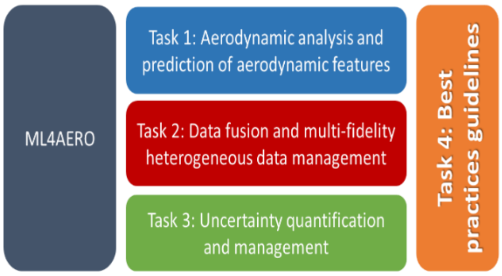
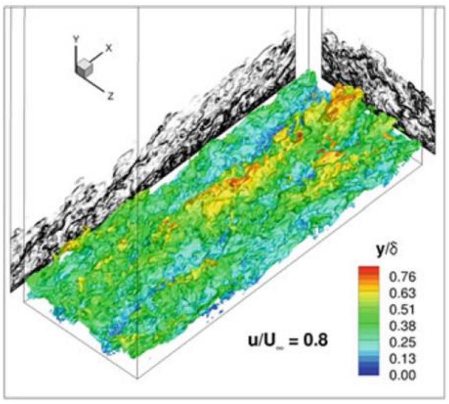
Activities in 2020 were affected by the worldwide COVID-19 pandemic and the progress of most AGs and EGs has slowed down due to these circumstances. Since the pandemic continues in 2021, further delays can be expected and extensions of AGs and EGs may be necessary.

Five Action Groups and two Exploratory Groups were active in 2020. One new AGs started at the end of 2020.

AD/AG-54	RANS-LES Interfacing for Hybrid and Embedded LES Approaches
 	The overall objective of AD/AG-54 has been to explore and further to develop and improve RANS-LES coupling for embedded LES (ELES) and hybrid RANS-LES methods, particularly, to address the "grey-area" problem present in zonal and non-zonal hybrid models, for aerodynamic applications. Both zonal and non-zonal approaches are considered. Three fundamental flow test cases have been selected to investigate the different methods. The AG started in April 2014 and the final meeting took place in Nov. 2018. The final report will be ready in the beginning of 2021. The chairperson is Shia-Hui Peng (FOI).

AD/AG-56	Coupled Fluid Dynamics and Flight Mechanics Simulation of Very Flexible Aircraft Configurations
 	Very flexible aircraft are light-weight constructions that require multi-disciplinary design tools. Main objectives of AD/AG-56 are to enhance the partners' capabilities in aeroelastic simulations to more accurately predict aerodynamic loads and structural deformations for manoeuvre and disturbance conditions, and to allow for the benchmarking of inhouse tools amongst the partners through the use of a common research model. In 2020, limited progress has been made, in part because of a change in chairmanship. The chairperson is Richard van Enkhuizen (NLR).

AD/AG-57	Secondary Inlets and Outlets for Ventilation
	Aircraft require a variety of secondary air inlets and outlets mostly for environmental control systems, APU operation, ventilation and cooling purposes. Main objectives of AD/AG-57 are to analyse and improve the efficiency of conventional secondary air inlets for different applications on fuselage and wing, and to explore the feasibility of new low-observable concepts hidden within the main engine intake. In 2020, most activities had to be suspended because of the COVID-19 pandemic. The chairperson is Jose Angel Hernanz-Manrique (Airbus Operations).
AD/AG-58	Supersonic Air Intakes
	Supersonic air intakes are of foremost importance in the design of supersonic air-breathing vehicles. Main objectives of AD/AG-58 are to gather a database of relevant flow features on representative test cases and to validate CFD codes on these specific topics. Investigations include the control of cowl oblique shock / boundary layer interactions, internal bleed flows, and effects of intake diffusers and scramjet isolators. In 2020, geometries have been selected and exchanged. The first ZDES computations have been launched and compared to RANS approaches. Nevertheless, activity has been delayed and a one-year extension is needed. The chairperson is Christophe Nottin (MBDA).
AD/AG-59	Improving the Simulation of Laminar Separation Bubbles
	Laminar separation bubbles are one of the main critical aspects of flows at low Reynolds number, of order of magnitude 10^4 to 10^5, which are relevant for small aircraft such as UAV. Main objectives of AD/AG-59 are advancements in the understanding of the evolution of laminar separation bubbles and their effect on airfoil flows, and the improvement of the numerical prediction of flows with laminar separation bubbles. In 2020, activities comprised two wind tunnel experiments in WP 1 and numerical investigations for the different test cases in WP 1 to WP 4. The chairperson is Pietro Catalano (CIRA).

AD/EG-77 → AD/AG-60	Machine Learning and Data-Driven Approaches for Aerodynamic Analysis and Uncertainty Quantification
	Aerodynamic analysis and uncertainty quantification are key capabilities used in aircraft design. Main objectives of AD/AG-60 are the improvement of machine learning capabilities and valuable knowledge of the selected data-driven techniques in aerodynamic analysis and uncertainty quantification. Through the proposed activities it is expected that best practice guidelines will be concluded and the use of machine learning methods is facilitated in the aeronautical industry. In 2020, the AG proposal has been finalized and was approved by Council. The chairperson is Esther Andrés (INTA).
AD/EG-78	Hybrid RANS/LES methods for WMLES and Embedded LES
	For future aircraft design and certification, wall-bounded turbulence-resolving hybrid RANS/LES methods are of particular interest for the prediction of flow phenomena related to aeroacoustics, unsteady loads, mild flow separations or boundary layers undergoing strong adverse pressure gradients. A work programme is developed in order to enhance the capabilities of wall-modelled LES and embedded LES. In 2020, the AG proposal has been prepared as a follow-on of AD/AG-54 and will be finalized in 2021. The chairperson is Nicolas Renard (ONERA).

5.1.3 GoR-AD Membership

The membership of GoR-AD in 2020 is presented in the table below.

Chairperson		
Kai Richter	DLR	Germany
Members		
Giuseppe Mingione	CIRA	Italy
Eric Coustols	ONERA	France
Fernando Monge	INTA	Spain
Bruno Stefes	Airbus Operations	Germany
Magnus Tormalm	FOI	Sweden
Harmen van der Ven	NLR	Netherlands
Per Weinerfelt	SAAB	Sweden
Industrial Points of Contact		
Nicola Ceresola	Leonardo Company	Italy
Michel Mallet	Dassault Aviation	France
Didier Pagan	MBDA	France
Luis P. Ruiz-Calavera	AIRBUS D&S	Spain

5.2 Group of Responsables – Aviation Security (AS)

5.2.1 GoR-AS Overview

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

The GoR-AS initiates, organises and performs computational and experimental multidisciplinary research in the following areas: on board software, artificial intelligence, risk assessment, cybersecurity, airport operations, image recognition, Data analytics, decision making tools, RAMS analysis, FMECA, Fault Tree, event tree analysis, HMI, CONOPS.

The main aim is to increase security, safety and operation performance for critical assets in the aviation domain.

5.2.2 GoR-AS Activities

The approach in 2020 aimed at keeping links with other running initiatives like ES4AWG, Optics2 project, ACARE WG4.

Furthermore, the chairperson started to attend the SAGAS Stakeholders' Advisory Group on Aviation Security meetings. The role of this group is to advise the Commission in the preparation of legislative proposals and policy initiatives as well as in relation to the implementation of existing legislation. The Group shall be kept informed by the Regulatory Committee on Aviation Security during the entire regulatory process. The Group meets back to back with the Committee approximately six times a year and is open to European representative organisations engaged in, or directly affected by, aviation security.

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

In Italy contacts with the following stakeholders increased awareness about their interests:

> <u>Leonardo</u>: Hostile Drone Interception, Drone Identification, Drone Localization and Tracking, and related challenges.

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

The current scope of the security activities in the GoR covers “Drone as threats and solutions”. The idea to launch such a topic as an action, has brought increase in competence to start applying for collaboration opportunities.

The main actions in 2020 were:

1. To further develop and share ideas among the active members (CIRA, ONERA, INTA) to identify research challenges and collaboration approaches involving ONERA and DLR in a project proposal to set up an experimental network;
2. To support existing initiatives in aviation security at European level in order to promote harmonization among them and with GARTEUR;
3. To involve the industries interested in the chosen topics Eurocontrol, AENA (the first airport operator company in the world by number of passengers), ENAIRE (the Spanish air navigation service provider), Soulsoftware, ALISCARL, Leonardo;
4. To contact the Italian Armed Forces Italian Joint C-UAS Centre of Excellence and currently defining a MoU to collaborate with them;
5. To involve ENAC (The Italian aviation Authority) and EASA which are in ASPRID advisory board to keep them informed about the approach and to get relevant information from their domains;
6. To write a paper for ESREL 2020 conference;
7. To monitor current funded initiatives to apply for with a collaborative approach involving other key players.

The actions are summarized in the following table:

Id	Action	Responsible	Due Date	Deliverable
1	Finalize the choice of the common topic	GoR-AS chairperson	May	Contribution to pilot paper
2	Definition of a research concept for C-UAS	GoR-AS chairperson + ONERA, NLR, DLR	July	Pilot paper
2	Identify the objectives and involve partners	GoR-AS chairperson + All	September	Pilot Paper
3	Prepare and finalize the Consortium agreement and Grant Agreement	CIRA, ONERA, INTA + other partners	October	
4	Start of ASPRID project	INTA, CIRA, ONERA + other partners	November	Plan for GoR-AS activities
5	Monitor progress and organize digital meetings	GoR-AS chairperson	November, December	Scheduling and agenda
6	Present the paper at ESREL 2020	GoR-AS chairperson	November	

During 2020 work has been done by the active members (CIRA, ONERA, INTA) on the research theme of “Malevolent use of RPAS”.

In 2020, working towards an action group, by developing approaches to protect critical infrastructures by intruder’s attacks, GoR-AS has also monitored the external funded initiatives on the topics of interest. The action group was dedicated to start the work in the funded project and to work on a proposal preparation. The investigated topics have been kept:

- in line with FlightPath 2050;
- further dealt in the ACARE SRIA update and its dedicated Challenge on Aviation Safety and Security;
- fitting with the PADR (Preparatory Action for defence research) in Horizon 2020 and FP9;
- aligned with EREA Security for Aviation initiative;
- a priority for Europe.

A survey among GoR-AS participants was performed to assess the interest to participate in a proposal which seemed relevant to the GoR-AS perimeter of topics. The call was under H2020-Funding Scheme: ISFP-AG, to enhance European coordination in the testing of different UAS countermeasures solutions in order to provide Member States with a generic methodology and baseline understanding of the effectiveness of commercially available C-UAS solutions for the detection, tracking and identification (DTI) of drones that may be a security threat. An exploratory group, partially outside GARTEUR, made by ONERA, NLR, CIRA and DLR, dedicated focus to such theme and a project proposal led by NLR has been submitted, though the instrument was not specifically oriented to research establishments. The proposal was not funded.

Nevertheless, such a topic can be partially integrated in EREA Security for aviation working group and represents hints for exploratory and future action groups, provided the GoR-AS will receive the necessary commitment by the represented organizations.

The project ASPRID- Airport System Protection from Intruding Drones - belongs to Horizon 2020 Call: H2020-SESAR-2019-2 (SESAR 2020 EXPLORATORY RESEARCH) Topic: SESAR-ER4-13-2019 Type of action: SESAR-RIA. ASPRID project has started in November 2020.

ONERA, INTA and CIRA started the activities within ASPRID Project together with the industrial stakeholders to plan tasks and activities. The industrial partners are:

- ENAIRE, the Spanish Air Navigation Service Provider;
- Aena, the first airport operator company in the world by number of passengers;
- Two Italian companies, providers of counter drone solutions:
  - SoulSoftware SRL;
  - Aerospace Laboratory for Innovative components (ALI Scarl).

It represents a good chance for GoR-AS as it matches the theme identified as interesting for a possible AS action group.

The dissemination events during 2020 are represented by the following:

- A meeting (WebEx) was held among the GoR-AS in May 2020 between CIRA, INTA and ONERA. During this meeting information was shared to assess the interest to participate in a Conference ESREL 2020 to introduce the work done within the action group.

- Publication appeared in ESREL 2020 PSAM 15 The 30th European Safety and Reliability Conference Proceedings - T45-09 Solution Set-Up For Airport Protection From Intruder Drones Angela Vozella, Francisco Munoz Sanz, Mario Antonio Solazzo, Pierre Bieber, Giancarlo Ferrara, Edgar Martinavarro Armengol. This paper collects the concept developed in GoR-AS in 2018-2019 by CIRA, INTA, and ONERA.

5.2.3 GoR-AS Membership

The membership of GoR-AS in 2020 is presented in the table below.

Chairperson		
Angela Vozella	CIRA	Italy
Members		
Francisco Munoz Sanz	INTA	Spain
Pierre Bieber	ONERA	France
Rene Wiegers	NLR	The Netherlands
Andreas Bierig	DLR	Germany
Hans-Albert Eckel	DLR	Germany
Industrial Points of Contact		
Clive Goodchild	BAE Systems	UK

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

5.3.1 GoR-FM Overview

The Group of Responsables for Flight Mechanics, Systems and Integration is active in the field of flight systems technology in general.

The GoR-FM is responsible for all research and development subjects concerning a chain starting from the air vehicles and their flight mechanics, concerning embedded sensors, actuators, systems and information technology, cockpits, ground control and human integration issues, with reference to automation for both inhabited and uninhabited aircraft, including, but not limited to:

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

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

5.3.2 GoR-FM Activities

The activities in 2020 have been limited to exploring new opportunities for joint approach and obtaining members from all countries.

In 2020, two topics have been down selected from the discussed new topics. These two topics are Fault detection/recovery and distributed propulsion and positioning of the control surfaces. On both topics a pilot paper is initiated. Based on these pilot papers it will be decided in 2021 if the topics are viable for Exploratory Groups.

Furthermore, the following two topics are under consideration for a pilot paper:

- Flexible aircraft control
- Guidelines on certification

5.3.3 GoR-FM Membership

The membership of GoR-FM in 2020 is presented in the table below.

Chairperson		
Marinus Johannus van Enkhuizen	NLR	The Netherlands
Members		
Bernd Korn	DLR	Germany
Antonio Vitale	CIRA	Italy
Carsten Doll	ONERA	France
Jaime Cabezas Carrasco	INTA	Spain
Martin Hagström	FOI	Sweden
Andrew Rae	University of the Highlands and Islands in Scotland	UK
Industrial Points of Contact		
Laurent Goerig	Dassault	France
Philippe Goupil	Airbus	France
Martin Hanel	Airbus Defence and Space	Germany
Peter Rosander	Saab	Sweden

5.4 Group of Responsables – Helicopters (HC)

5.4.1 GoR-HC Overview

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

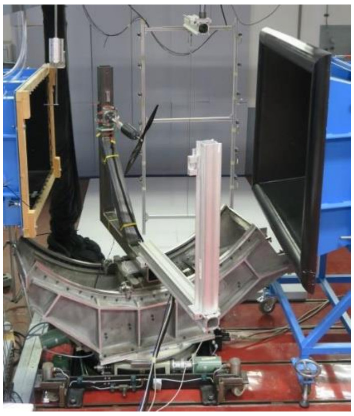
The GoR-HC initiates, organises and monitors basic and applied, computational and experimental multidisciplinary research in the following areas and in the context of application to rotorcraft vehicles (helicopters and VTOL aircraft, such as tilt rotors, compounds and multicopters) and systems technology.

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

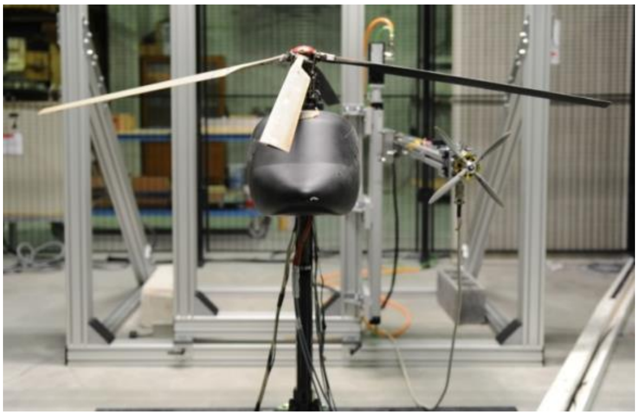
- Decrease costs (development and operation) through Virtual Engineering using numerical tools based on low-order (analytical, BEM) to high-order (CFD) methods, validated with relevant test campaigns;
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient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

Technical disciplines include, but are not limited to, aerodynamics, aeroelasticity including stability, structural dynamics and vibration, flight mechanics, control and handling qualities, vehicle design synthesis and optimisation, crew station and human factors, internal and external acoustics and environmental impact, flight testing, and simulation techniques and facilities for ground-based testing and simulation specific to rotorcraft.

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



Preliminary test of isolated rotor in 1m-tunnel at DLR Göttingen (HC/AG-25)



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

5.4.2 GoR-HC Activities

In 2020, GoR-HC monitored the following action groups:

HC/AG-21	*Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity* Main goal of the project is the development of new simulation assessment criteria for both open-loop predictive fidelity and closed-loop perceived fidelity. Final simulation trials were done in 2016 and analysed in 2017. All technical activities are closed. The final report was delivered on 1st Oct. 2020.
HC/AG-25	*Rotor-Rotor-Interaction* The main objective is to investigate, both numerically and experimentally the effect of rotor / rotor and rotor / propeller wakes interactions on high speed rotorcraft operating in low speed conditions with the aim to establish low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes. The AG started in October 2019.

The following Exploratory Groups were active or decided to start in January 2021:

HC/EG-38	*Verification & Validation: Metrics for the Qualification of Simulation Quality* To define metrics for the qualification of the quality of rotorcraft simulations, as a contribution to the Verification and Validation (V&V) process of numerical codes. The progress in this EG was limited and the workshop in 2019 did not bring the expected clarity for the next steps. As the topic is very relevant GoR-HC is still supporting the key ideas of this EG. It is to be considered that the EU CS2 Project RoCS (Rotorcraft Certification by Simulation) is covering very similar topics. Due to limited resources in the relevant organizations it was decided to put this EG on hold from 1st July 2020 until the end of the RoCS project. Due to effects of the COVID-19 pandemic an extension of RoCS until the end of 2022 can be expected. With the end of RoCS GoR-HC will try a restart of HC/EG-38 in order to produce meaningful Terms of Reference for possible AGs.
HC/EG-39	*Testing and modelling procedures for Turbulent Boundary layer noise* To identify ways how to reduce the flow induced noise in rotorcraft. The chairperson was in 2020 a visiting scientist at NASA working on other topics and took up the EG-lead after his return in September 2020. The first meeting took place in December 2020.
HC/EG-40	Gust Resilience of VTOL Aircraft The objective is to set-up a team of researchers able to investigate and test the different approaches that might be employed to achieve gust resilience of multi-rotor vehicles. This EG was identified in 2019 and was expected to be active in 2020. Unfortunately, Cranfield’s application for UK funding to support this activity was not successful therefore Cranfield had to withdraw from chairing this EG. The new chairperson is Prof. Lovera from Politecnico di Milano who will restart this EG in 2021.
HC/EG-41	Noise Radiation and Propagation for Multirotor System Configurations The objective is to investigate noise radiation and propagation (installation effect) of multirotor systems. Compared to conventional helicopters the importance of the various noise sources and the influence of noise scattering can be totally different for multi rotor configurations. The list of interested parties was established in 2020 and this EG will get active in 2021.

New topics under consideration are:

Modelling of electric systems for e-VTOLS (pre-design) To provide simple relations for considering the electric system of eVTOLS in predesign.
Drone impact on Helicopters (rotating parts) To gain insight in the severity level of drone rotor blade interactions.
Ice accretion and performance prediction on rotary wings To improve the assessment of performance degradation when flying with rotorcraft in icing conditions.
Human Factors issues and Training methods for complex automation in cockpit To improve the overall performance of the pilot / rotorcraft system in accomplishing missions
PSP/TSP for rotors/propellers (drone, eVTOLS...) To assess the potential and the limitations of pressure and temperature sensitive paint in rotorcraft wind tunnel tests.
Analysis and Decomposition of the Aerodynamic Force Acting on Rotary Wings To study the application to rotary wings of aerodynamic force analysis and decomposition methods.

5.4.3 GoR-HC Membership

The membership of GoR-HC in 2020 is presented in the table below.

Chairperson		
Klausdieter Pahlke	DLR	Germany
Members		
Joost Hakkaart	NLR	The Netherlands
Mark White	Uni. of Liverpool	United Kingdom
Arnaud Le Pape	ONERA	France
Antonio Visingardi	CIRA	Italy
Industrial Points of Contact		
Rainer Heger	Airbus Helicopters	Germany
Observer		
Richard Markiewicz	Dstl	United Kingdom

5.5 Group of Responsables – Structures and Materials (SM)

5.5.1 GoR-SM Overview

The GoR-SM is active in initiating and organizing aeronautics-oriented research on structures, structural dynamics and materials in general. Materials oriented research is related to material systems primarily for the airframe; it includes specific aspects of polymers, metals and various composite systems. Structural research is devoted to computational mechanics, loads and design methodology. Research on structural dynamics involves more especially response to shock and impact loading.

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 simulation 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.

Although the specific topics vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas of future activity; in this context many new ideas were proposed and explored during the year 2020.

Activities within the Exploratory and Action Groups cover several aspects of improved conventional and new technologies, new structural concepts and new design and verification criteria. Recent, current and upcoming work is devoted to:

- Fatigue and damage tolerance assessment of hybrid structures
- Damage repair with composites in composite and metallic structures
- Characterization and modelling of Composites with Ceramic Matrix submitted to severe thermo-mechanical loading
- Characterization of composites with polymer matrix at high temperatures
- Characterization and optimization of shock absorbers for civil aircraft fuselages
- Additive Layer Manufacturing

5.5.2 GoR-SM Activities

In 2020, GoR-SM monitored the following Action Groups:

SM/AG-34	**Damage repair with composites** This Action Group started in the second half of 2012 and originated from SM/EG-40. The main objective of the work consists in the definition of effective repair techniques both for civil and military aircraft structures through the development of numerical/experimental methodologies. There has been no activity in the past two years. However, the work is almost completed and a draft report is under validation. A final version of the report will be issued beginning of 2021.
SM/AG-35	**Fatigue and Damage Tolerance Assessment of Hybrid Structures** This Action Group started in March 2012 and is a result from SM/EG-38. The final report is ready and should be sent beginning of 2021.

The following Exploratory Group was still open in 2020:

SM/EG-43	**Development of additive layer manufacturing for aerospace applications** This Exploratory Group started in the second half of 2014 and only met once in February 2015. At that time, it was proposed to launch a benchmark to compare three different machines (2 SLM machines by NLR and DLR) and an ARCAM machine by CIRA. Given the evolution of techniques and following the departure of most of participants, it was decided to close the group.

The following Exploratory Groups were launched in October 2020:

SM/EG-44	**Characterization of composites with polymer matrix at high temperatures** The main objective consists in the characterization of the mechanical properties of Composites with Polymer Matrix submitted to high thermal conditions. The work will be mainly experimental with the definition and improvement of experimental methods. The final objective would be to provide a test stand for the testing of classical coupons.
SM/EG-45	**Characterization and modelling of CMC submitted to severe thermo-mechanical loading** The main objective consists in the characterization of the mechanical properties and modelling of Composites with Ceramic Matrix (CMC) submitted to high mechanical loadings and extreme thermal conditions (>1000°C).
SM/EG-46	**Characterization and optimization of shock absorbers for civil aircraft fuselages** The main objective consists in the design and verification of composite/metal hybrid structures capable of reducing passenger cabin acceleration peaks during a fuselage crash event.
SM/EG-47	**Additive Layer Manufacturing** Two topics are under consideration for this EG. They consist in: • Novel aluminium alloys with the objective to explore new aluminium alloys suitable for processing via metal additive manufacturing techniques ; • Pre-identified development of intermetallics with the objective to investigate the metal 3D printing process for a commercial g-TiAl alloy.

Several other interesting and promising topics were discussed by the GoR members, and their potential for possible GARTEUR collaborative programmes has been thoroughly examined. Topics included:

- Additive Layer Manufacturing for polymers
- Bolted joints

5.5.3 GoR-SM Membership

The membership of GoR-SM in 2020 is presented in the table below.

Chairperson		
Florence Roudolff	ONERA	France
Members		
Bert Thuis	NLR	Netherlands
Aniello Riccio	SUN	Italy
Javier San Millan	INTA	Spain
Peter Wierach	DLR	Germany
Thomas Ireman	SAAB	Sweden
Mats Dalenbring	FOI	Sweden
Industrial Points of Contact		
Roland Lang	Airbus Defence and Space	Germany
Mathias Jessrang	Airbus Operations	Germany
Robin Olsson	RISE	Sweden

6 List of abbreviations

ACARE: Advisory Council for Aviation Research and Innovation in Europe

AG: Action Group

ATI: Aerospace Technology Institute (UK)

CIRA: Italian Aerospace Research Centre

DLR: German Aerospace Centre

DNS: Direct Numerical Simulation

DSTL: Defence and Science Technology Laboratory (UK)

EASA: European Union Aviation Safety Agency

EDA: European Defence Agency

EG: Exploratory Group

EREA: Association of European Research Establishments in Aeronautics

EU: European Union

FOI: Swedish Defence Research Agency

FP: Framework Programme

GARTEUR: Group for Aeronautical Research and Technology in Europe

- GoR: Group of Responsables
- AD: Aerodynamics
- AS: Aviation Security
- FM: Flight Mechanics, Systems & Integration
- HC: Helicopters
- SM: Structures & Materials
- RC: Rotorcraft

IPoC: Industrial Points of Contact

INTA: National Institute of Aerospace Technology (Spain)

JTI: Joint Technology Initiative

JU: Joint Undertaking

LES: Large Eddy Simulation

NATO: North Atlantic Treaty Organization

NLR: Netherlands Aerospace Centre

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

PADR: Preparatory Action on Defence Research

PPP: Public-Private Partnership

RANS: Reynolds-Average Navier-Stokes

RPAS: Remotely Piloted Aircraft System

R&T: Research & Technology

RTD: Research & Technology Development

SESAR: Single European Sky Air Traffic Management Research

SME: Small and Medium-sized Enterprise

SRIA: Strategic Research & Innovation Agenda

STO: Science and Technology Organisation

TRL: Technology Readiness Level

UAV: Unmanned Air Vehicle

XC: Executive Committee

7 Organigram

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

GARTEUR ORGANISATION

Updated 23rd November 2020

GARTEUR Chair Country 2020-2021: Netherlands
Council Chair: Mr. E. Nijenhuis

XC Chair: Mr. Kees Wijnberg
Secretary: Ms. Ligeia Paletti

GARTEUR COUNCIL

Function	France	Germany	Italy	Netherlands	Spain	Sweden	United Kingdom
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XC Member	O. Vasseur	J. Bode	L. Paparone	K. Wijnberg	J. García	A. Wahlström	S. Gates
Other Members of Delegation	P. Beaumier	H. Hemmer M. Fischer		C. Beers L. Paletti	A. Coronel Granado F. Muñoz Sanz J.F. Reyes-Sánchez R. Garcia	M.O. Olsson N. Tooloutalaie	M. Scott S. Weeks S. Pendry

GROUPS OF RESPONSABLES

Aerodynamics (AD)		Aviation Security (AS)		Flight Mechanics, Systems & Integration (FM)		Rotorcraft (RC)		Structures & Materials (SM)	
GoR AD members		**GoR AS members**		**GoR FM members**		**GoR HC members**		**GoR SM members**	
K. Richter	DE	**A. Vozella**	IT	**R. van Enkhuizen**	NL	**K. Pahlke**	DE	**F. Roudolff**	FR
H. van der Ven	NL	P. Bieber	FR	M. Hagstrom	SE	M. White	UK	T. Ireman	SE
E. Coustols	FR	A. Bierig	DE	B. Korn	DE	A. Visingardi	IT	J. San Millan	ES
G. Mingione	IT	H.A. Eckel	DE	A. Vitale	IT	J. Hakkaart	NL	A. Riccio	IT
P. Weinerfelt	SE	F. Muñoz Sanz	ES	C. Doll	FR	A. Le Pape	FR	B. Thuis	NL
M. Tormalm	SE	R. Wiegers	NL	J. Cabezas Carrsco	ES			P. Wierach	DE
F. Monge	ES			A. Rae	UK			M. Dalenbring	SE
P. Weinerfelt	SE								
Industrial Points of Contacts		**Industrial Points of Contacts**		**Industrial Points of Contacts**		**Industrial Points of Contacts**		**Industrial Points of Contacts**	
N. Ceresola	IT	C. Goodchild	UK	P. Goupil	FR	R. Heger	DE	R. Lang	DE
M. Mallet	FR			L. Goerig	FR	R. Markiewicz	UK	M. Jessrang	DE
D. Pagan	FR			M. Hanel	DE			R. Olsson	SE
L. P. Ruiz-Calavera	ES			P. Rosander	SE				

8 Appendix A: Annex GoR-AD

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AERODYNAMICS"

Remit

The GoR-AD initiates and organises basic and applied aerodynamic research in the field of aeronautics. The current scope of activities covers the following areas:

- Aerodynamics;
- Aero-thermodynamics;
- Aero-acoustics;
- Aero-(servo-)elasticity;
- Aerodynamic shape optimization;
- Aerodynamics coupled to flight mechanics;
- Aerodynamics systems integration.

The activities aim to advance the collaborative aerodynamic research in Europe, combining both numerical and experimental research. Dedicated experiments are carried out using advanced experimental techniques and measurements methods in order to generate valuable data needed for the further understanding of basic flow physics, for the investigation of specific aerodynamic problems, and for the validation of numerical simulation tools in a number of areas. The computational activities comprise the further development of simulation and prediction tools of different classes of fidelity, the tool validation using experimental data, and also the application of these tools for the investigation of specific problems arising in aeronautical applications. The close collaboration of experimental and numerical activities is of great benefit and enables enhanced progress in aeronautical research.

Whilst the majority of the research activities focusses on mono-disciplinary aerodynamics, some of the work also has a significant amount of multi-disciplinary content. This trend is driven by industrial interests, and is likely to increase in the future.

Funding for GARTEUR activities is relatively small and, in general, is insufficient to fully support new research. In most cases therefore the AG activities are combined with activities funded through other routes, such as EU, NATO STO (Science and Technology Organisation) or national aeronautical research programmes.

Research initiated in GoR-AD programmes sometimes leads to an EU proposal or compliments concurrent EU program content. In addition, the content of GoR-AD activities can be cross sectorial in covering both civil and military interests.

GoR-AD Overview

GoR Activities

The primary task of the GoR is to monitor Action Groups, encourage Exploratory Groups, and stimulate new ideas. In 2020, one Action Group (AD/AG-54) was completed and four others were active (AD/AG-56, AD/AG-57, AD/AG-58, AD/AG-59). Two Exploratory Groups (AD/EG-77, AD/EG-78) were active. AD/EG-78 was transformed into an Action Group (AD/AG-60). Details about these groups can be found below.

Another task of the GoR is the interaction with the other GoRs by promoting interdisciplinary topics. An example of such a topic are the aero-servo-elastic simulations conducted in AD/AG-56. The chairs of the different GoRs interact during the Council meetings or meet in specific sessions dedicated to new multi-disciplinary topics.

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

In 2020, several ideas for possible new Groups were on the table. Among those that have not yet resulted in an EG are: Natural Laminar Flow Monitoring, Morphing for Load Control, Convective Heat Transfer, Immersed Boundary Simulations, Hypersonic Flows, Thermal Management for Electric Propulsion, Corner Flows, Human Droplet Dispersion.

Activities in 2020 were affected by the worldwide COVID-19 pandemic and the progress of most AGs and EGs has slowed down due to these circumstances. Since the pandemic continues in 2021, further delays can be expected and extensions of AGs and EGs may be necessary.

Management

Two meetings have been held in 2020. Due to the COVID-19 pandemic, only the first meeting could be held as a physical meeting. Meeting AD/A-104 took place at NLR in Amsterdam on the 3rd and 4th of March 2020. Meeting AD/A-105 was established as an online meeting on the 9th of September 2020.

Five members were able to physically attended the meeting in Amsterdam and four members joined by Webex. The online meeting in September was attended by nine members. In average, three of them from Industry. Lack of funding and time were the reasons for the members who could not attend the Amsterdam meeting in person.

There is still no British representation in the GoR. This is a point of concern, as British input in both the GoR and the Action Groups is valuable and has always been much appreciated.

Due to the COVID-19 pandemic, future meetings in 2021 are planned as online meetings for the time being. Instead of two physical one-day meetings, four half-day online meetings are envisaged:

1) AD/A-107 Meeting on 22nd of January 2021, online
2) AD/A-108 Meeting on 7th of April 2021, online
3) AD/A-109 Meeting on 1st of July 2021, online
4) AD/A-110 Meeting in October 2021, online

For the period 2020 – 2021 the chairs are:

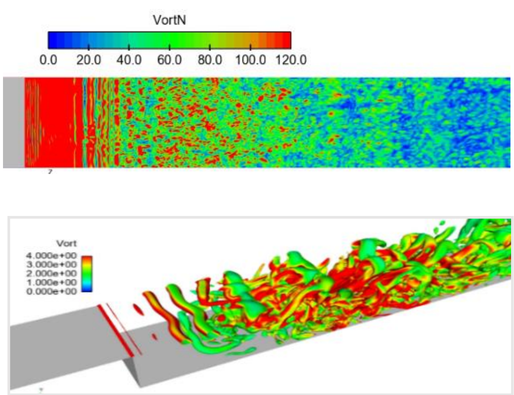
Chair: Kai Richter, DLR
Vice-Chair: Giuseppe Mingione, CIRA

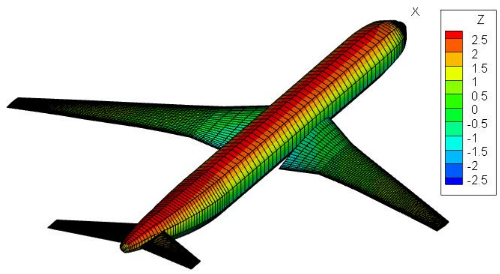
Dissemination of GARTEUR activities and results

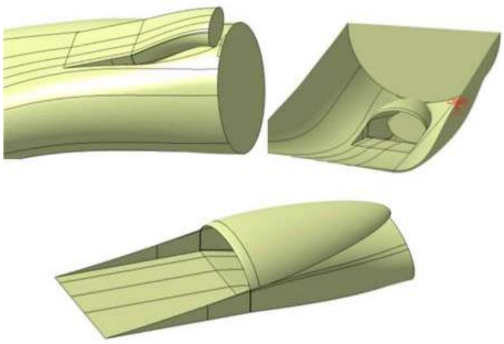
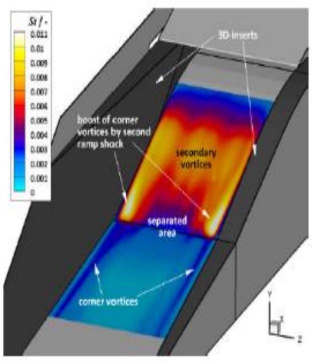
No final reports were published in 2020.

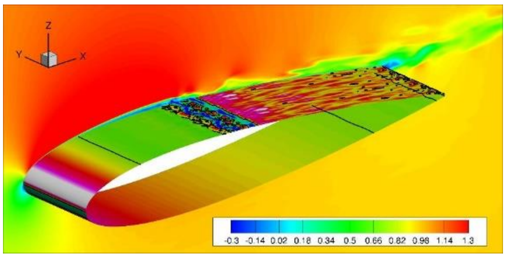
Status of Action Groups and Exploratory Groups

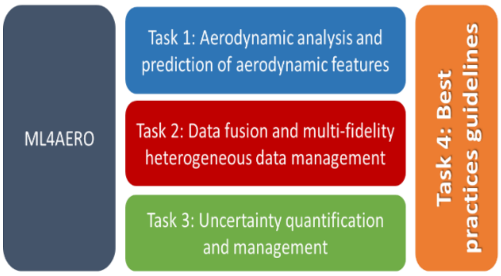
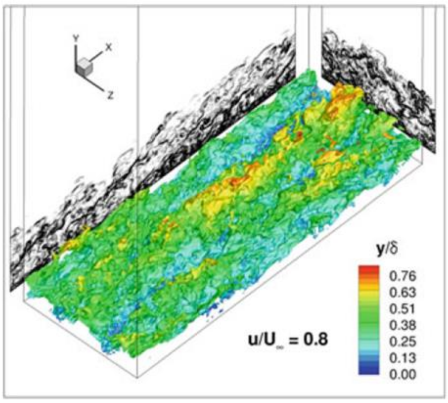
Five Action Groups and two Exploratory Groups were active in 2020. One new AGs started at the end of 2020.

AD/AG-54	RANS-LES Interfacing for Hybrid and Embedded LES Approaches
	The overall objective of AD/AG-54 has been to explore and further to develop and improve RANS-LES coupling for embedded LES (ELES) and hybrid RANS-LES methods, particularly, to address the "grey-area" problem present in zonal and non-zonal hybrid models, for aerodynamic applications. Both zonal and non-zonal approaches are considered. Three fundamental flow test cases have been selected to investigate the different methods. The AG started in April 2014 and the final meeting took place in Nov. 2018. The final report will be ready in the beginning of 2021. The chairperson is Shia-Hui Peng (FOI).

AD/AG-56	Coupled Fluid Dynamics and Flight Mechanics Simulation of Very Flexible Aircraft Configurations
	Very flexible aircraft are light-weight constructions that require multi-disciplinary design tools. Main objectives of AD/AG-56 are to enhance the partners' capabilities in aeroelastic simulations to more accurately predict aerodynamic loads and structural deformations for manoeuvre and disturbance conditions, and to allow for the benchmarking of inhouse tools amongst the partners through the use of a common research model. In 2020, limited progress has been made, in part because of a change in chairmanship. The chairman is Richard van Enkhuizen (NLR).

AD/AG-57	Secondary Inlets and Outlets for Ventilation
	Aircraft require a variety of secondary air inlets and outlets mostly for environmental control systems, APU operation, ventilation and cooling purposes. Main objectives of AD/AG-57 are to analyse and improve the efficiency of conventional secondary air inlets for different applications on fuselage and wing, and to explore the feasibility of new low-observable concepts hidden within the main engine intake. In 2020, most activities had to be suspended because of the COVID-19 pandemic. The chairperson is Jose Angel Hernanz-Manrique (Airbus Operations).
AD/AG-58	Supersonic Air Intakes
	Supersonic air intakes are of foremost importance in the design of supersonic air-breathing vehicles. Main objectives of AD/AG-58 are to gather a database of relevant flow features on representative test cases and to validate CFD codes on these specific topics. Investigations include the control of cowl oblique shock / boundary layer interactions, internal bleed flows, and effects of intake diffusers and scramjet isolators. In 2020, geometries have been selected and exchanged. The first ZDES computations have been launched and compared to RANS approaches. Nevertheless, activity has been delayed and a one-year extension is needed. The chairperson is Christophe Nottin (MBDA).

AD/AG-59	Improving the Simulation of Laminar Separation Bubbles
	Laminar separation bubbles are one of the main critical aspects of flows at low Reynolds number, of order of magnitude 10^4 to 10^5, which are relevant for small aircraft such as UAV. Main objectives of AD/AG-59 are advancements in the understanding of the evolution of laminar separation bubbles and their effect on airfoil flows, and the improvement of the numerical prediction of flows with laminar separation bubbles. In 2020, activities comprised two wind tunnel experiments in WP 1 and numerical investigations for the different test cases in WP 1 to WP 4. The chairperson is Pietro Catalano (CIRA).

AD/EG-77 → AD/AG-60	Machine Learning and Data-Driven Approaches for Aerodynamic Analysis and Uncertainty Quantification
	Aerodynamic analysis and uncertainty quantification are key capabilities used in aircraft design. Main objectives of AD/AG-60 are the improvement of machine learning capabilities and valuable knowledge of the selected data-driven techniques in aerodynamic analysis and uncertainty quantification. Through the proposed activities it is expected that best practice guidelines will be concluded and the use of machine learning methods is facilitated in the aeronautical industry. In 2020, the AG proposal has been finalized and was approved by Council. The chairperson is Esther Andrés (INTA).
AD/EG-78	Hybrid RANS/LES methods for WMLES and Embedded LES
	For future aircraft design and certification, wall-bounded turbulence-resolving hybrid RANS/LES methods are of particular interest for the prediction of flow phenomena related to aeroacoustics, unsteady loads, mild flow separations or boundary layers undergoing strong adverse pressure gradients. A work programme is developed in order to enhance the capabilities of wall-modelled LES and embedded LES. In 2020, the AG proposal has been prepared as a follow-on of AD/AG-54 and will be finalized in 2021. The chairperson is Nicolas Renard (ONERA).

Rolling plan

No.	Topic	2015	2016	2017	2018	2019	2020	2021	2022	2023
AD/AG-54	RANS-LES Interfacing Hybrid RANS-LES and Embedded LES Approaches									
AD/AG-56	Coupled Fluid Dynamics and Flight Mechanics Simulation for Very Flexible Aircraft			EG-72 →						
AD/AG-57	Secondary Inlets and Outlets for Ventilation			EG-73 →						
AD/AG-58	Supersonic Air Intakes				EG-75 →					
AD/AG-59	Improving the Simulation of Laminar Separation Bubbles				EG-76 →					
AD/EG-77 AD/AG-60	Machine Learning and Data-Driven Approaches for AO and UQ									
AD/EG-78	Hybrid RANS/LES methods for WMLES and Embedded LES									

GoR membership

Chairperson		
Kai Richter	DLR	Germany
Vice-Chairperson		
Giuseppe Mingione	CIRA	Italy
Members		
Eric Coustols	ONERA	France
Fernando Monge	INTA	Spain
Bruno Stefes	Airbus Operations	Germany
Magnus Tormalm	FOI	Sweden
Harmen van der Ven	NLR	Netherlands
Per Weinerfelt	SAAB	Sweden
Industrial Points of Contact		
Nicola Ceresola	Leonardo Company	Italy
Michel Mallet	Dassault Aviation	France
Didier Pagan	MBDA	France
Luis P. Ruiz-Calavera	AIRBUS D&S	Spain

Table of participating organizations

	AG-54	AG-55	AG-56	AG-57	AG-58	AG-59	AG-60	EG-77	EG-78
Research Establishments									
CIRA	□		□	□		■	□	□	□
DLR	□		□	□		□	□		□
FOI	■	■			□		□	□	□
INTA	□						■	■	
NLR	□	□	■	□			□	□	□
ONERA	□		□	□	□	□	□	□	■
Industry									
Airbus Defence & Space		□	□				□	□	
Airbus Operations GmbH			□				□	□	
Airbus Operations S.A.S	□			■					
Leonardo Company									
Dassault Aviation									
EADS	□								
LACROIX		□							
MBDA-F		□			■				
MBDA-D					□				
SAAB	□				□				□
OPTIMAD							□		
Academic Institutions									
Imperial College						□			
Royal Inst. of Technology KTH									
Technical Univ. Munich	□								□
University of Manchester	□								□
Zurich Univ. of Applied Sciences	□								□
Univ. of Napoli “Federico II”						□			
Marche Polytechnic University						□			

	AG-54	AG-55	AG-56	AG-57	AG-58	AG-59	AG-60	EG-77	EG-78
IRT Saint Exupéry								☐	
Univ. of Strasbourg						☐			
Univ. of Southampton						☐			
Institute of Marine Engineering (INMCNR)						☐			
Nat. Institute for Research in Digit. Science and Technology							☐		
University of Twente							☐		

Total yearly costs of AG research programmes

AG	2015		2016		2017		2018		2019		2020	
	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
54	22	140	18	80	20	100	12	50				
56							14	7	12	14	12	14
57							21	29	22	29	22	29
58									13		13	
59									16	9	21	13
TOTAL	74	251	61	179	40	124	55	94	63	53	69	56

Action Group Reports

AD/AG-54 RaLESin: RANS-LES coupling in hybrid RANS-LES and embedded LES approaches

Chair:	Prof. S-H. Peng, FOI
Vice Chair	Dr. S. Deck, ONERA
Monitoring Responsable:	Mr. M. Tormalm, FOI

- **Objectives**

The overall objective of AD/AG-54 has been, by means of international collaborative effort, to explore, develop and improve RANS-LES coupling for embedded LES (ELES) and hybrid RANS-LES methods. A particular focus was to address the “grey-area” problem present in zonal and non-zonal hybrid models for aerodynamic applications. The main objectives have been: (1) To evaluate RANS-LES interfacing methods adopted in current hybrid RANS-LES modelling approaches; (2) To develop Grey-Area Mitigation (GAM) methods for improving RANS-LES interaction and improving the RANS and LES modes in hybrid modelling; (3) To develop improved RANS-LES coupling methods for zonal and non-zonal hybrid RANS-LES modelling and for embedded LES methods; (4) To validate and verify the developed methods for a number of selected scale-resolving simulation test cases.

- **Main Achievements**

AD/AG-54 consists of 12 members of which three are from universities, six from research organizations and three from industries. The work in AG54 has been divided in three technical tasks. Task 1 deals with non-zonal hybrid RANS-LES methods. Task 2 focuses on RANS-LES coupling for zonal (including wall-modelled LES, WMLES) and embedded LES. Two test cases (TC), a mandatory and an optional, are defined in each Tasks 1 & 2. The methods developed are then further verified and assessed in Task 3 by computations of a mandatory and relatively complex flow test case.

In 2018, the group progressed in line with the technical work plan and successfully completed the overall technical work. The main activities and achievements were: (a) Completion of computations of all TCs for evaluating zonal and non-zonal hybrid RANS-LES methods; (b) Initial cross-plotting and comparisons of results for all three mandatory TCs as well as the two optional TCs; (c) Refined modelling to enhance turbulence-resolving capabilities with special focus on the “grey-area”; (d) Assessment and verification of modelling methods based on comparative studies of computations of the TCs. (e) Setup of a framework of the final report in terms of the technical contents and timelines.

Task 1 addressed the “grey-area” problem for non-zonal (or seamless) hybrid modelling by means of improved modelling formulation, among others, X-LES based model with stochastic backscatter, high-pass filter and/or temporal/ spatial correlation, HYB0- and HYB1-based energy backscatter using velocity gradients and vorticity-based LES length scale, improved ZDES with vorticity-based length scale, SST-IDDES model with a well-defined hybrid length scale, commutation terms as a measure for enhancing resolved turbulent diffusion. Figure 1 shows an example of computations using non-zonal methods for the mixing layer (TC M1) and a cross-plotting example of some partners’ contributions, which show the improved capabilities in resolving the mixing layer and mitigating the grey-area in the initial stage of the mixing layer.

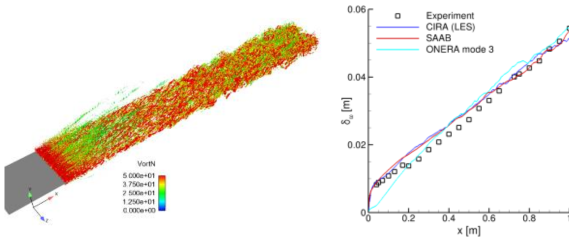


Figure 1: An example of computations for TC M1 (mixing layer). Resolved turbulent structures (Left) and predictions of mixing-layer vorticity thickness (Right).

For zonal hybrid RANS-LES modelling in Task 2, the main work has been dedicated to improving the method of generating synthetic turbulence (ST) for refining RANS-LES interface and enabling effective grey-area mitigation. The modelling verification is based on TC M2 (Spatially developing turbulent boundary layer), of which an example is shown in Figure 2 to illustrate the synthetic-turbulence method as a robust GAM method.

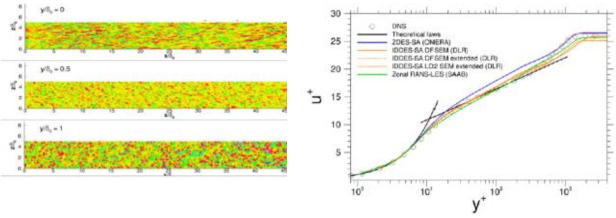


Figure 2: Computation of TC M2 (spatially developing turbulent boundary) using synthetic turbulence. Turbulent structure in relation to ST (Left) and mean Velocity in the boundary layer (Right).

The effectiveness of re-establishing turbulence after the RANS-LES interface section is further verified in Figure 3 for test case TC O2 (NASA hump flow) by displaying the predicted wall surface pressure along the bottom wall and the resolved turbulent stress profile at x/C=1.1 in comparison with measured data, showing reasonable agreement.

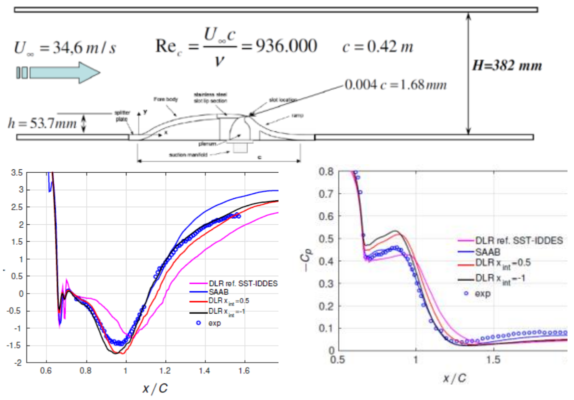


Figure 3: Example for TC O2 using zonal modelling supported by ST methods. The lower row shows bottom wall skin-friction coefficient (Left) and pressure coefficient (Right).

The mandatory test case (co-flow of boundary layer and wake) selected in Task 3 was used for overall assessment and verification of the developed methods in Tasks 1 & 2. All partners made computations using respective improvements in IDDES, WMLES, DDES, ZDES and HYB0 models, some further supported by ST and low-dissipative/dispersive schemes. Some TC3 results are compared in Figure 4.

In addition to the mandatory test cases (M1, M2 and M3) and the optional case TC O2 shown here, computations on the optional case TC O1 have also been carried out by a few partners. For all these test cases, cross-plotting has been processed.

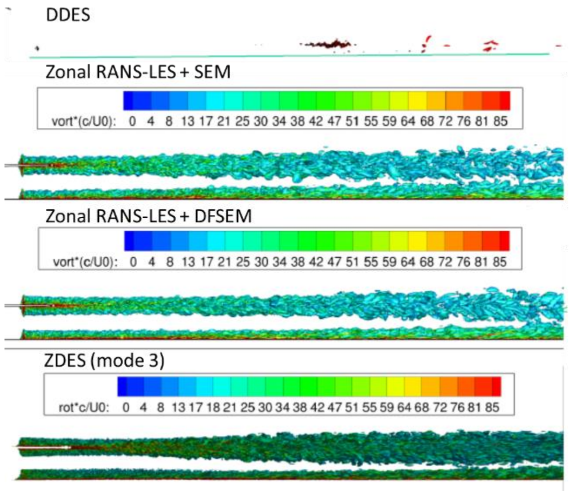


Figure 4: Example for TC M3. Resolved turbulent structures downstream by means of zonal methods supported by ST after the RANS-LES interface.

During 2020, all efforts have been towards completing the final report. The first draft was available in the fall of 2020 and is currently being reviewed by the members.

- **Resources**

Resources		**Year**					**Total**
		2014	2015	2016	2017	2018	
Person-months	Actual/ Planned	A18 P18	A22 P22	A18 P18	A20 P20	A12 P12	A90 P90
Other costs (in K€)	Actual/ Planned	A100 P100	A140 P138	A80 P80	A100 P100	A50 P50	A470 P468

- **Completion of milestones**

Work package	Planned		Actual
	Initially	Currently	
Kick-off meeting	April. 2014		April 2014
Tasks 1, 2 & 3 def. TCs	Oct 2014		Oct. 2014
1st progress meeting	Oct. 2014		Oct. 2014
Tasks 1, 2 & 3: Website	Oct. 2014		Nov. 2016
Expt. data of all TCs	Sept. 2015		Nov. 2015
2nd Progress meeting	Oct. 2015		Oct. 2015
3rd Progress meeting	June 2016	Nov.2016	Nov. 2016
4th Progress meeting	Nov., 2017		Nov. 2017
Final meeting	Nov. 2018		Nov. 2018

- **Achieved results/benefits**

AD/AG-54 has successfully achieved all its technical goals by which a set of zonal and non-zonal hybrid models have been improved with particular focus on the grey-area problem. These improved methods have been, or will be, implemented further into the CFD tools of AG members and, consequently, being exploited in other related R&D activities and in industrial applications.

- **AD/AG-54 membership**

Member	Organisation
P. Catalano	CIRA
F. Capizzano	CIRA
T. Knopp	DLR
A. Probst	DLR
D. Schwamborn	DLR
S.-H. Peng	FOI
C. Lozano	INTA
J. Kok	NLR
S. Deck	ONERA
S. Arvidson	Saab
C. Breitsamter	TUM
A. Revell	UniMan
L. Tourrette	Airbus-FR
M. Righi	ZUAS

AD/AG-56 Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations

Monitoring Responsable:	H. Van der Ven NLR
Chairperson:	M.J. van Enkhuizen NLR

- **Background**

With the increasing importance of environmental issues, various technologies are being developed to create more efficient aircraft designs, reducing fuel burn. In terms of airframe enhancements, these include utilizing lighter structures and higher aspect ratio wings, leading to very flexible configurations. By more actively accounting for the large structural deformations in very flexible configurations, greater weight savings and larger aspect ratios can be realized.

To allow for better optimization of such flexible configurations, studies are carried out in bringing closer the various disciplines supporting aircraft design, especially taking into account the large structural deflections in flight mechanics analyses. Building upon GARTEUR (FM) AG-19 where use has been made of simplified aerodynamic models, AG-56 makes use of high-fidelity aerodynamic models coupled with structural models for such very flexible aircraft. Within AG-56, capabilities will be developed to perform aeroelastic simulations of very flexible aircraft. These capabilities will be assessed and benchmarked by performing simulations with varying degrees of fidelity.

- **Objectives**

The goals of AG-56 are twofold: firstly, this endeavour aims to enhance each partner's capabilities in aeroelastic simulations pertaining to very flexible aircraft. This entails more accurately predicting aerodynamic loads and structural deformations for manoeuvre and disturbance conditions. A second aim of AG-56 is to define and develop a common test case in terms of aircraft and manoeuvre. This will allow the various partners to benchmark their solvers and tools.

This topic poses a challenge due to various requirements inherent to such analyses:

- A flight mechanics model for flexible structures,
- CFD methods with robust grid handling technique capable of modelling a combination of large rigid body motion and large flexible motion,
- Fluid-structure interaction procedures that are capable of modelling large translations and finite rotations.

- **Approach**

Analyses will be performed using the Airbus XRF-1 benchmark model which has been modified to accommodate for more wing flexibility. The baseline XRF-1 model has been made available by AI-O.

Four scenarios will be considered; two gust disturbance conditions and two manoeuvres. The manoeuvre conditions are a 2.5g pull-up and an elevator deflection. Aeroelastic simulations with six degrees of freedom will be performed in a CFD environment. To achieve this, the complexity of the simulations will be increased step-by-step, starting with a purely aerodynamic (assuming a rigid aircraft) simulation, subsequently followed by an aeroelastic simulation without motion, and finally the 6-DOF aeroelastic simulation. Results will be compared to lower fidelity aeroelastic simulations that do not consider a CFD environment. This is done in the NASTRAN and ZAERO environments by means of aeropanels. As stated earlier, the underlying goal of more accurate aeroelastic analyses for very flexible aircraft is to impose less stringent stiffness criteria, allowing for fuel burn reductions with lighter structures and higher aspect ratios. As such, a final analysis will consider an MDO optimized aircraft. This will provide insight in the potential gains and aeroelastic behaviour when optimizing very flexible aircraft wings.

- **Main achievements**

Due to challenges in obtaining the XRF-1 FEM and CAD models, work in the first year was limited. The main achievement was to obtain the model from Airbus with all associated legal requirements. Additionally, the disturbance and manoeuvre conditions have been defined. In the second year, the generic FEM and CAD models have been modified for AG-56 purposes. For the CAD geometry, modifications included geometry clean-up for CFD (un)structured mesh generation and the inclusion of an elevator surface (see fig. 1). For the FEM model, wing elasticity has been modified for increased tip deflections; aiming for 10 percent tip deflection in 1g flight (see fig. 2). This has been done for a worst-case mass condition. The front and rear spar have been tuned to attain the desired tip deflection; iterating for the gust condition of interest in a panel code environment (see fig. 3).

Due to the world-wide pandemic in 2020, COVID-19, very limited progress is achieved in 2020. Some progress is achieved to setup first simulations, but actual results are not expected before spring 2021.

In 2021, partners will run the various simulations making use of these common CAD and FEM models. Given the completed underlying models, partners will initiate rigid aerodynamic analyses, determining horizontal tailplane deflection angle for trimmed 1g flight; for the two flight conditions of interest. Results will be compared, after which the disturbance and control deflection conditions will be performed for rigid and aeroelastic models. Simultaneously panel code simulations will be performed.

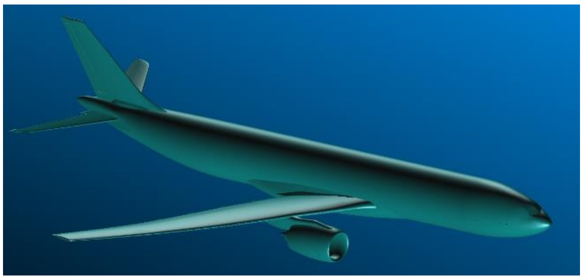


Fig. 1 The CAD geometry of the XRF-1.

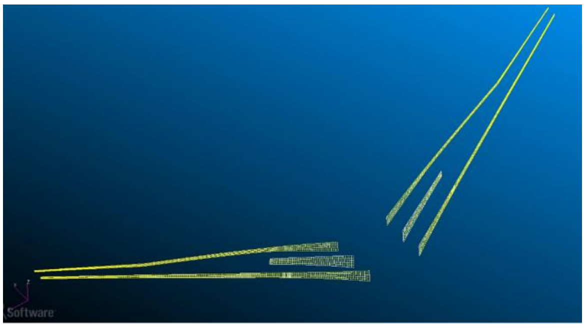


Fig. 2 Depiction of the wing structure in the FEM model. The elasticity of the front and rear spar is tuned for 10 percent tip deflection in 1g flight.

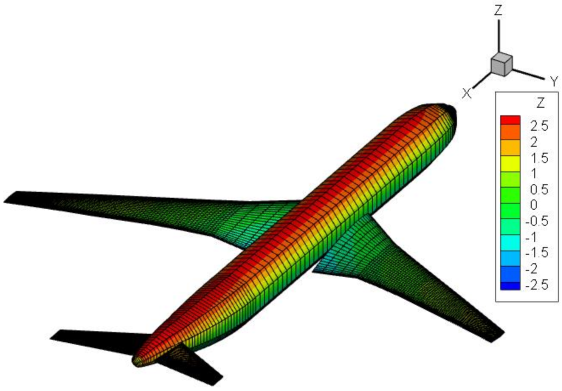


Fig. 3 Panel model used to tune the wing structure for 10% tip deflection for worst-case gust.

- **Project management**

It has been decided to have alternating physical and teleconference meetings every 3 months. The kick-off meeting took place on the 9th of March 2018 in Amsterdam, hosted by NLR. Two teleconference progress meetings have been held on the 25th of October 2018 and the 25th of March 2019, as well as a physical meeting in Manching, hosted by Airbus Defence and Space on January 24th, 2019. July 4th 2019, a teleconference meeting pertaining to model updates, while various teleconferences have been held between partners pertaining to model generation.

In autumn 2020 the chairmanship has been transferred to M.J. van Enkhuizen. On January 25th 2021 the most recent teleconference meeting was hosted by NLR. The meeting was about the progress of the initial trim simulations. The next teleconference meeting is scheduled on April 9th 2021 to discuss first results of the initial trim simulations.

- **Expected results/benefits**

The various simulations in this project are expected to enhance the understanding, tools and capabilities of partners in the nonlinear aeroelastic domain. Secondly, this project will allow for benchmarking of inhouse tools amongst the partners through the use of a common research model.

- **AD/AG-56 membership**

Member	Organisation	E-mail
K. Elssel	Airbus D&S	kolja.elssel@airbus.com
H. Bleecke	Airbus O	hans.bleecke@airbus.com
P. Vitagliano	CIRA	p.vitagliano@cira.it
M. Ritter	DLR	markus.ritter@dlr.de
MJ. van Enkhuizen	NLR	richard.van.enkhuizen@nlr.nl
Cédric Liauzin	ONERA	cedric.liauzun@onera.fr

- **Resources**

Resources		Year					Total
		2018	2019	2020	2021	2022	
Person-months	Actual/ Planned	14 14	8 12	1 12	8	8	38
Other costs (in K€)	Actual/ Planned	7 7	7 14	1 14	10.5	10.5	36

- **Progress/Completion of milestones**

Milestone	Actual
MS 1: Access to common research model	Completed
MS 2: Completion of CAD model for CFD mesh generation	Completed
MS 3: Completion of FEM model for simulations	Completed
MS 4: Panel code lower fidelity free-free simulations (disturbance)	
MS 5: Initial CFD 1g static aerodynamic analyses around flight shape	
MS 6: Rigid structure CFD simulations (manoeuvre + disturbance)	
MS 7: Aeroelastic CFD simulations with linear structure (manoeuvre + disturbance)	
MS 8: Aeroelastic CFD simulations with non-linear structure (manoeuvre + disturbance)	
MS 9: Generation of MDO optimized linear XRF-1 aircraft model	
MS 10: Aeroelastic CFD simulations with MDO optimized linear structure (disturbance)	
MS 11: Cross-plotting and analysis of all results	
MS 12: Final report	

AD/AG-57 Secondary Air Inlets and Outlets

Monitoring Responsable: G. Mingione
CIRA

Chairperson: A.Carozza
CIRA

- **Background**

Aircraft capture outside air for the purpose of air conditioning, ventilation and cooling. This is achieved by means of secondary air inlets. Their shapes differ widely depending on integration possibilities, performance requirements and minimization of interference effects (including drag). In case of transport aircraft (civil and military), it is expected that the capabilities of secondary air inlets have to increase considering the tendency to replace bleed air from the main engines by the acquisition of outside air for air-conditioning purposes. This tendency is also driven by the requirement to prevent fumes from entering the cabin as well as to create a possibility to utilise engine bleed air for active flow control purposes.
In case of combat aircraft, the significant use of composite materials for structural parts and their inability to convect/dissipate heat in combination with increasing energy consumption of on-board equipment generates a novel cooling challenge. Here, the integration of secondary air inlets that provide an increased mass flow is predominantly determined by low-observable aspects, since these inlets are critical components for advanced combat aircraft with high requirements for reduced radar signature. The hidden integration of secondary inlets points towards an installation inside the main engine air intake. Such a configuration would considerably reduce the radar cross section of the aircraft on the one hand, but requires additional attention to the quality of the intake flow field and to engine/intake-compatibility on the other hand.

- **Objectives**

Analyse the efficiency of a submerged NACA type air intake for multiple flight envelopes using state-of-the-art CFD and performance evaluation methods. Investigate whether such an air intake can comply with novel requirements for air-conditioning for large transport aircraft (civil and military).

Analyse the feasibility of a low-observable secondary inlet integrated in the main air intake duct of a combat aircraft and assess the impact on the intake duct flow field and on engine/intake-compatibility. Investigate different types of secondary inlets, shapes, locations, and sizes with respect to advantages regarding radar cross section and aerodynamic performance.

- **Approach**

The focus is placed on the methods based on the Reynolds Averaged Navier Stokes (RANS) equations. The capabilities of secondary air inlets for transport aircraft (civil and military) and combat aircraft will be investigated in terms of mass flow rates for a wide range of flow conditions.

Different methodologies both for drag computation and geometries design will be also considered.

- **Management issues**

The kick-off meeting was held at Manching, Munich, Germany in Airbus Defence and Space Factory on May 16th and 20th 2018. The first annual progress meeting has been held on-line on September 2018. The next progress meeting has been held in Amsterdam at NLR on May 9th to 10th May 2019. The last online review meeting has been held on September 2019. In 2020, the chairperson Jose Hernanz Manrique form Airbus (Madrid, Spain) left the group and has been replaced by Antonio Carozza from CIRA (Italy) with the support by Alvaro Rodriguez from Airbus as a vice-chairperson. Because of the COVID-19 pandemic all the activities have been stopped up to the early 2021.

- **Expected results/benefits**

A code to code comparison will be done in order to investigate and establish the best approach to analyse the performance of secondary inlets and outlets for both military and civil aircrafts.

A natural outcome is also that the partners obtain improved simulation tools. This year there will be a series of progress meetings in order to write the final report including all the activities from each partner.

- **AD/AG-57 membership**

Member	Organisation
A.Carozza	CIRA
Carlos Gonzales Biedma	Airbus
A.J.H. Rodriguez	Airbus
R. Ehrmayr	Airbus
U. Krause	Airbus
H. Maseland	NLR
J. Himisch	DLR

- **Resources**

	Year				Total
Resources planned	2018	2019	2020	2021	
Person-months	3	3	3	3	12
Other costs	1	1	1	1	4

AD/AG-58 Supersonic Air Intakes

Monitoring Responsable: D. Pagan
MBDA

Chairperson: C. Nottin
MBDA

- **Background**

Supersonic air intakes are of foremost importance in the design of a supersonic air-breathing vehicle, whether the propulsion system is a turbojet, a ramjet or a scramjet. They are critical in the performance (thrust, drag, consumption) but also in the mass budget, the general architecture and the radar signature. They need to be accurately designed very early in the development phase. Currently, the design heavily relies on numerical simulations (CFD).

An Action Group on supersonic air intakes was completed in 2007 (AD/AG-34). It was focused on shock / boundary layer interactions and the modelling of porous walls and bumps. It is proposed to build on the results of this AG and to launch a new research activity in this domain which is of primary interest for military aircrafts and missiles.

- **Objectives**

The main objective for the AD/AG-58 is to gather a database of relevant flow features on representative test cases and validate CFD codes on these specific topics. The following investigation themes are proposed:

- Cowl oblique shock / boundary layer / mixing layer interactions
- Internal bleed flows
- Supersonic air intake diffusers and scramjet isolators including corner flows description.

It is expected to support each theme with recent and detailed experimental data as well as CFD modelling and/or validation.

The main conclusions of the activities carried out during the Action Group should cover the following specific issues:

- Clarify the benefit of new CFD methods (unsteady ZDES approach) and HPC capacities in comparison with the last AG34 for example,
- Assess RANS methodology (including turbulence modelling, grid mesh refinement) to tackle the proposed research topic, and
- Estimate the CPU cost of the comparative methodologies.

- **Main achievements**

WP1: Management

Due to COVID-19 pandemic, which complicated organisation and priorities in 2020 for many companies, the collaborative work planned last year has been postponed for a year. The final report is now expected in February 2023. An updated list of milestones is proposed.

WP2: Supersonic diffusers flows

The case proposed in WP2 involves shock trains prediction.

The main challenges are:

- prediction of shock / boundary layer interactions
- prediction of corner flow separations which distort the flow and affect the aerodynamic losses in a diffusor

The classical turbulence models based on linear closures generally fail to reproduce accurately these flows. More advanced models may be required based on RANS with non-linear closures or LES/DES techniques.

A 3D test case with thick BLs $Re\delta 2 \approx 6000$ and strong effect of corner flows from Fiévet et al (AIAA J, 2017) was identified by ONERA but the paper seems not self-sufficient to be used as a test-case. ONERA proposed to design a test-case similar for AD/AG-58 but with well-known flow conditions at boundaries, see Figure 1.

Several RANS computations were performed by ONERA. Inlet flow profiles are now available to all partners, see Figure 2. Outlet condition is a prescribed back pressure. ONERA will perform a DES mode 3 calculation that can be used as a reference to compare with RANS models. Members will perform DES and/or RANS calculations including non-linear closure turbulence models (SAQCR, RMS, …).

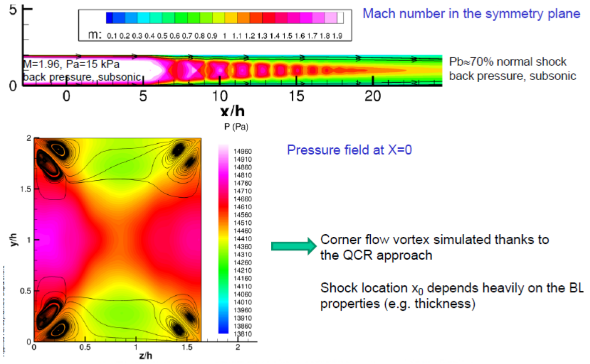


Fig. 1 Shock train in a rectangular cross-section channel. ONERA test-case.

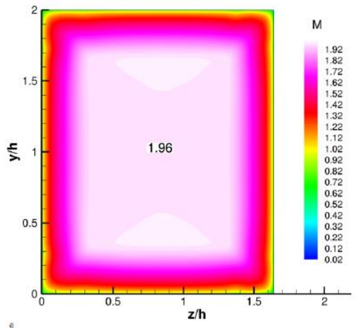


Fig. 2 Common inlet flow field proposed by ONERA for shock train case computations.

RANS computations were performed by ONERA using Spalart Allamaras (SA) and a non-linear closure variant (SA-QCR). Results obtained with SA-QCR model are quite different compared to those obtained with the standard SA model. The prediction of the corner flows is strongly modified resulting in a non-symmetric development of the shock train inside the duct for the SA and a symmetric one for the SA-QCR (cf. Fig. 3).

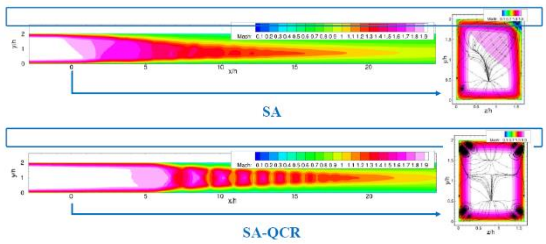


Fig. 3 Effects of QCR closure with the Spalart Allmaras model on corner flows and shock train development for WP2 test-case (ONERA).

Comparisons of CFD predictions with available pressure measurements and published DNS results show local improvements with the non-linear closure of the turbulence model (cf. Fig. 4 and Fig.5).

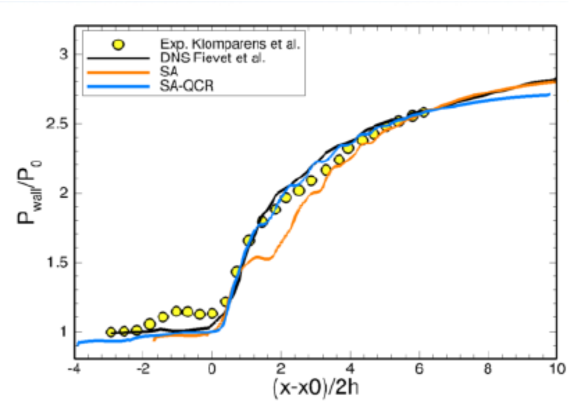


Fig. 4 Effects of QCR closure with the Spalart Allmaras model and comparison with wall pressure measurements (ONERA).

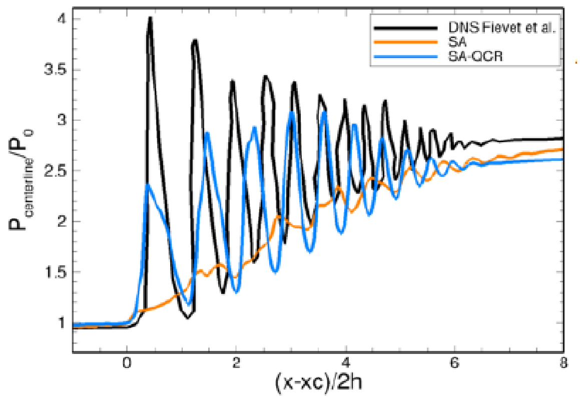
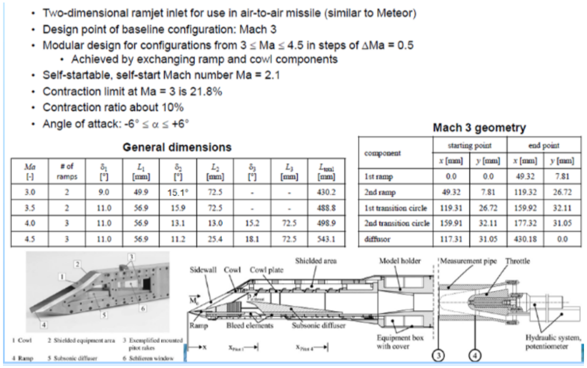


Fig. 5 Effects of QCR closure with the Spalart Allmaras model and comparison with axial pressure computations from DNS published by Fiévet et al. (ONERA).

Further investigation by ONERA and other partners will focus on SST, SST-QCR, Reynolds Stress Model (RSM) as well as ZDES turbulence models.

WP3: Mach 3 ramjet intake

DLR has described in detail experimental results obtained in several existing wind-tunnel test campaigns for a ramjet intake design for Mach 3, see Figure 6.



Ma [-]	# of ramps	δ_1 [°]	L_1 [mm]	δ_2 [°]	L_2 [mm]	δ_3 [°]	L_3 [mm]	L_{total} [mm]
3.0	2	9.0	49.9	15.1°	72.5	-	-	430.2
3.5	2	11.0	56.9	15.9	72.5	-	-	488.8
4.0	3	11.0	56.9	13.1	13.0	15.2	72.5	498.9
4.5	3	11.0	56.9	11.2	25.4	18.1	72.5	543.1

component	starting point		end point	
	x [mm]	y [mm]	x [mm]	y [mm]
1st ramp	0.0	0.0	49.32	7.81
2nd ramp	49.32	7.81	119.32	26.72
1st transition circle	119.31	26.72	159.92	32.11
2nd transition circle	159.91	32.11	177.32	31.05
diffusor	117.31	31.05	430.18	0.0

Fig. 6 DLR experimental model for the Mach 3 ramjet intake.

This large existing database includes several effects:

- internal bleed geometry, open or closed
- flow conditions such as Mach number (on and off design conditions) and angle of attack
- geometry of the ramps and cowl

It was decided to focus the GARTEUR activities on bleed prediction effects in design and off-design Mach number conditions. The members agreed to select the following experimental conditions:

- No bleed versus bleed 22/22 (bleed entrance length/bleed exit length in mm)
- Effect of Mach number: Mach 3.0 (on-design condition, shocks on cowl lip) and Mach 3.5 (off-design conditions, shocks from ramps interact inside the duct on the internal cowl).
- T_{t0} = 290 K, p_{t0} = 5.8 bar, $Re_\infty = 40.8 \cdot 10^6\ m^{-1}$
- No Angle of attack and no sideslip
- Throttling effects at downstream sonic throat condition (throat section can be changed using a translating plug).

The available experimental data contain (cf. Fig. 7):

- Schlieren images
- Wall pressure measurements
  - 34 pressure ports along centreline of ramp, cowl and diffuser
  - Static pressure measurements with 8400 PSI System by Pressure Systems
  - Unsteady press. measurements with XCL-100 Kulite sensors for frequency analysis of inlet buzzing
- Six Pitot rakes with different lengths available
  - Can be integrated in four different axial locations in the diffuser section
  - two additional Pitot rakes for exterior flow above and below the model
- Mass flow measurements by conical throttle
- Pressure measurements in throttle used for determination of pressure recovery.

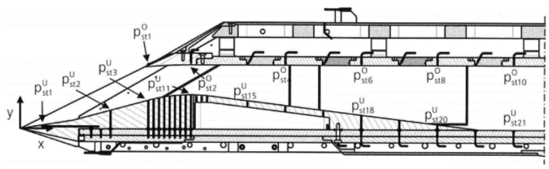


Fig. 7 DLR experiments with measurements and rakes location.

Accuracy on the air intake performances provided by DLR are presented below.

Table 4 Measurement uncertainties of throttle device

M_0	$\Delta(\dot{m}_3/\dot{m}_0)/(\dot{m}_3/\dot{m}_0)$, %	$\Delta p_{st3}/p_{st3}$, %	$\Delta A_3/A_3$, %	$\Delta(p_{t3}/p_{t0})/(p_{t3}/p_{t0})$, %
2.5	1.70	0.03	0.03	0.09
3.0	1.90	0.03	0.03	0.09
3.5	2.06	0.03	0.03	0.09

After a detailed investigation of the model and the boundary conditions needed for the calculations, DLR prepared and shared the CAD files with the fixed modifications commonly agreed at a teleconference meeting.

Regarding boundary conditions, DLR will assess the potential effect of wind-tunnel walls on the bleed mass flow rate by 2D computations, as the internal bleed has no sonic outlet as illustrated by Fig. 8.

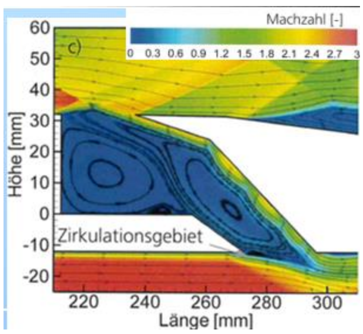


Fig. 8 Illustration of Mach number of the internal flow inside the bleed (DLR).

The 3D CAD file, ready to mesh, has been provided to all members (see. Fig. 9)

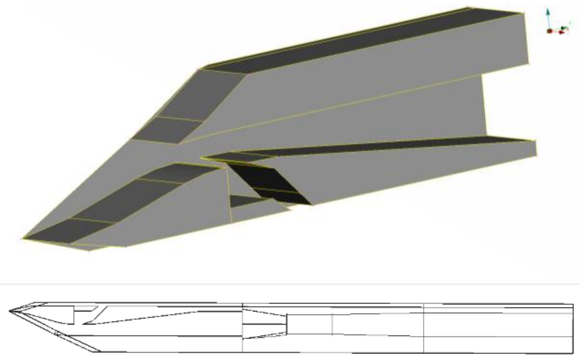


Fig. 9 CAD provided by DLR for the WP3 computation (open bleed case).

The CAD extension down to the throttling device (plug) has been provided as an option so that the throttling effect can be computed either using back pressure on short domain or by modifying the sonic throat on the full domain in the computational process. This could have an effect in case unsteady computations of surging regime is planned (this is not a priority of the WP3).

The experimental measurement data will be provided shortly by DLR to all members. Computations efforts will be focused on RANS approach with the same turbulence models as those proposed in WP2.

WP4: Mach 7.5 scramjet intake

The proposed test-case is illustrated in Figure 10.

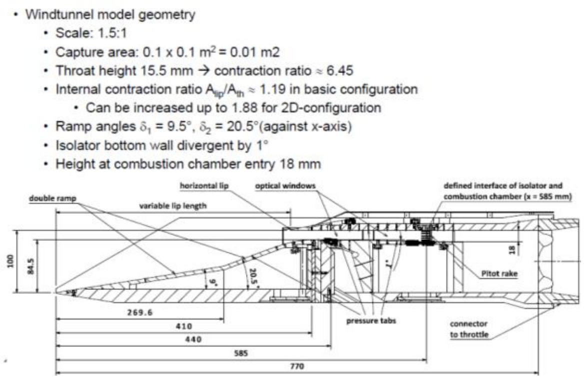


Fig. 10 DLR experimental model for the scramjet Mach 7.5 intake

One topic for WP4 will be the aerothermal fluxes prediction and effects of sidewalls compression, see some examples of experimental results in Figure 11.

It was decided to compute the closed bleed configuration in supercritical conditions with a downstream extension sufficient to include the Pitot rake available in the experiments. The experimental conditions for the CFD validation of heat fluxes still need to be fixed for future calculations as experimental tests were performed with different conditions depending on area of interest (pressure measurement inside the isolator or infrared measurements on the ramps for the heat fluxes).

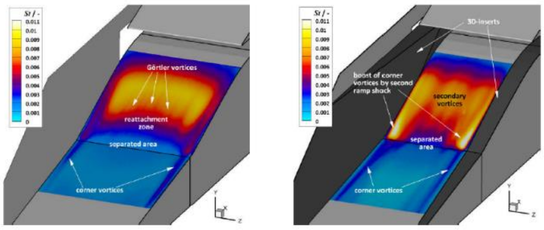


Fig. 11 DLR experiments on the scramjet intakes, with IR thermography. Effect of sidewalls compression on heat fluxes and corner flow.

The CAD, ready to mesh, provided by DLR is presented in the Figure 12. The exit plane is located downstream the isolator Pitot rake.

Computational efforts will be focused on RANS approach with the same turbulence models as those proposed in WP2.

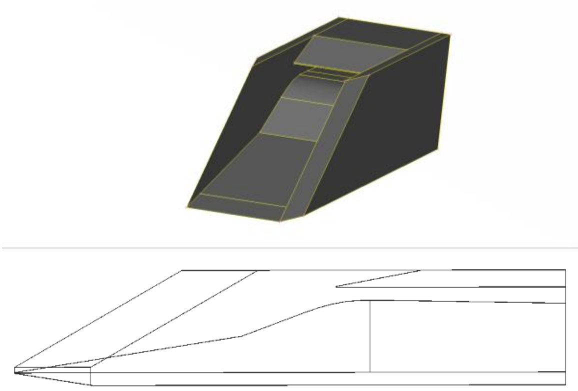


Fig. 11 CAD provided by DLR for the WP4 computation (closed bleed case).

- **Expected results/benefits**

The project is expected to yield increased understanding of turbulence modelling issues for complex internal flows in supersonic and hypersonic intakes. A natural outcome is also that the partners obtain improved best practices for intake flow computations.

- **AD/AG-58 membership**

Member	Organisation
Patrick Gruhn	DLR
Oliver Hohn	DLR
Magnus Tormalm	FOI
Henrik Edefur	FOI
Didier Pagan	MBDA France
Christophe Nottin	MBDA France
Scott Schaw	MBDA UK
Sébastien Deck	ONERA
Neil Sandham	University of Southampton

- **Progress/Completion of milestones**

Milestones	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1: Kick-off meeting	Q4 2018	February 2019	Done
WP1: 2020 Meeting	Q1 2020	January 2020	Done
WP1: 2021 1st Meeting	Q1 2021	Q2 2021	Not started
WP1: 2021 2nd Meeting	Q4 2021	Q4 2021	Not started
WP1: 2022 1st Meeting	Q1 2022	Q1 2022	Not started
WP1: 2022 2nd Meeting	Q3 2022	Q3 2022	Not started
WP1: Final report and meeting	February 2022	February 2023	Not started
WP2: Definition of a numerical case for shock train computations	Q1 2019	Q1 2019	Done
WP2: Each member to prepare his grid and obtain RANS computations	Q4 2019	Q3 2021	In progress
WP2: DES computations	Q3 2020	Q4 2021	In progress
WP3: Fix experimental conditions and provide CAD file	Q3 2019	January 2020	Done
WP3: Each member to prepare his grid and obtain preliminary computations	Q4 2020	Q4 2021	In progress
WP3: Final computations	Q3 2021	Q3 2022	Not started
WP4: Fix experimental conditions and provide CAD file	Q4 2019	January 2020	Done
WP4: Each member to prepare his grid and obtain preliminary computations	Q4 2020	Q4 2021	Not started
WP4: Final computations	Q3 2021	Q3 2022	Not started

AD/AG-59 Improving the simulation of laminar separation bubbles

Monitoring Responsable:	G. Mingione CIRA
Chairperson:	P.Catalano CIRA

- **Background**

The laminar separation bubble is one of the main critical aspects of flows at Reynolds number on the order of magnitude 10^4-10^5. However, the reproduction of this phenomenon results to be crucial also for flows at higher Reynolds number. In fact, very tiny laminar separation bubbles are present on airfoil used for turbine applications operating at Reynolds number on the order of magnitude of 10^6.

An interest is growing towards the employment of rotary wing aircraft as valid technological means for a rapid and efficient exploration of planet Mars. The challenge of this new technological solution lies entirely in the specific environmental conditions these aircraft will be required to operate in. Mars atmosphere is 95% constituted by CO_2 and the force of gravity is about 1/3 compared to the Earth. The reduced atmospheric pressure and density, together with the low temperatures, produce flight conditions characterised by very low Reynolds numbers, about 2% of those on the Earth, in combination with high Mach numbers, 1.5 times higher than the terrestrial ones. The evaluation of the aerodynamic characteristics of airfoils and wings in such particular conditions, scarcely investigated so far, is becoming increasingly more important for the understanding of the feasibility of such technological solution.

- **Objectives**

The main objective is to improve the modelling of the numerical methods used in the reproduction of the laminar separation bubbles and the consequent effects on flow instability.

The main issues to be addressed are:

- The determination of the transition location and of the transition region,
- The enhancement of the production of the turbulent kinetic energy in the separated flow inside the recirculation region,
- Evolution of the bubble with the incidence and with turbulence level,
- Possible burst of the bubble at high incidence and consequences on the stall characteristics,
- Critical evaluation of the laminar boundary-layer instability analysis methods treatment of laminar separation bubbles.

- **Approach**

The focus is placed on the simulation methods based on the Reynolds Averaged Navier Stokes (RANS) equations and on the hybrid RANS-LES methods. Boundary layer instability analysis tools will also be used and compared with the RANS results to ascertain deficiencies of the turbulent onset point; moreover, the RANS embedded turbulence/transition models will also provide significant insight into the efficacy of the boundary-layer instability criteria and hence transition criteria.

- **Main achievements**

A cross-comparison of results achieved with different models has been performed for test cases of WP 1, in particular for the SD7003, Eppler-387, and NACA0015 airfoils. The experimental test campaign for the NACA 0012 airfoil (see Fig. 1), another test case of WP 1, is proceeding. Experimental data will be made available by ONERA to the AD/AG-59 members.

Fig. 1 NACA0012 airfoil model in ONERA S2L wind tunnel.

Numerical simulations have been performed for the S809 airfoil test case of WP 2 by several partners using different numerical tools, and comparisons of the numerical and experimental data have been started for the analysis, see Fig. 2 as an example.

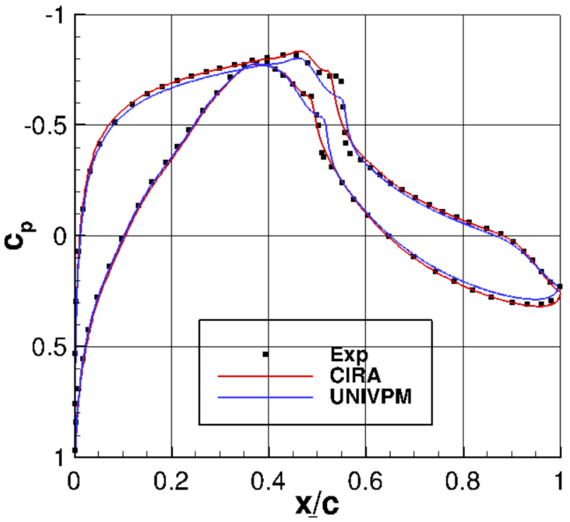


Fig. 2 Comparison of CFD results for S809 airfoil at Re=2 x 10^6.

In WP 3, detailed numerical investigations have been performed for a triangular airfoil placed in a “Mars” wind tunnel, see Fig. 3. A common test case has been fixed for WP 4.

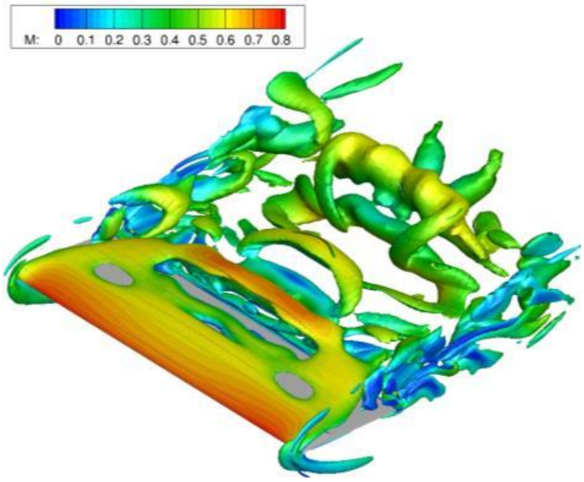


Fig. 3 Numerical simulation of triangular airfoil at M=0.5 and Re=3000.

- **Management issues**

A review meeting has been held on-line on October 30th 2020. All the partners have presented an update of their activities.

- **Expected results/benefits**

The project is expected to yield increased understanding of modelling of laminar separation bubbles. A natural outcome is also that the partners obtain improved simulation tools. Experimental data for two test cases, the flow at low Reynolds number around the NACA0012 and NACA0015 airfoils will be made available for the AD/AG-59 members.

- **AD/AG-59 membership**

Member	Organisation
P.Catalano	CIRA
D. deRosa	CIRA
G. Delattre	ONERA Toulouse
I. Bernardos	ONERA Meudon
P. Molton	ONERA Meudon
S. Hien	DLR
M. Righi	University of Strasbourg (Visiting scientist)
R: Tognaccini	University of Napoli
B. Mele	University of Napoli
Z. HU	University of Southampton
V. D'Alessandro	Marche Polytechnic University
S. Mughal	Imperial College
M. Miozzi	Institute of Marine Engineering (INM-CNR)
Yannick Hourau	University of Strasbourg

- **Progress/Completion of milestones**

Milestone	Planned	Actual
MS 1: first assessment of models	T0 + 22 (new planning)	50%
MS 2: Results for optional test cases of WP 1	T0 + 27	75%
MS 3: Results for test cases of WP 2	T0 + 29	50%
MS 4: Results for mandatory test cases of WP 1	T0 + 30	
MS 5: Results for 2D test cases of WP 3	T0 + 21	deleted
MS 6. Results for 3D test case of WP 3	T0 + 27	50%

- **Resources**

	Year			Total
Resources planned	2019	2020	2021	
Person-months	16	21	21	58
Other costs	9.3	12.5	14	35.8

AD/EG-77 Machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification (ML4AERO)

Monitoring Responsable:	F. Monge (INTA)
Chairpersons:	E. Andrés (INTA) D. Quagliarella (CIRA)

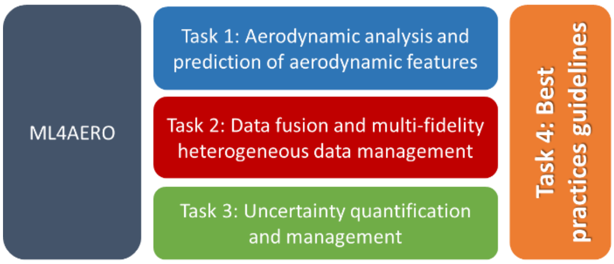
The GARTEUR AD/EG-77 was established to investigate the potential application of machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification

- **Objectives**

The objectives of the proposed Action Group are:

- **Objective 1**: Extensive comparison of deep learning, surrogate models and machine learning techniques for aerodynamic analysis and prediction;
- **Objective 2:** Exploitation of the potential of data fusion (Multi-fidelity) within surrogate modelling by efficient management of heterogeneous data from different sources (CFD with different precision, wind-tunnel, flight test data, etc.);
- **Objective 3:** Exploration of the potential of machine-learning and data-driven techniques for uncertainty quantification and management.

The activities of this AG have been structured in four main tasks, according to the three defined objectives:



The AIRBUS XRF1 configuration will be used as the common test case for methods comparison.

- **Progress**

The Exploratory Group has finished during 2020 and submitted a proposal for the creation of an Action Group that has been approved by the Council (AD/AG-60). The group will start its activities in 2021. The initial duration of the project is two years.

- **Benefits**

This AG is expected to yield better understanding of machine learning techniques and their application to aerodynamic analysis and uncertainty quantification. At the end of the proposed AG, the involved partners will have improved machine learning capabilities and valuable knowledge of the selected set of data-driven techniques. Through the proposed activities, it is expected that some “best practice” guidelines will be concluded and, consequently, facilitating the use of machine learning methods in aeronautic industries. It is also foreseen that the AG will lead to several publications, either as conference papers or as journal articles.

- **AD/EG-77 membership**

The group consists of 12 partners, including nine research establishments (CIRA, NLR, UT, INTA, DLR, FOI, ONERA, IRT and INRIA), two industrial partners (AIRBUS Defence & Space, AIRBUS) and one SME (OPTIMAD).

Country	Organization	PoC
THE NETHERLANDS	NLR	Robert Maas
	UT	Bojana Rosic
FRANCE	ONERA	Jacques Peter
	IRT	Anne Gazaix
		Matthias De Lozzo
	INRIA	Angelo Iollo
ITALY	CIRA	Domenico Quagliarella
		Pietro Catalano
		Mattia Barbarino
	OPTIMAD	Haysam Telib
		Alessandro Alaia
		Angela Scardigli
GERMANY	DLR	Philipp Bekemeyer
SWEDEN	FOI	Olivier Amoignon
		Boban Pavlovic
SPAIN	AIRBUS-Military	Sergio de Lucas Bodas
		Daniel González
	AIRBUS	Daniel Redondo Marta Gonzalez Blanca Martinez
	INTA	Esther Andrés

- **Resources planned**

Resources	Year		Total
	2021	2022	
Person-months	24	24	58
ther costs (in K€)	62	62	124

AD/EG-78 182	**Hybrid RANS/LES methods for WMLES and Embedded LES**
Monitoring Responsable:	E. Coustols (ONERA)
Chairpersons:	N. Renard (ONERA) S.-H. Peng (FOI)

The GARTEUR AD/EG-78 was established to make progress towards the industrial use of hybrid RANS/LES and embedded LES methods for turbulence modelling where the fluctuations in the outer region of attached boundary layers are LES-resolved rather than RANS-modelled, unlike the former AD/EG-54 which focused more on RANS representations of attached boundary layers. The approaches considered here may be seen as Wall-Modelled Large Eddy Simulation strategies (the model is the RANS near-wall region) compatible with the RANS treatment of other regions of the flow, which is key to obtain a computationally affordable and simple-to-use scale-resolving approach.

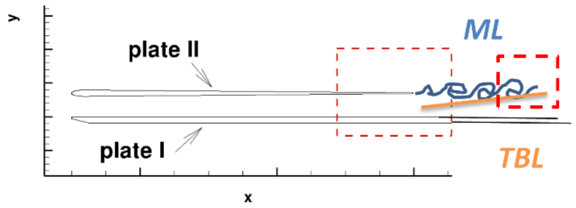
- **Objectives**

The long-term objective of the proposed Action Group is to facilitate the introduction in the industry of hybrid RANS/LES methods resolving wall-bounded turbulence for design and certification processes, which is needed for the prevision of phenomena such as aeroacoustics, unsteady loads, mild flow separations or boundary layers undergoing strong adverse pressure gradients. Several elements must be improved to reach this objective:

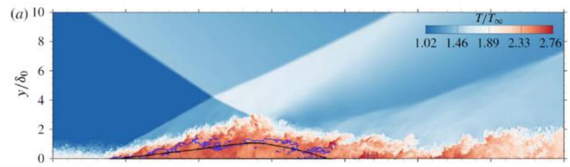
- Resolved turbulence injection near the upstream boundary of (WM)LES domains
- Prediction of mild flow separation on a smooth surface
- Interaction between resolved wall-bounded turbulence and a shock wave
- Prediction of wall pressure fluctuations
- Applicability to multi-domain curvilinear geometries
- Interaction between modelled and resolved turbulence, mitigation of the *log layer mismatch*

The activities of this AG have been structured in two work packages, one for the project management, communication and reporting, the second one for the test cases. The above elements are addressed by means of the following four test cases:

TC1: Mixing co-flow of wake and Boundary Layer

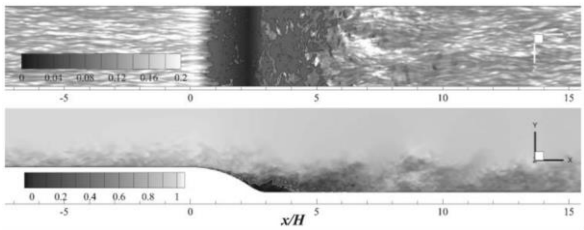


TC2: Shock Wave-Boundary Layer Interaction



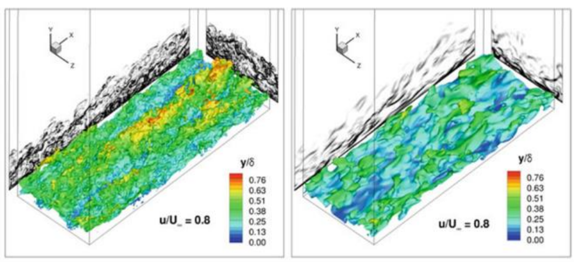
PASQUARIELLO ET AL. (JFM 2017)

TC3: Shallow flow separation from a smooth surface



BENTALEB ET AL., JOT 2012

TC4: Fundamental WMLES test case – ZPG flat-plate boundary layer



- **Progress**

An Exploratory Group first meeting took place in Stockholm on the 28/29th of November 2018, followed by email interactions in 2019. The COVID-19 pandemic caused some delay in 2020 to finalize the process. As a result of the Exploratory Group, a proposal for the establishment of an Action Group (AD/AG-61) has been prepared and accepted in the GoR-AD meeting on the 22nd of January 2021. The expected starting date for the AG is summer 2021. The initial duration of the project is three years and a half.

- **Benefits**

The AG is expected to contribute to the introduction of hybrid RANS/LES and embedded LES methods with wall-bounded turbulence resolution into the industry thanks to progress made on the key elements identified above. Beyond the final report of the AG, publications both in conferences and in peer-reviewed journals may also be expected.

- **AD/EG-78 membership**

The group consists of eight partners, including seven research establishments (ONERA, FOI, CIRA, DLR, NLR, University of Manchester, Université de Strasbourg) and one industry partner (SAAB).

Country	Organization	PoC
FRANCE	ONERA	Nicolas Renard Sébastien Deck
	Université de Strasbourg	Yannick Hoarau
SWEDEN	FOI	Shia-Hui Peng
	SAAB	Sebastian Arvidson
ITALY	CIRA	Pietro Catalano & Francesco Capizzano
GERMANY	DLR	Axel Probst & Silvia Probst
THE NETHERLANDS	NLR	Johan Kok
UK	University of Manchester	Alistair Revell

- **Resources planned**

Resources	Year				Total
	2021	2022	2023	2024	
Person-months	12.5	17.5	19	17	66
Other costs (incl. CPU) (in k€)	59	84	84	77	304

9 Appendix B: Annex GoR-AS

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AVIATION SECURITY"

Remit

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

The GoR-AS initiates, organises and performs computational and experimental multidisciplinary research in the following areas: on board software, artificial intelligence, risk assessment, cybersecurity, airport operations, image recognition, Data analytics, decision making tools, RAMS analysis, FMECA, Fault Tree, event tree analysis, HMI, CONOPS.

The main aim is to Increase security, safety and operation performance for critical assets in the aviation domain.

GoR-AS Overview

During 2020 work has been done by the active members (CIRA, ONERA, INTA) on the following research theme:

Malevolent use of RPAS

The approach in 2020 has aimed at keeping links with other running initiatives like ES4AWG, Optics2 project, ACARE WG4.

Furthermore, the chairperson has started to attend the SAGAS Stakeholders' Advisory Group on Aviation Security meetings. The role of this group is to advise the Commission in the preparation of legislative proposals and policy initiatives as well as in relation to the implementation of existing legislation. The Group shall be kept informed by the Regulatory Committee on Aviation Security during the entire regulatory process. The Group meets back to back with the Committee approximately six times a year and is open to European representative organisations engaged in, or directly affected by, aviation security.

The action group was dedicated to start the work in the funded project and to work on a proposal preparation. The investigated topics have been kept:

- in line with FlightPath 2050;
- further dealt in the ACARE SRIA update and its dedicated Challenge on Aviation Safety & Security;

- fitting with the PADR (Preparatory Action for defence research) in Horizon 2020 and FP9;
- aligned with EREA Security for Aviation initiative;
- a priority for Europe.

The main actions in 2020 were:

1. To further develop and share ideas among the active members (CIRA, ONERA, INTA) to identify research challenges and collaboration approaches involving ONERA and DLR in a project proposal to set up an experimental network.
2. To involve the industries interested in the chosen topics Eurocontrol, AENA(the first airport operator company in the world by number of passengers), ENAIRE (the Spanish air navigation service provider), Soulsoftware, ALISCARL, Leonardo.
3. To contact the Italian Armed Forces Italian Joint C-UAS Centre of Excellence and currently defining a MoU to collaborate with them.
4. To involve ENAC (The Italian aviation Authority) and EASA which are in ASPRID advisory board to keep them informed about the approach and to get relevant information from their domains.
5. To write a paper for ESREL 2020 conference.
6. To monitor current funded initiatives to apply for with a collaborative approach involving other key players

ID	ACTION	RESPONSIBLE	DUE DATE	DELIVERABLE
1	Finalize the choice of the common topic	GoR-AS chairperson	May	Contribution to pilot paper
2	Definition of a research concept for C-UAS	GoR-AS chairperson + ONERA, NLR, DLR	July	Pilot paper
2	Identify the objectives and involve partners	GoR-AS chairperson + All	September	Pilot Paper
3	Prepare and Finalize the Consortium agreement and Grant Agreement	CIRA, ONERA, INTA + other partners	October	
4	Start-up of ASPRID project	INTA, CIRA, ONERA + other partners	November	Plan for GoR-AS activities
5	Monitor Progress and organize webexes	GoR-AS chairperson	November, December	Scheduling and agenda
6	Present the paper at ESREL 2020	GoR-AS chairperson	November	

GoR Activities

The GoR-AS involved the other colleagues by email to organize remote meetings.

During these meetings information was shared about the current activities in each involved institution to finalize the action group decision.

A survey among GoR-AS participants was performed to assess the interest to participate in a proposal which seemed relevant to the GoR-AS perimeter of topics.

The call was under **H2020-**Funding Scheme: **ISFP-AG**, to enhance European coordination in the testing of different UAS countermeasures solutions in order to provide Member States with a generic methodology and baseline understanding of the effectiveness of commercially available C-UAS solutions for the detection, tracking and identification (DTI) of drones that may be a security threat. An exploratory group, partially outside GARTEUR, made by ONERA, NLR, CIRA and DLR, has dedicated focus to such a theme and a project proposal led by NLR has been submitted, though the instrument was not specifically oriented to research establishments. The proposal was not funded.

Nevertheless, such a topic can be partially integrated in EREA Security for aviation working group and represents hints for exploratory and future action groups, provided the GoR-AS will receive the necessary commitment by the represented organizations.

In Italy contacts with the following stakeholders increased awareness about their interests.

Leonardo: Hostile Drone Interception , Drone Identification, Drone Localization & Tracking and related challenges.

ONERA, INTA and CIRA started the activities within ASPRID Project:

Horizon 2020 Call: H2020-SESAR-2019-2 (SESAR 2020 EXPLORATORY RESEARCH) **Topic: SESAR-ER4-13-2019 Type of action: SESAR-RIA,** Airport System Protection from Intruding Drones.

It represents a good chance for GoR-AS as it matches the theme we identified as interesting for our action group, together with the other participants:

- ENAIRE, the Spanish Air Navigation Service Provider;
- Aena, the first airport operator company in the world by number of passengers;
- Two Italian companies, providers of counter drone solutions:
  - SoulSoftware SRL
  - Aerospace Laboratory for Innovative components (ALI Scarl)

Management

A remote meeting was held in May to assess the related activities and other remote meetings were performed during Autumn 2020.

Dissemination of GARTEUR activities and results

The dissemination events during 2020 are represented by the following:

Publication in ESREL 2020 PSAM 15 The 30th European Safety and Reliability Conference - T45-09 Solution Set-Up For Airport Protection From Intruder Drones Angela Vozella, Francisco Munoz Sanz, Mario Antonio Solazzo, Pierre Bieber, Giancarlo Ferrara (Eurocontrol), Edgar Martinavarro Armengol (it is a paper collecting the concept developed in GoR-AS in 2018-2019 among: CIRA, INTA, ONERA…).

Other meetings and contacts with Italian stakeholders have allowed the collection of information about the initiatives in progress on the chosen topic.

Status of Action Group

An extended team (made by GoR-AS and industrial stakeholders, LEAs and Authorities has been set up for identifying collaboration opportunities at national and European level.

There are the following criticalities:

1. INTA has to involve another team member for GoR-AS.
2. DLR has to confirm the members.
3. NLR has to verify interest.

GoR membership

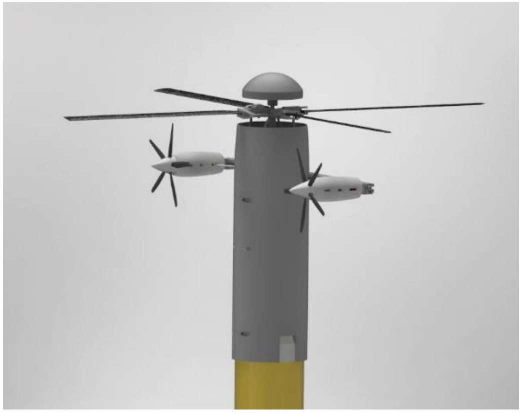
Chairperson		
Angela Vozella	CIRA	Italy
Vice-Chairperson		
Francisco Munoz Sanz	INTA	Spain
Members		
Pierre Bieber	ONERA	France
Rene Wiegers	NLR	Netherlands
Andreas Bierig	DLR	Germany
Hans-Albert Eckel	DLR	Germany
Clive Goodchild	BAE Systems	UK

Total yearly costs of EG research programmes

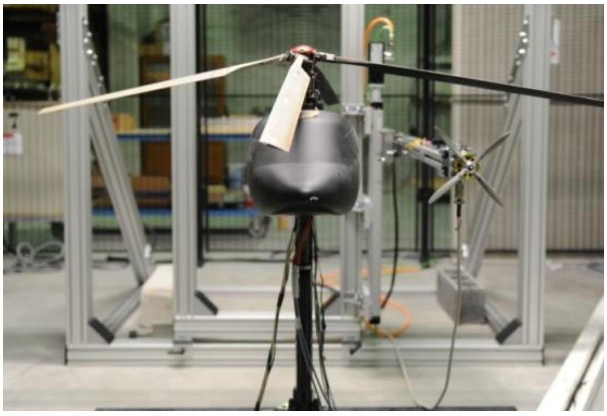
	<2017>	<2018>	<2019>	<2020>
Person-month	2	3	4	3
Other costs (k€)	1	1	1	1

10 Appendix C: Annex GoR-HC

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES “HELICOPTERS”



Design of POLIMI Test Rig (HC/AG-25)



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

Remit

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

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

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

- Decrease costs (development and operation) through Virtual Engineering using numerical tools based on low-order (analytical, BEM) to high-order (CFD) methods, validated with relevant tests campaigns;
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines, more electric rotorcraft ...);
- Increase security, safety:
    - Security studies, UAVs, advanced technologies for surveillance, rescue and recovery,
    - Flight mechanics, flight procedures, human factors, new commands and control technologies,
    - Increase crashworthiness, ballistic protection, etc.;
- Integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations);
- Tackle environmental issues:

  - Greening, pollution,
  - Noise (external, internal);
- Progress in pioneering: breakthrough capabilities.

Technical disciplines include, but are not limited to, aerodynamics, aeroelasticity including stability, structural dynamics and vibration, flight mechanics, control and handling qualities, vehicle design synthesis and optimisation, crew station and human factors, internal and external acoustics and environmental impact, flight testing, and simulation techniques and facilities for ground-based testing and simulation specific to rotorcraft.

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

The GoR-HC, wherever practicable, informs, seeks specialist advice and participation where appropriate, and interacts with activities in other GARTEUR Groups of Responsables.

GoR-HC Overview

GoR Activities

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

This membership enables the GoR to act as a highly effective forum in its primary function of promoting collaborative research through Exploratory Groups and Action Groups. It has been successful in establishing collaborative research programmes, at a non-competitive level, to the benefit of the European rotorcraft community, including both governmental and industrial interests. In addition, the GoR represents a unique forum within Europe for the interaction of the research establishments and industry, for the exchange of knowledge and understanding in the field of rotorcraft research and technology. An increasing number of University teams are associated to the activities of the action groups. Since 2011 the University of Liverpool is an active member of the GoR. The Helicopter GoR is a kernel for ideas for new research projects and supported the preparation of several EU proposals, even if the number of helicopter dedicated projects within H2020 has significantly been reduced compared to previous framework programmes. The GoR-HC is concerned by the fact that rotorcraft topics are not included in the working program for CS3 Clean Aviation.

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

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

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

Management

The chairmanship in 2020 was held by Klausdieter Pahlke (DLR). Vice-chairman was Joost Hakkaart (NLR).

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

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

During the reporting period, the GoR-HC held two meetings:

- 81st GoR Meeting: 24th February 2020, Webex.
- 82nd GoR Meeting: 30th September -1st October 2020, Skype.

The main business of the meetings was to discuss about further topics and to implement the 3-5-year planning process as well as to present the status of the current AGs and EGs. The GoR meetings were used to harmonize the views and the involvement of members regarding preparations for proposals EU calls, as well as future issues to be considered. Furthermore, the dissemination of GARTEUR results on international conferences like the European Rotorcraft Forum (ERF) and the Annual Forum of the Vertical Flight Society (VFS) (former American Helicopter Society (AHS)) and the Asian/Australian Rotorcraft Forum (ARF) was harmonized and supported.

In 2020 the activities in the HC-AGs were at a low level. 2020 started formally with two active Action Groups and three Exploratory Groups; one of the Action Groups delivered their final report in 2020 so that only one running AG was left.

Dissemination of GARTEUR activities and results

Results coming from Action Groups are traditionally prone to publication either in Journals or in Conferences. In the field of Helicopters, the two conferences having the greatest impact are the European Rotorcraft Forum and the Annual Forum of the Vertical Flight Society. Due to the fact that only one AG was active in terms of technical activities and since this AG is in the phase of activity preparation no papers were published in 2020.

Reports issued

In 2020, one AG published its final report:

AG	Report	Reference	Authors	Title
HC/AG-21	GARTEUR	TP–189	Prof. Mark D. White The University of Liverpool (Chair), Dr. Marilena D. Pavel Delft University of Technology (Deputy Chair)	ROTORCRAFT SIMULATION FIDELITY ASSESSMENT PREDICTED AND PERCEIVED MEASURES OF FIDELITY

Status of Action Groups and Exploratory Groups

Action groups (AG)

The following Action Groups were active throughout 2020:

HC/AG-21	*Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity* Main goal of the project is the development of new simulation assessment criteria for both open-loop predictive fidelity and closed-loop perceived fidelity. Final simulation trials were done in 2016 and analysed in 2017. All technical activities were closed in 2017. The final report was delivered on 1st Oct. 2020.
HC/AG-25	*Rotor-Rotor-Interaction* The main objective is to investigate, both numerically and experimentally the effect of rotor / rotor and rotor / propeller wakes interactions on high speed rotorcraft operating in low speed conditions with the aim to establish low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes. The AG started in October 2019.

Exploratory groups (EG)

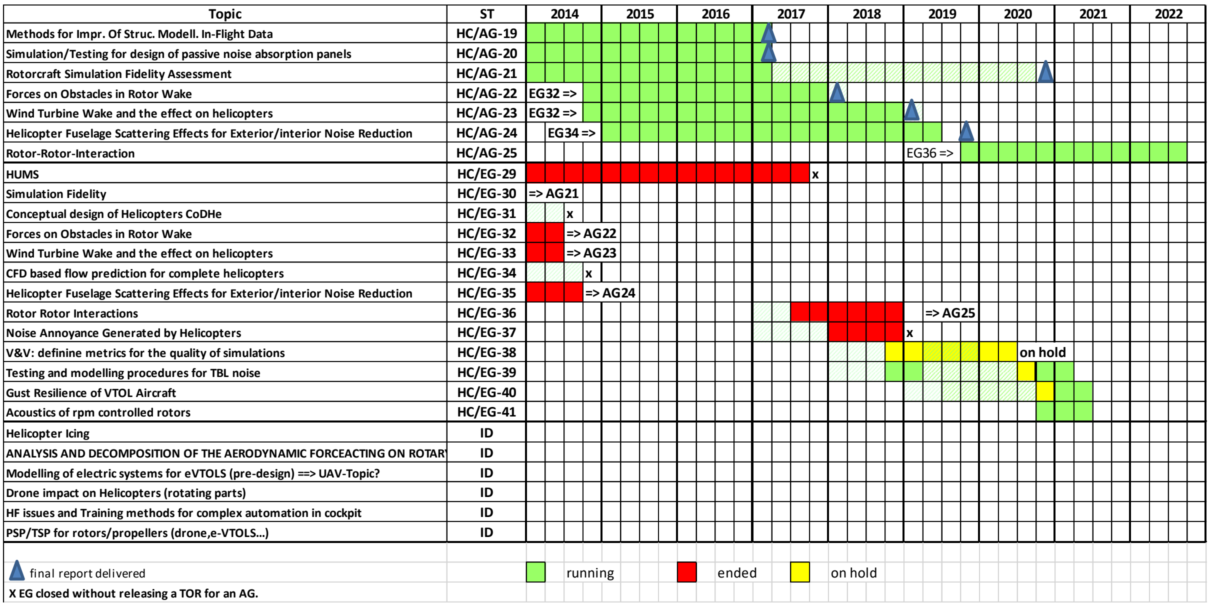
The following Exploratory Groups were active throughout 2020:

HC/EG-38	*Verification & Validation: Metrics for the Qualification of Simulation Quality* To define metrics for the qualification of the quality of rotorcraft simulations, as a contribution to the Verification and Validation (V&V) process of numerical codes. The progress in this EG was limited and the workshop in 2019 didn't bring the expected clarity for the next steps. As the topic is very relevant GoR-HC is still supporting the key ideas of this EG. It is to be considered that the EU CS2 Project RoCS (Rotorcraft Certification by Simulation) is covering very similar topics. Due to limited resources in the relevant organizations it was decided to put this EG on hold from 1st July 2020 on until the end of the RoCS project. Due to effects of the COVID-19 pandemic an extension of RoCS until the end of 2022 can be expected. With the end of RoCS GoR-HC will try a restart of HC/EG-38 in order to produce meaningful Terms of Reference for possible AGs.
HC/EG-39	*Testing and modelling procedures for Turbulent Boundary layer noise* To identify ways how to reduce the flow induced noise in rotorcraft. The chairperson was in 2020 a visiting scientist at NASA working on other topics and took up the EG-lead after his return in Sept. 2020. The first meeting took place in December 2020.
HC/EG-40	*Gust Resilience of VTOL Aircraft* The objective is to set-up a team of researchers able to investigate and test the different approaches that might be employed to achieve gust resilience of multi-rotor vehicles. This EG was identified in 2019 and was expected to be active in 2020. Unfortunately, Cranfield's application for UK funding to support this activity was not successful therefore Cranfield had to withdraw from chairing this EG. The new chairperson is Prof. Lovera from Politecnico di Milano who will restart this EG in 2021.
HC/EG-41	*Noise Radiation and Propagation for Multirotor System Configurations* The objective is to investigate noise radiation and propagation (installation effect) of multirotor systems. Compared to conventional helicopters the importance of the various noise sources and the influence of noise scattering can be totally different for multi rotor configurations. The list of interested parties was established in 2020 and this EG will get active in 2021.

Rolling plan

The 3–5-year planning will continue to be implemented over the years. This list is implemented with new topics according to the GoR discussions.

During the GoR meetings, several topics of mutual interest have been discussed and their potential for GARTEUR collaborative programmes has been examined.



GoR membership

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

Table of participating organisations

	AG25	EG38	EG39	EG40	EG41
Research Establishments					
ONERA	■	□	■	□	□
DLR	□	□	□	□	■
CIRA	□		□	□	□
NLR		□	□	□	□
Dstl					
CNR-INSEAN					
Industry					
Airbus Helicopters, France		□			
Airbus Helicopters, Germany		□			
AgustaWestland / Leonardo					
Thales					
LMS (Belgium)					
CAE (UK)					
ZF Luftfahrttechnik GmbH (D)					
IMA Dresden (D)					
MICROFLOWN					
Academic Institutes					
University of Liverpool (UK)					
University of Cranfield (UK)					
University of Glasgow (UK)	□	□			
TU Delft (NL)		□		□	
University of Munich (D)					
University of Stuttgart IAG (D)	□			□	□
University of Magdeburg (D)				□	
University of Roma 3 (IT)				□	
Politecnico di Milano (IT)	□	■		■	□
National Technical Univ. of Athens (G)	□				
Institut Supérieur de l'Aéronautique et de l'Espace (F)		□			

□ = Member ■ = Chair

Total yearly costs of AG research programmes

	2014	2015	2016	2017	2018	2019	2020	Total
Person-month	44,4	88,7	79,5	55,0	26,5	10,0	26,0	330,1
Other costs (k€)	38,0	103,1	102,9	54,0	20,0	27,0	33,0	378,0

Action Group Reports

Remark: As there were no technical activities in HC/AG-21 in 2020, this AG is not reported below.

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

HC/AG-25: Rotor – Rotor Wakes Interactions

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

Background

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

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

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

Programme/Objectives

Objectives

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

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

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

The work programme is structured in four work packages:

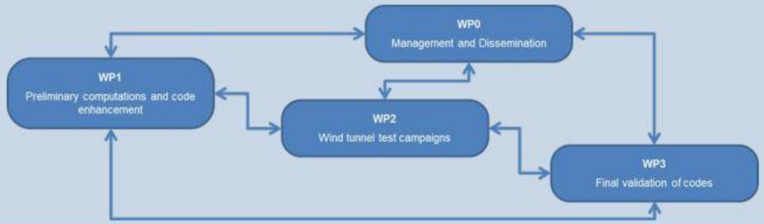
- WP0 – Management & Dissemination: is aimed at the fulfilment of all the obligations concerning the project management and the dissemination of the results.
- WP1 – Preliminary Computations & Code Enhancements: deals with a preparation phase during which partners are involved in literature review and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

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

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

GARTEUR Responsable:

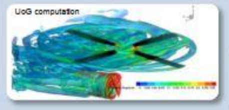
A. Lepape	ONERA

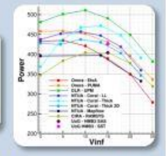


Results

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

All the partners have performed first calculations of the isolated propeller from Onera experiment for different wind speed. The first results outline some scattering between the different numerical methods. All the results will be compared to experiments in 2021. Geometry of the main rotor from Onera experiment and the propellers from DLR experiment were made available to all the participant at the end of 2020. first numerical results are expected in the beginning of 2021.





Most of the experimental activities has been slowed down due to the Covid19 crisis. However, Onera isolated propeller experiment has be performed and results are now available. Polimi test rig configuration has been chosen and test rig is now ready. On DLR side, isolated propeller experiment was performed and results were shared

University of Stuttgart Institute of Aerodynamics and Gas Dynamics

Centro Italiano Ricerche Aerospaziali

DLR

University of Glasgow

ONERA THE FRENCH AEROSPACE LAB

HC/AG-25	**Rotor - Rotor Wake Interactions**
Monitoring Responsable:	**A. Le Pape** **ONERA**
Chairperson:	**R. Boisard** **ONERA**

- **Objectives**

If rotor-rotor or rotor-propeller interactions can nowadays be numerically addressed by high order aerodynamic tools (CFD), such approaches are extremely expensive in terms of CPU time due to the difference in terms of rotating speed between the main rotor and the propeller, and also to the fact that the rotor and propeller wake have to be propagated with high accuracy on long distances. Moreover, at low speed, phenomena are highly unsteady and therefore need to be averaged over a long period of time. Therefore, there is a clear need of low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes. Developing such low-order models requires adequate experimental databases, which are moreover mandatory to validate CFD or free-wake models. However, the analysis of the previous work clearly highlights the lack of such experimental databases.

An exploratory group (EG-36) was created with the aim to promote activities which could contribute to fill these gaps. For the purpose, EG36 proposed the creation of the action group HC/AG-25 gathering a team of researcher willing to investigate, both numerically and experimentally the effect of rotor / propeller wakes interactions on high speed rotorcraft operating in low speed conditions.

The time scale for the project is three years during which the following activities are planned:

• Application and possible improvement of computational tools for the study of rotor / propeller wakes interactions;

• Setting up some cost-effective wind tunnel test campaigns aiming at producing experimental database for the validation of numerical methodologies;

• Final validation of the numerical methodologies.

- **Activities**

The AG consists of 4 work packages:

<u>WP0 – Management & Dissemination:</u>
This work package aims at the fulfilment of all the obligations concerning the project management and the dissemination of the results. Through it the project interacts with the Group of Responsables (GoR), by receiving inputs and providing the information required, and the scientific community, by collecting the results of the activities of the other three work packages and disseminating them.

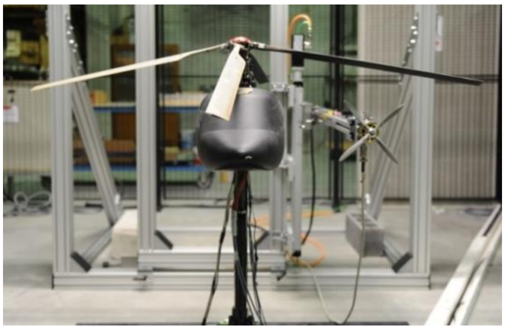
<u>WP1 – Preliminary Computations & Code Enhancements:</u>
The main goal here is literature review and computational actions aimed at providing necessary and useful inputs to the two following work packages where experimental databases are produced (WP2) and the modelling capabilities of the applied numerical tools are validated (WP3). It also provides WP0 with all the information required for management and dissemination.

<u>WP2 – Wind Tunnel Test Campaigns</u>:
In this work package all the wind tunnel test campaigns that have been identified by partners as particularly meaningful for the phenomenological understanding of the wakes interactions will be performed. The resulting experimental databases will be delivered to WP3 for the final validation of the numerical tools proposed by the partners. It will also provide WP0 with all the information required for management and dissemination.

<u>WP3 – Final Validation of Codes:</u>
In this work package, the final validation of the numerical tools proposed by partners will be performed by comparing the numerical results of the computational activity with the experimental data produced during the wind tunnel test campaigns of the project in the framework of WP2. The work package also provides WP0 with all the information required for management and dissemination.

- **Management**

This AG is planned to run for three years. The kick-off meeting was held at ONERA Lille, France in October 2019.



- **Results/benefits**

The action group started its activities on 1st of October 2019. All the foreseen wind tunnel test campaigns are in a preparation phase. The geometry of the ONERA wind tunnel test was shared and all the partners involved in the numerical activities have started some pre-test computations. On 16th June 2020 a web conference took place for progress monitoring. A second web conference took place in November 2020. In 2020 the preparation of experiments was continued. There was a clear negative effect of the COVID-19 pandemic on the test preparation. Due to the need of the physical presence of the technicians and scientists in the labs or test facilities which was partially not allowed because of lockdown regulations in the different partner nations. Furthermore, the procurement of material and sensors etc. was slowed down because many suppliers were also suffering from lockdown regulations. At ONERA isolated propeller tests were conducted in summer 2020 and the data will be delivered to the partners. The partners are setting up their numerical methods and code-to-code comparisons as well as the comparison of experimental and numerical results are foreseen for 2021.

- **HC/AG-25 membership**

Member	**Organisation**
R. Boisard (Chair)	ONERA
Q. Gallas	ONERA
Le Pape	ONERA
Visingardi	CIRA
Gardner	DLR
Schwarz	DLR
Raffel	DLR
Riziotis	NTUA
Voutsinas	NTUA
Zanotti	POLIMI
Gibertini	POLIMI
Barakos	UoG
Green	UoG
Kessler	IAG

- **Resources**

Person month resources were confirmed during the kick-off meeting and have been split tentatively in years. The table below provides these numbers and the final numbers for 2020.

Resources		Year				Total
		2019	2020	2021	2022	
Person-months	Actual/	8,3	26,0	0,0	0,0	34,3
	Planned	6,8	30,3	40,0	26,1	103,2
Other costs (in k€)	Actual/	0,0	33,0	0,0	0,0	33,0
	Planned	9,4	64,5	43,0	28,1	145,0

11 Appendix D: Annex GoR-SM

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "STRUCTURES AND MATERIALS"

Remit

Structural and material research in aeronautics strives to reduce structural weight, improve safety and reliability, keep operation cost low, reduce environmental impact and improve passenger comfort. In many cases the research tasks are strongly interconnected so that an optimum design can only be reached through balanced improvements in all fields.

The GoR-SM is active in initiating and organizing aeronautics oriented research on structures, structural dynamics 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 the key to further enhance the performance of materials. Structural research is devoted to computational mechanics, loads and design methodology. Research on structural dynamics more especially involves response to shock and impact loading.

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.

Although the specific topics vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas of future activity; in this context many new ideas were proposed and explored during the year 2020.

Activities within the Exploratory and Action Groups cover several aspects of improved conventional and new technologies, new structural concepts and new design and verification criteria. Recent, current and upcoming work is devoted to:

- Fatigue and damage tolerance assessment of hybrid structures
- Damage repair with composites in composite and metallic structures
- Characterization and modelling of Composites with Ceramic Matrix submitted to severe thermo-mechanical loading
- Characterization of composites with polymer matrix at high temperatures
- Characterization and optimization of shock absorbers for civil aircraft fuselages
- Additive Layer Manufacturing

GoR-SM Overview

GoR Activities

The activities within the Action Groups cover several aspects of new technologies, new structural concepts and new design and verification criteria. Past works are devoted to the following topics:

- Fatigue and damage tolerance assessment of hybrid structures;
- Damage repair in composite and metal structures.

A major challenge in the fatigue analysis and subsequent fatigue testing of hybrid structures originates from the differences in deriving fatigue spectra for metal and composites and incorporation of required environmental load factors for composites. For example, elimination of peak loads in the spectrum for metals is conservative as crack retardation is prevented whereas for composites this is not conservative. Also, the effect of larger scatter and environmental effects are for composites incorporated by means of a Load Enhancement Factor, thereby applying in the order of 10-20% higher loads which will result in potential premature failure of metal components in the fatigue test.

The structure of aircraft in service will obtain various types of damage e.g. from impact loading. It is therefore important to have effective repair methods. Damages caused by impact are in general much more severe in composite structures than in metals structures. Reparability of such damage is an important consideration in the selection of composites for aircraft applications. Repair techniques both for civil and military aircraft structures are defined through the development of numerical/experimental methodologies. The following issues are addressed: repair criteria, design of patches and repair strategies, analysis of the repair, manufacturing and test, repair strategies and technology, effective repair methods. The effective outcomes can be summarized in minimizing down-time of the aircraft for repair operations; minimizing costs for repair; promoting the repair of components instead of their substitution; reducing the costs and time for certification of repaired structures.

The technical work in the Actions groups has been completed and draft versions of the final reports have been prepared.

As an important future technology, the topic of additive manufacturing will continue to be prioritized within the scope of an Exploratory Group. Additive Manufacturing (AM) with metals is an emerging technology that finds more and more applications in different markets such as orthopaedic implants, dentistry and high-end industry. There is also a lot of interest coming from the Aerospace industry.

Metal AM technology can provide great advantages with respect to conventional metal working techniques, such as significantly lower waste of materials, a larger freedom of design, high potential for weight reduction and the possibility to integrate additional functionality. Specific design guide lines must be taken into account and currently available CAD design tools are considered inadequate for designing for AM. Currently it still is difficult for AM technologies to compete with traditional techniques on reliability and reproducibility because the quality of final products depends very strongly on material and process parameters. Metal AM material qualification and process certification methods are not available yet. Qualification and Certification is essential for high demanding applications for example in aerospace.

The goal of the new Exploratory Group will probably be dedicated to the development of an Additive Manufacturing process for high-performance novel aluminium alloys in order to support the manufacturing industry and increase its competitiveness.

Although the specific topics vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas on future activities. Two Exploratory Groups will be dedicated to the characterisation and modelling of composite materials at high temperature. They concern CFRP and CMC materials and will probably include both experiments and modelling, foster the development of standards for high temperature characterisation of materials (there is an industrial demand for this), initiate the building of a database with confident data, etc.

Another Exploratory Group will work on the characterization and optimization of shock absorbers for civil aircraft fuselages.

Management

In 2020, two meetings were held, mainly by videoconference. Five members and two IPoC's attended the first meeting on March 12, followed on March 13 with technical presentations by ONERA. Another meeting was held on October 8, attended by seven members and two IPoC's.

The measures taken last year to revitalize the Structures and Materials group were confirmed. Action Groups should be finalized quickly, and four Exploratory Groups were launched at the end of the year.

Dissemination of GARTEUR activities and results

No new publications were published in the past reporting period.

Reports issued

No new reports have been issued in 2020. The final reports for SM/AG-34 and SM/AG-35 are currently in preparation and will be issued soon. A draft version of SM/AAG-34 was sent to members and IPoC's.

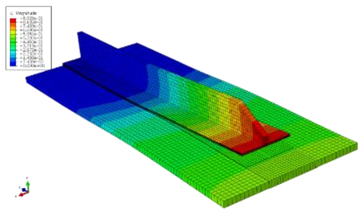
Status of Action Groups and Exploratory Groups

Two action groups were formally active in 2020. Both action groups have finished their technical activities and are involved in finalizing the reports. Unfortunately, the reports in the Action Groups could not be issued as expected even though draft versions were distributed to members. Part of the reason is the health crisis.

One Exploratory Group (EG-43) was still open in 2020. It dealt with Additive Layer Manufacturing (ALM) and was launched in October 2014. A meeting was organised in February 2015 by NLR in which DLR, CIRA and ONERA participated. It was proposed to launch a benchmark to compare three different machines (2 SLM machines by NLR and DLR) and an ARCAM machine by CIRA. The second meeting was never held. People involved in the group are, for most of them, no longer present. Machines and techniques have also progressed since this first meeting. It was decided to close the Exploratory Group.

Four additional Exploratory Groups (EG-44, EG-45, EG-46, EG-47) were launched at the end of the year.

SM/AG-34 **Damage repair with composites**



The objective of the group is the definition of effective repair techniques both for civil and military aircraft structures through the development of numerical/experimental methodologies. This will lead to minimized down-time of the aircraft for repair operation, minimized costs for repair, reduced certification costs and time for certification and will promote the repair of components instead of their substitution. The technical activities of this group have finished and the final report is currently under finalization.

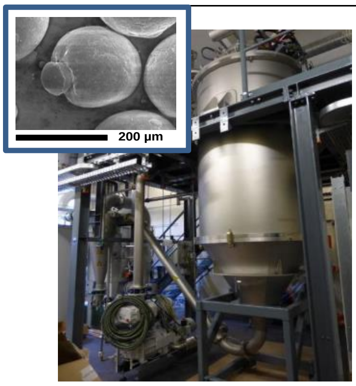
The chair is Aniello Riccio

SM/AG-35 **Fatigue and damage tolerance assessment of hybrid structure**

The objective of the group is to validate the basic assumptions for any applied spectrum manipulation techniques for fatigue test of hybrid structures, to examine the capabilities and benefits of a probabilistic approach, to determine the optimum way to account for thermal loads in a non-thermo test set-up with the goal to find a joint 'best practice' approach for testing of hybrid airframe structural components. The technical activities of this group have finished and the final report is currently under finalization.

The chair is J. Laméris, who has retired since finishing the technical activities. Finalization of the report is handled by O. Bartels.

SM/EG-43 **Development of additive layer manufacturing for aerospace applications**



The objective of the exploratory group is to investigate the influence of powder quality on the properties of AM materials and components, to study the differences between materials and components made with e-beam AM and laser beam AM and to examine the Influence of different machine parameters for laser beam AM Material. Due to inactivity, the group has been closed in 2020.

The chair is L. 't Hoen

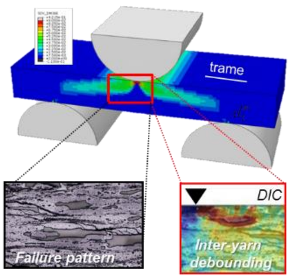
SM/EG-44 **Characterization of composites with polymer matrix at high temperatures**

This topic has first been proposed by ONERA and DLR. Both partners participate to the SuCoHS H2020 project (Sustainable & Cost efficient High-performance composite Structures) which emphasizes the industrial needs of experimental characterization methods for composite properties at high temperature (< 400°C). More detailed objectives consist in:

- The definition of experimental methods for mechanical properties for the ply and the interface
- How to take into account the thermal degradation in the characterization process
- experimental methods and analysis of DMA results in temperature
- characterization of the thermal expansion coefficient
- analysis of the thermomechanical results by taking into account the thermal strain evolution
- providing a test stand for testing classical coupons

The chair is Tobias Wille

SM/EG-45 **Characterization and modelling of CMC submitted to severe thermo-mechanical loading**

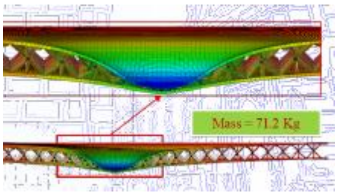


This topic has been proposed by ONERA and DLR. The objective consists in the characterization of the mechanical properties and modelling of Composites with Ceramic Matrix (CMC) submitted to high mechanical loadings and extreme thermal conditions. More detailed objectives consist in the:

- comprehension of the damage and failure mechanisms under static and fatigue loading at very high temperatures
- definition of standard tests for the measurement of mechanical properties (behaviour, damage, failure) at very high temperatures
- proposition of damage and failure models to predict behaviour damage, failure and fatigue lifetime of composite materials
- testing and simulation of CMC composite structures under static or fatigue loading (evaluation of predictive capabilities of models)

The chair is Frédéric Laurin (ONERA)

SM/EG-46 **Characterization and optimization of shock absorbers for civil aircraft fuselages**

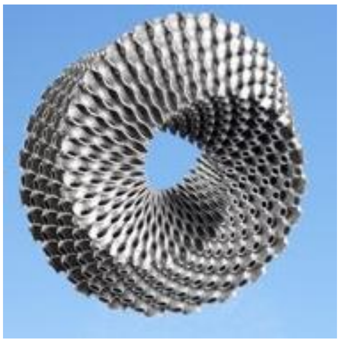


The objective of the group is to work on the design and verification of composite/metal hybrid structures capable of reducing passenger cabin acceleration peaks during a fuselage crash event. Main topics should be:

- Fine tuning of advanced FEM models for crash simulation
- Selection of critical components for energy absorption
- Damage propagation model development
- Design solution for shock absorbers with ALM

The chair is Salvatore Saputo (University of Campania “Luigi Vanvitelli”)

SM/EG-47 **Additive layer manufacturing**



Two potential topics are under discussion by the group.

The first one deals with novel aluminium alloys. The objective consists in the exploration of new aluminium alloys suitable for processing via metal additive manufacturing techniques, i.e. L-PBF and/or DED. This work will focus on the following steps: Alloy selection – Alloy production (powder production) – AM process optimisation – Design values – Microstructure and mechanical performance – Feasibility study: demonstrator.

The second topic is related to the pre-identified development of intermetallics with the objective to investigate the metal 3D printing process for a commercial g-TiAl alloy. The present work is aimed at investigating the influence of FDM and/or MBJ process parameters for this non-weldable material in order to produce sound parts. This work will focus on the process optimisation (including debinding and sintering steps) and also on the microstructural and mechanical characterisation of test samples.

The chair is Maria Luz Montero

Rolling plans

Cat	Topic	2014	2015	2016	2017	2018	2019	2020
SM/AG 34	Damage repair with composites	Active	Active	Active	Extended	Extended	Extended	Extended
SM/AG 35	Fatigue and damage tolerance assessment of hybrid structure	Active	Active	Active	Extended	Extended	Extended	Extended
SM/EG 43	Development of additive layer manufacturing for aerospace applications	Active (Q4)	Active	Inactive	Inactive	Inactive	Inactive	Inactive (Q1), Stopped (Q2)
SM/EG 44	Characterization of composites with polymer matrix at high temperatures							Active (Q4)
SM/EG 45	Characterization and modelling of CMC submitted to severe thermo-mechanical loading							Active (Q4)
SM/EG 46	Characterization and optimization of shock absorbers for civil aircraft fuselages							Active (Q4)
SM/EG 47	Additive Layer Manufacturing							Active (Q4)

Active Extended Inactive Stopped

GoR membership

Chairperson		
Florence Roudolff	ONERA	France
Vice-Chairperson		
Bert Thuis	NLR	The Netherlands
Members		
Aniello Riccio	SUN	Italy
Javier San Millan	INTA	Spain
Peter Wierach	DLR	Germany
Thomas Ireman	SAAB	Sweden
Mats Dalenbring	FOI	Sweden
Industrial Points of Contact		
Roland Lang	Airbus Defence and Space	Germany
Mathias Jessrang	Airbus Operations	Germany
Robin Olsson	RISE	Sweden

Table of participating organisations

	AG-34	AG-35	EG-44	EG-45	EG-46	EG-47
Research Establishments, Universities			Under definition	Under definition	Under definition	Under definition
CIRA	☐					
DLR		☐	■	☐		☐
FOI	☐	☐				
INTA	☐					
NLR	☐	■				■
ONERA			☐	■		☐
CNR	☐					
Industries						
Airbus						☐
SAAB	☐					☐
Fokker		☐				
GKN						
Leonardo Company	☐					
RISE/Swerea SICOMP	☐					
QinetiQ	☐					
ALENIA	☐					
Academic Institutions						
University of Campania	■				■	☐
Imperial College	☐					
Lulea University of Technology	☐					
Norwegian University of Science and Technology (NTNU)	☐					

Action Groups reports

SM/AG-34 : Damage Repair with Composites

Action Group Chairman: Aniello Riccio (Aniello.RICCIO@unicampania.it)

Background

Composites are much more prone to be damaged in service than metals, for example, by mechanical impact. Reparability of such damage is an important consideration in the selection of composites for aircraft applications. In addition, metal structures can be repaired by using composite patches with great potential benefits such as costs reduction, time saving. Repair techniques can be considered applicable to a wide range of structures both metallic and composites (laminates or sandwich).

The repair scheme used for structural restoration should be the simplest and least intrusive that can restore structural stiffness and strain capability to the required level and be implemented in the repair environment, without compromising other functions of the component or structure.

It is usually necessary to restore the capability of the structure to withstand a design's ultimate loads and to maintain this capability (or some high percentage of it) for the full service life.

The functions that must be restored include: aerodynamic shape, balance, clearance of moving parts, resistance to lightning strike. The requirement in military to restore the stealth properties of the component may also have to be considered and may influence the type of repair chosen.

The wide spreading use of composite structures but also the need to reduce costs (both for metals and composites) have lead to an increasing interest in repair and especially in repair with composites and in its potential applications.

However, uncertainties remain in the behaviour of repaired structures that generally lead aircraft manufacturer to use repair only for secondary structures, to prefer bolted repair (mechanical fastened repair) to bonded repair (adhesively bonded repair) and to limit the use of bonding only to limited-size damage.

Programme/Objectives

Objectives

In order to meet the needs of strengthening the use of repair in aircraft structures and to overcome the state of the art in repair with composites, the main objective of this Action Group is:

"Definition of effective repair techniques both for aircraft structures through the development of numerical/experimental methodologies"

The objective addresses the following issue:

Repair criteria, design of patches and repair strategies, analysis of the repair, manufacturing and test, repair strategies and technology, effective repair methods

The activities have been split in Work Packages:

WP1 REPAIR CRITERIA (WHEN UNDERTAKING REPAIR)

Task 1-1 – Methodologies for the assessment of residual strength in damaged composite components to decide when repair has to be undertaken

Task 1-2 – Crack growth analysis (static and fatigue)

WP2 DESIGN OF PATCHES AND REPAIR STRATEGIES

WP 3 ANALYSIS OF THE REPAIR

WP4 MANUFACTURING AND TEST

Task 4.1 - Manufacturing and repair procedure issues

Task 4.2 - Experimental tests

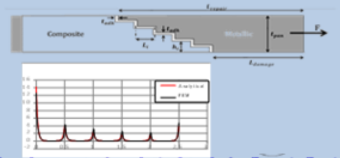
WP5 - EFFECTIVE REPAIR METHODS

Task 5.1 - Optimization of the patching efficiency

Task 5.2 - Certification issues;

Task 5.3 - Technologies for repair;

Task 5.4 - Definition of guidelines for an effective repair of both civil and military aircraft structures



Development of analytical tools for Repair Design

Results

The effective outcomes can be summarised in:
- Minimize down-time of the aircraft for repair operations;
- Minimize costs for repair;
- Promote the repair of components instead of their substitution;
- Reduce certification costs and of the time for certification for repaired structures.

The main challenges addressed consisted in:

Failure mechanisms

When dealing with bonded repair (composite patches) problems are related to the complex behaviour of composite material itself as well as to the many potential failure mechanisms associated with its design and use. It is worth noting that, in this kind of failure mechanisms, both the adhesive behaviour but also manufacturing issues such as the surface treatment play an important role. Indeed, any contamination-be it dust or fluid- between the adhesive and the bonding surface can cause an adhesive failure. The development of failure mechanisms has been extensively simulated in the frame of the project.

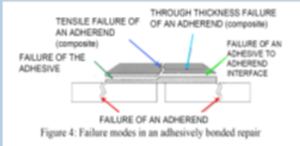


Figure 4: Failure modes in an adhesively bonded repair

Repair design procedures

The design of effective repairs on the structures have been considered. The choice of proper geometry for the repair patch and the correct dimensions for the repaired area have been proven to provide advantage in repair operations.

QinetiQ – Università degli Studi della Campania Luigi Vanvitelli – Luleå University of Technology – CIRA Centro Italiano Ricerche Aerospaziali – FOI – NLR – INTA – RISE SICOMP – Imperial College London – Consiglio Nazionale delle Ricerche – Alenia Aermacchi – NTNU Norwegian University of Science and Technology – SAAB

SM/AG-34 Damage Repair with Composites

Monitoring Responsable: **D. Tescione CIRA**

Chairperson: **Dr. A. Riccio UCL**

- **Objectives**

Based on of the emerging needs (detailed in the previous section) related to the composites usage in aerospace applications, the main objective of this Action Group is:

- "Definition of effective repair techniques both for civil and military aircraft structures through the development of numerical/experimental methodologies ".

This objective addresses the following issues:

- Repair criteria, design of patches and repair strategies, analysis of the repair, manufacturing and test, repair strategies and technology, effective repair methods.

- **Statement of work**

The detailed description of the activities to be performed under each WP and task is given hereafter.

<u>WP 1 Repair criteria (when undertaking repair)</u>

- Task 1.1: Methodologies for the assessment of residual strength in damaged composite components to decide when repair has to be undertaken:
- Task 1.2: Crack growth analysis (static and fatigue).

<u>WP 2 Design of patches and repair strategies</u>

<u>WP 3 Analysis of the repair</u>

<u>WP 4 Manufacturing and tests</u>

- Task 4.1: Manufacturing and repair procedure issues;
- Task 4.2: Experimental tests.

<u>WP 5 Effective repair methods</u>

- Task 5.1: Optimization of the patching efficiency;
- Task 5.2: Certification issues;
- Task 5.3: Technologies for repair;
- Task 5.4: Definition of guidelines for an effective repair of both civil and military aircraft structures.

- **Main achievements**

Tasks accomplished in 2020:

- The results of the partners were presented in the last reporting period
- In the current reporting period, the aim was to compile the final report based on the results achieved
- Due to the high number of partners and the recent active work phase, only a draft report could be completed in the current reporting period
- The report is expected to be finalized in the coming reporting period.

- **Expected results/benefits**

The effective outcomes can be summarized in:

1) Minimize down-time of the aircraft for repair operations;

2) Minimize costs for repair;

3) promote the repair of components instead of their substitution;

4) Reduction of the costs and time for certification of repaired structures.

- **SM/AG-34 membership**

Member	Organisation
Aniello Riccio (chairman)	SUN
Iñaki Armendariz (Vice Chairman)	INTA
Andrea Sellitto	SUN
Dimitra Ramantani	SICOMP
David Mattsson	SICOMP
Ralf Creemers	NLR
Joakim Schon	FOI
Umberto Mercurio	CIRA
Paul Robinson IMPERIAL	IMPERIAL COLLEGE
Benedetto Gambino	LEONARDO
Charlotte Meeks	QINETIQ
Mauro Zarrelli	CNR
Janis Varna	LULEA UNIVERSITY of TECHNOLOGY
Marcus Henriksson	Saab
Andreas Echtermeyer	NTNU
Giovanni Perillo	NTNU

- **Resources**

Resources		Year									Total
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2012-2016
Person-Months	Act./Plan.	-	50/36	50/30	/0	/0	/0	/0	/0	/0	100/66
Other costs (in k€)	Act./Plan.	-	49/32	20/0	/0	/0	/0	/0	/0	/0	69/32

- **Progress/Completion of milestone**

Work package	Planned		Actual
	Initially (end of...)	Currently (updated)	
WP1 Report	Oct 2014	Oct 2014	Oct 2014
WP2 Report	Apr 2016	Apr 2017	Apr 2020
WP3 Report	Apr 2016	Apr 2017	Apr 2020
WP4 Report	Apr 2016	Apr 2017	Apr 2020
WP5 Report	Oct 2016	Oct 2017	Oct 2020
Final Report	Oct 2016	Oct 2017	March 2021

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

SM/AG-35 : Fatigue and damage Tolerance Assessment of Hybrid Structures

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

Background

Hybrid structures, i.e. structures consisting of a metallic and CFRP components, will become more prevalent in aircraft structures in the future. Structural components made out of metal require a different approach with respect to fatigue-analysis and fatigue-testing than components made out of fiber reinforced plastics (composites). 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. Also the joining of metallic components with carbon fiber reinforced polymers will require additional care and attention in terms of design and assembly requirements. In particular the influence of the environment is of importance for hybrid structures. Due to the differences in thermal expansion coefficient between metal and composites thermal stresses may arise and have to be dealt with in the static and fatigue strength substantiation. Another concern is the long-term stability and degradation of bonded joints and fiber-metal laminates (FML) due to environmental influences: the aging of joints in humid environments.

Programme/Objectives

Objectives

The main objectives are listed below. They should lead to a joint "best practice" approach for testing of hybrid airframe structural components.

Task 1: Loading aspects of full-scale Fatigue and Damage Tolerance tests

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. The following aspects can be addressed:

- Composite structure is sensitive to environmental conditions, metal parts usually are not. Relevant aspects of the 'environment' are in this case the temperature and the in-service moisture content, both as environmental history effect during the lifetime of the structure as well as conditions during proof of residual strength. 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?
- Material scatter for composites is much larger than for metals. 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.
- 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.
- 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 .

Task 2: Determination of the optimum way to account for thermal loads in a non-thermal test set-up of hybrid airframe structural components

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 (e.g. for attachment areas between a warm fuselage and a cold wing), come in addition to the 'mechanical' loads. In non-thermal fatigue testing, it is a challenge to apply these loads mechanically. As thermal loads will generally build up in all directions throughout an aircraft structure, the combination with 'mechanical' loading can result in either a uni-axial or a bi-axial stress state. It is to be discussed when the thermal loads are significant enough to be considered for the fatigue and damage tolerance justification.

Task 3: Environmental influences

One particular focus of this research is on the long-term stability and degradation of bonded joints and fiber-metal laminates (FML) due to environmental influences: the aging of joints in humid environments. Very often the major challenge in adhesive bonding is not the load-carrying performance of the joints, which can typically be realized even with simple surface pretreatment technologies like grit-blasting, but in ensuring that the joints will not fail after a short period due to e.g. the effect of water.

Results

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

Task 1: The experimental program for this task was designed to show any differences between a traditional - and widely accepted - approach for the derivation of the test spectrum for a hybrid structure and two new approaches, the Load-Life-Shift (LLS) and Multi- LEF approach respectively.

Task 2: Experimental and numerical studies of static and fatigue bearing failure were conducted in uniaxial and biaxial loading of composite joints at elevated temperature. The experiments were designed to isolate the local phenomena and to represent, in a simplified way, the effect of thermally induced loads on hybrid composite-aluminium assemblages.

Task 3: The bonding and resistance against degradation by water has been studied for different aerospace relevant titanium alloys joint with the thermoplastic PEEK. Morphological details of pretreated metal surfaces, wetting and infiltration by the polymer melt, mechanical and aging behavior have been characterized in order to further the understanding of aging and bonding mechanisms and to derive specific surface pretreatments for reliable high-performance adhesive joints.

FOI NLR DLR FOKKER AEROSTRUCTURES SAAB TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

SM/AG-35 Fatigue and Damage Tolerance Assessment of Hybrid Structures

Monitoring Responsable: **B. Thuis**
NLR

Chairperson: **R. P. G. Veul**
(till 31/08/2013)
NLR
J. Laméris
(from 01/09/2013)
NLR

- **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.

- **Main achievements**

Tasks accomplished in 2020

The results of the partners were briefly presented in the last reporting period and summarized the major outcomes with respect to the determination of a test spectrum, the implementation of a probabilistic approach and the effect of environmental influences.
All scientific work is completed. Unfortunately, the report could not be delivered in the last reporting period. Low available resources, the leaving of central project staff and the health crisis have delayed completion. The aim is to finalize the report in the next reporting period.

- **Expected results/benefits** Recent developments and papers in the field of fatigue testing of hybrid structures indicate a few problem areas where conflicts between the 'metal'- and the 'composite' side of the test evidence need to be resolved before compliance with the fatigue and damage tolerance requirements for hybrid structures can be shown with one fatigue test article.

- **SM/AG-35 membership**

Member	Organisation
Dr.-Ing Joachim Hausmann till 01/09/14	DLR
Dr Jan Haubrich from 01/09/14	DLR
Dr Anders Blom	FOI
Dr Joakim Schön	FOI
Tim Janssen	Fokker Aerostructures
Frank Grooteman	NLR
Dr Jaap Laméris	NLR
Hans van Tongeren	NLR
Rudy Veul	NLR
Hans Ansell	SAAB
Zlatan Kapidzic	SAAB

- **Planned Resources**

Resources		Year									Total
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2012-2016
Person-Months	Act./Plan.	1/1	10.5/11	11/11	/10	/0	/0	/0	/0	/0	22.5/42.5
Other costs (in k€)	Act./Plan.	1/2	16/30	41/41.5	/35	/0	/0	/0	/0	/0	58/128

- **Progress/Completion of milestone**

Work task	Planned		Actual
	Initially (end of...)	Currently (updated)	
Task 1	April 2015	December 2017	December 2017
Task 2	June 2015	December 2017	December 2017
Task 3	June 2015	December 2017	December 2017
Report	October 2015	December 2017	March 2021

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