GARTEUR

ANNUAL REPORT 2024

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

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GARTEUR ANNUAL REPORT 2024

GARTEUR aims at stimulating and coordinating cooperation between Research Establishments and Industry in the areas of Aerodynamics, Flight Mechanics, Systems and Integration, Rotorcraft, Structures & Materials and Aviation Security.

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1. Introduction

Dear reader,

It is my pleasure to present this Annual Report, which documents the activities, achievements, and continued development of the GARTEUR network during the period of my chairmanship of the Council.

GARTEUR remains a unique and highly valued framework for multinational cooperation in aeronautical research. Its strength lies in the long-term commitment of its member nations, the scientific excellence of its working groups, and the open and constructive exchange that characterises our collaboration.

During the period covered by this report, the Council focused on strengthening GARTEUR's strategic positioning and ensuring its continued relevance within an evolving European and international research landscape. particular emphasis was placed on increasing the attractiveness and visibility of GARTEUR, both within the scientific community and towards external stakeholders.

In parallel, the Council initiated important steps to improve and streamline administrative processes, with the aim of enabling more efficient, transparent, and effective collaboration across all working groups and member nations. These efforts provide a stronger foundation for GARTEUR's future development.

The achievements presented in this report would not have been possible without the dedication and professionalism of the researchers, group leaders, national coordinators, and the Secretariat. I would like to express my sincere appreciation to all those who have contributed their time, expertise, and commitment to GARTEUR.

I am confident that the measures taken during this period will support GARTEUR's continued success and further strengthen its role as a leading platform for collaborative aeronautical research. I invite you to explore this report and to join us in shaping the next chapter of GARTEUR's development.

Jan Bode

Chairman of GARTEUR Council 2024-2025

Dear Ladies and gentlemen, dear GARTEUR Friends, dear colleagues,

It has been a great honour and a privilege to serve as Chairman in 2024. When I assumed the GARTEUR responsibilities operationally at the very beginning of the German Chairmanship, I quickly realised what a complex, demanding, and at the same time highly interesting and rewarding task this role would be. The diversity of topics, the multinational structures, and the depth of expertise within GARTEUR made this an especially engaging and enriching experience from the very first day.

As Chairman of the Executive Committee, it is also my pleasure to introduce this Annual Report, which reflects another productive and forward-looking year for the GARTEUR network. The achievements documented in this report are the result of strong commitment, excellent scientific work, and close cooperation across all member nations.

At the beginning of Germany's Chairmanship, we defined a clear set of objectives for the first year. Central among these was the goal of strengthening GARTEUR's attractiveness and visibility within the European and international aeronautics research landscape. GARTEUR plays a unique role as a long-standing framework for collaborative research, and enhancing its visibility was essential to ensure continued relevance, engagement, and impact.

A key milestone in pursuing this objective was the establishment of a strategic cooperation with the International Council of the Aeronautical Sciences (ICAS). This partnership provides GARTEUR with a permanent opportunity over the next ten years to present its research activities and results at ICAS Congresses. It significantly enhances GARTEUR's international presence and creates a strong link between our collaborative research and the global aeronautics community.

Beyond visibility, the first year also focused on reinforcing the value proposition of GARTEUR for its members — by highlighting the quality of scientific exchange, the benefits of multinational collaboration, and the role of GARTEUR as a trusted platform connecting national and European research efforts. The activities and results presented in this report demonstrate how these objectives have been translated into concrete actions and measurable progress. They also provide a solid foundation for the subsequent initiatives undertaken in the following year.

I would like to thank all contributors — researchers, group leaders, national coordinators, and administrative teams — for their dedication and professionalism. Their efforts continue to shape GARTEUR as a dynamic, visible, and impactful research network.

Bastian Hammer

Chairman of GARTEUR Executive Committee 2024-2025

Dear GARTEUR Friends,

I was delighted to be appointed as GARTEUR secretary in 2024. I was very happy to take over this role from my Italian predecessor during the German Chairmanship and was immediately welcomed into the GARTEUR family. The tasks are very varied and I really enjoy them. One of my priorities is to increase the visibility of GARTEUR. I am looking forward to the secretarial tasks in the coming year 2025.

Jutta Fröhling

GARTEUR Secretary

(2024-2025)

2. Executive summary

The GARTEUR Annual Report 2024 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, rotorcraft, flight mechanics and systems integration, and aviation 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 Europe 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).

The GARTEUR scientific and technical activities are reported in section 5, with each of the five GoRs presenting a summary of their work during 2024.

3. GARTEUR Council

3.1 Chairmanship and membership

On the 1st of January 2024, Germany succeeded Italy as chair of GARTEUR for a period of two years, ending on the 31st of December 2025. Therefore, the present report handles the first year of reporting.

During 2024, the first year of the German chairmanship of GARTEUR, Jan Bode served as Chairman of the Council and Mr. Dr. Bastian Hammer served as Chairman of the Executive Committee. Mrs. Jutta Fröhling acted as GARTEUR secretary.

C.W. de Rooij (HoD of NL) has moved to a different position; a successor has not yet been named. C. Kvarnström has been replaced by J. Rignér (Sweden) and S. Weeks and S. Pendry have been replaced by C. Low (UK).

1. Organisation *(on February 21, 2024)*

GARTEUR COUNCIL							
Function	**France**	**Germany**	**Italy**	**Netherlands**	**Spain**	**Sweden**	**United Kingdom**
Head of Delegation	J.S. Martinez De Castilla	J. Bode	P. Renzoni	C.W. de Rooij	R. Gonzalez Armengod	R. Stridh	P. Griffiths
XC Member	O. Vasseur	B. Hammer	V. Puoti	O. Bartels	J.J. Fernandez Orio	A. Wahlström	R. Gardner
Other Members of Delegation	P. Beaumier	H. Hemmer A. Manecke	-	B. Thuis	J.F. Reyes-Sánchez R. García	M.O. Olsson I. Eriksson C. Kvarnström	S. Weeks S. Pendry N. Bhadasia
GARTEUR Secretary		J. Fröhling					

GoR Chairs	**AS**	**FM**	**AD**	**RC**	**SM**
	P. Bieber	C. Doll	J-L. Hantrais-Gervois	M. White	Javier San Millan (INTA, Spain)

Figure 1: Organisational chart of GARTEUR members (December 2024)

At the beginning of Germany's chairmanship, we defined a clear set of objectives for the first year. Central among these was the goal of strengthening GARTEUR's attractiveness and visibility within the European and international aeronautics research landscape. GARTEUR plays a unique role as a long-standing framework for collaborative research, and enhancing its visibility was essential to ensure continued relevance, engagement, and impact.

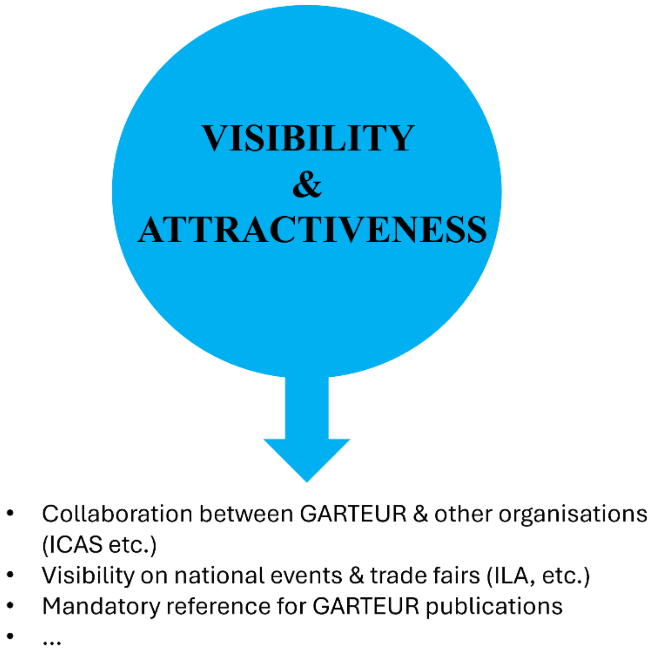


Figure 2: Main focus for the first year of German Chairmanship

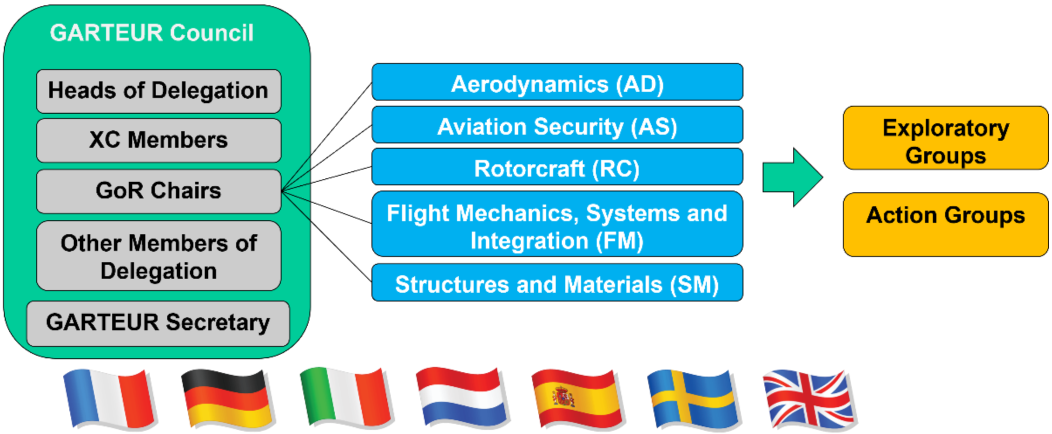
3.2 GARTEUR Organisation

GARTEUR is an independent organisation based on government-to-government agreement between France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom; it has, however, no staff of its own or a common fund at its disposal. The necessary resources (staff, facilities, costs in kind) for the joint research activities are made available by the governments of the member countries out of their national programmes, or by the participating organisations on the basis of balanced contributions.

In general, GARTEUR is organised at three main levels: GARTEUR's highest level is the GARTEUR Council. In the Council, delegated representatives of each member country come together. These representatives come from all relevant Ministries and Research Establishments. An Executive Committee (XC) and a GARTEUR Secretary assists the Council. This XC is composed of one member from each national delegation.

The second highest level is formed by the Groups of Responsables (GoR) that act as scientific management bodies. They also represent the think-tank of GARTEUR. The GoRs are composed of representatives from national research establishments, industry and academia. Currently, five GoRs manage GARTEUR research activities in the fields of Aerodynamics (AD), Aviation Security (AS, since March 2014), Flight Mechanics, Systems and Integration (FM), Rotorcraft (RC), and Structures and Materials (SM).

Action Groups (AGs) form the third level of GARTEUR. AGs are the technical expert bodies that formulate the GARTEUR research programme and execute the research work. Potential research areas and subjects are identified by the Groups of Responsables and investigated for collaboration feasibility by Exploratory Groups (EGs). If an Exploratory Group establishes an agreed proposal, an Action group is launched. A GARTEUR AG needs participation from at least three GARTEUR countries.



3.3 GARTEUR Chairmanship Change

GARTEUR has no permanent secretariat or headquarters. The actual co-ordination and information centre of GARTEUR resides in practice with the Chairman of the Executive Committee and the GARTEUR Secretary, and therefore changes according to the nationality of these offices. Both the Chairman of the Executive Committee (as well as the Chairman of the Council) and the GARTEUR Secretary are members of the country holding the present chairmanship.

A handover meeting between the Italian and the German delegation took place virtually on 5th December 2024. All important administrative processes were handed over and important information was exchanged.

3.4 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.

The following Council and XC meetings took place in 2024:

- XC172 – 7th February 2024, Naples, Italy
- C76 – 19th – 20th March 2024, London, UK
- XC173 – 30th September – 1st October 2024, Amsterdam, NL
- C77 – 27th – 28th November 2024, Linköping, Sweden

3.4.1 XC172 - Naples

The first XC meeting under the German Chairmanship was held on 7th February 2024 at Talent Garden, Via S. Giacomo, 43, in 80133 Naples, Italy. The XC Committee was represented in person by

Germany:	B. Hammer (XC),
France:	O. Vasseur (XC),
Italy:	V. Puoti (XC)
United Kingdom:	R. Gardner (XC)
Spain:	
Netherlands:	
Sweden:	A. Wahlström (XC)
GARTEUR secretary:	Jutta Fröhling
Guests:	Antonio Visingardi (former Chair of GoR)

Figure 3: XC members at XC172 in Naples

In the first meeting under the German chairmanship, B. Hammer welcomed all participants on behalf of the German delegation. After informative words on the German Chairmanship, B. Hammer gave a short summary of the event in Pozzuoli last year. R. Gardner continued and presented prepared papers which include the final conference session summary, the discussions about the needs to make proposals to the Council and a helpful analysis by Chris Low as a result of attending the conference. There are big questions about scope, reach, resources, independence and funding. GARTEUR has great technical assets and accumulated achievements which provide an excellent foundation for building further into the future.

B. Hammer informed that GARTEUR will be part of the International Aerospace Exhibition (ILA) in Berlin from 5th to 9th June 2024 and represented at the stand of the Federal Ministry for Economic Affairs and Climate Action in the area of the Agency for Aviation Research (Programme Management Agency for Aviation Research - PT-LF).

Development of GARTEUR:

> R. Gardner presented a discussion paper – Review of GARTEUR status and forward look. The main points are: Which goals has GARTEUR for the future and where does GARTEUR wants to go in future?

Make GARTEUR more attractive:

B. Hammer pointed out that GARTEUR needs to decide how to handle and to regulate the participation of foreign nationals coming from outside the 7 GARTEUR member countries, even if employed in organizations in the 7 GARTEUR member countries. This may be a condition to participate in an EG/AG and maintained throughout the activities.

B. Hammer and R. Gardner started a discussion about the attractiveness of GARTEUR for younger people. On one hand some younger people are afraid of participating in GARTEUR because of the existing expert knowledge and on the other hand they are not interested. The question is which measures are necessary to attract prospective scientists. In general, GARTEUR needs to be more present at research institutions (and congresses) in order to acquire future projects. B. Hammer suggested that the “GARTEUR note” should be integrated into paper publications if the results will be/have been achieved within the framework of a GARTEUR Action Group.

In addition to the points mentioned, the following fundamental topics were discussed:

- Social media / Public relations of GARTEUR

- Access to GARTEUR website

- Annual Report 2023

- Preparation for Council Meeting (C76, UK, March 2024)

B. Hammer informed about a contact to ICAS (International Council of the Aeronautical Sciences) for a meeting with the German delegation of GARTEUR wrt a possible collaboration. The meeting will take place at DLR in February 2024.

3.4.2 C76 - London

The first Council meeting under the German Chairmanship was held on 19th and 20th March 2024 at Aerospace Technology Institute (ATI), 10 Midford Place, London W1T, UK The Council was represented by following members:

Germany:	J. Bode (HoD), B. Hammer (XC), F. Antrack (MoD),
France:	J.S. Martinez De Castilla (HoD), O. Vasseur (XC),
Italy:	P. Renzoni (HoD), V. Puoti (XC)
United Kingdom:	R. Gardner (XC)
Spain:	J.J. Fernandez Orio (XC), R. Garcia Esparza (MoD)
Netherlands:	O. Bartels (XC), B. Thuis (MoD)
Sweden:	R. Stridh (HoD), A. Wahlström (XC)
GoR(AD):	J.-L. Hantrais-Gervois
GoR(RC):	M. White
GoR(FM):	C. Döll
GoR(SM):	-
GoR(AS):	P. Bieber
GARTEUR secretary:	Jutta Fröhling
Guests:	Chris Low

Figure 4: Council members portrayed at the ATI in London.

R. Gardner opens the meeting with a warm welcome to the GARTEUR delegates. The meeting starts with a short presentation from Chris Low, representative from Aerospace Technology Institute (ATI), host of the meeting. C. Low is proud to host the Council meeting in the ATI's London Headquarter. The presentation gives an overview over the various activities and tasks of ATI and ends with a note to the "Destination Zero ATI Conference 2024 ICC" in Wales from 8th to 9th October 2024 (ati.org.uk/conference).

The GARTEUR Chairman, J. Bode and XC, B. Hammer welcome the GARTEUR delegates to the meeting.

After checking the attendance of the Council members, GoR chairmen and other attendees, a very warm welcome is given to the new participants of the GARTEUR Council meeting: Jean-Luc Hantrais-Gervois, new Chairman of AD GoR and Jutta Fröhling, new Secretary of GARTEUR.

In order to introduce Council members to the new attendees, an individual presentation of members is asked to the delegates.

Presentation of Future Paper:

> R. Gardner presents the future paper and shows the cross-cutting-level-matrix. How are the groups related and how can they interact?
> Networking / Interaction with Universities could be a possibility to get new ideas and input. V. Puoti mentions that the link with the Pegasus-Network could be useful. F. Antrack proposes to start projects with EASA under the name of GARTEUR. The budget is quite small, but there is an agreement with the EU. J. Bode replies that the budget is too small so this is not possible.

GARTEUR-ICAS:

B. Hammer informed the Council about a meeting between the German delegation and Axel Probst from ICAS. ICAS offers GARTEUR a timeslot in the next ICAS-meeting to present research projects. This could be a possibility to make GARTEUR more visible. J.L. Hantrais-Gervois mentions that this is a good platform for the published reports and gathering from other results. Additionally, ICAS offers a permanent collaboration and wants to prepare a Memory of Understanding (MoU). The decision of a prospective collaboration has to be made in the next Council Meeting. It has been decided to invite A. Probst (ICAS secretary) to the next XC meeting in order to discuss in detail a possible collaboration based on a MoU.

Mandatory reference in reports

According to a suggestion by B. Hammer, mandatory references should appear in future publications, indicating that the work was produced within the framework of GARTEUR.

GARTEUR networking: Aviation Research Ecosystem Advanced Novel Approach (AREANA)

J. Bode mentions that AREANA could be interesting for GARTEUR. Checking a possible connection between GARTEUR and AREANA. A future exchange between the two organisations is being sought.

Security paper

The XC members will compose a paper concerning the future handling of the access to the GARTEUR website and the download of reports. XC members will prepare a handout/paper for the Council members wrt the security of the GARTEUR documents.

In addition to the points mentioned, the following fundamental topic were discussed:

- Discussion about new research areas (Propulsion and AI research, etc.)

3.4.3 XC173 - Amsterdam

The XC173 took place from 30th of September to 1st of October 2024 at the NLR (Royal Netherlands Aerospace Centre), Anthony Fokkerweg 2, 1059 CM Amsterdam, Netherlands.

The XC Committee was represented in person by:

Germany:	B. Hammer (XC),
France:	O. Vasseur (XC),
Italy:	V. Puoti (XC)
United Kingdom:	R. Gardner (XC)
Spain:	J.J. Fernandez Orio (XC)
Netherlands:	O. Bartels (XC)
Sweden:	A. Wahlström (XC)

GARTEUR secretary: Jutta Fröhling

Guests: Axel Probst (ICAS secretary)

Figure 5: XC members and invited guest Mr. Axel Probst (ICAS Secretary) at XC 173

Due to the invitation of a guest, the meeting was held on two days, contrary to the usual XC meetings. The main focus of this meeting was therefore the discussion of all possible ideas for cooperation between GARTEUR and ICAS.

At the beginning of the meeting, a previously prepared draft MoU was discussed in detail and further finalised by the XC members. B. Hammer then welcomed the meeting guest Axel Probst (ICAS secretary). After a short presentation and introduction of GARTEUR and ICAS (International Council of the Aeronautical Sciences), the MoU draft for the collaboration with GARTEUR and ICAS was discussed and changes/additions have been made.

The usual programme items (Open/new Action Items, Preparation of next Council meeting) of the XC meeting were discussed on the second meeting day.

In addition to the points mentioned, the following fundamental topics were discussed:

- Update on GARTEUR – Pegasus collaboration:
  It has been decided to organise/ or participate in a joint workshop.

- Security regulations:
  There is a "nationality problem" if a member of a non GARTEUR EU country wants to work within a GoR. Approaches to this were discussed in depth by the committee.

- Mandatory reference:
  In future, a mandatory reference should be included in GARTEUR reports to draw attention to GARTEUR and to increase visibility. The XC suggests adapting the template and not changing the basic document.

- Technology gaps for GARTEUR research:
  It has been decided to create a technology matrix in order to identify technology gaps where new research projects (EGs/AGs) should start.

- Annual reports from GoR:
  The XC decides that the deadline for submitting annual reports should be set for the end of February in future.

- GARTEUR website:
  The official GARTEUR website has been updated to present security standards by the German delegation (social media assistant). Germany offers to maintain and to cover the costs of the hosting in future, even after the chairmanship will end for the time being in 2026.

The XC committee also agrees that in future the website should be used more by the research groups. For example, entries for meetings (dates etc.) should be added and current publications should be advertised.

B. Hammer informs that GARTEUR was part of the International Aerospace Exhibition (ILA) in Berlin from 5th to 9th June 2024.

Figure 6: J. Fröhling (GARTEUR Secretary) and J. Bode (Chairman GARTEUR Council) at ILA, Berlin

3.4.4 C77 - Linköping

The last Council meeting in 2004 took place at the Swedish Air Force Museum in Linköping, Sweden.

Germany:	J. Bode (HoD), B. Hammer (XC), A. Manecke (MoD),
France:	J.S. Martinez DeCastilla (HoD), O. Vasseur (XC),
Italy:	P. Renzoni (HoD), V. Puoti (XC)
United Kingdom:	R. Gardner (XC)
Spain:	J.J. Fernandez Orio (XC), R. Garcia Esparza (MoD)
Netherlands:	O. Bartels (XC)
Sweden:	R. Stridh (HoD), A. Wahlström (XC), I. Eriksson (MoD), M.O. Olsson (MoD)
GoR(AD):	J.-L. Hantrais-Gervois
GoR(RC):	M. White (virtual presence)
GoR(FM):	C. Döll
GoR(SM):	J. San Millan
GoR(AS):	P. Bieber
GARTEUR secretary:	Jutta Fröhling

Figure 7: Council members portrayed at C 77 (Swedish Air Force Museum, Linköping, Sweden)

The meeting starts with a warm welcome from the Swedish delegation, host of the meeting. R. Stridh is proud to host the Council meeting in the Flygvpapenmuseum (Swedish Airforce Museum) in Linköping. The GARTEUR Chairman, J. Bode and XC Chairman, B. Hammer also welcomed the GARTEUR delegates to the last Council meeting in 2024, the end of the first year under the 2-year GARTEUR-Chairmanship of Germany.

After B. Hammer gave an overview of the meetings held so far in this year 2024 and the results achieved, the following programme items were discussed at the meeting.

ICAS collaboration – MoU approval:

> B. Hammer showed a presentation concerning a “future” ICAS-GARTEUR collaboration. In addition, a timeline for the internal process of GARTEUR wrt participation in ICAS conferences and presenting papers from GARTEUR was shown and discussed.

Following additional suggestions have been made:
- GoR is responsible for initiating the process for creating proposals in the Groups.
- GoR send the proposal to secretary.

- XC decides on suitability and informs secretary.
- Secretary informs c/GoRs bout adjustments (if needed).
- GoR makes possible modifications and sends the reports back to the secretary.
- Secretary informs the XC and requests short-term approval.
- Secretary informs the ICAS secretary and sends the proposals.

The MoU has been unanimously and successfully approved by the Council.

Safety regulations in GARTEUR – Future security?

As GARTEUR Basic Documents do not address security risks associated with the engagement of personnel or organisations potentially linked to GARTEUR AG or EG research work, additional security measures were required.

Due to the fact that non-governmental nationalities are difficult to recognise in research groups and increasingly lead to safety-critical considerations, B. Hammer suggested the Council, that GARTEUR could change the template for starting Action Groups in which a separate column is inserted for the nationality. GARTEUR research is generally voluntary, so the Council does not regard this idea as an infringement of freedom. This subject will be part of next meetings.

Archive Data of GARTEUR:

Due to the fact that the IT-security regulations in DLR are very strict and on a high security level, it is not allowed to use the archive of GARTEUR which is saved on hard discs. J. Bode and B. Hammer mentioned that the problem will be present in future for any other nation in case of a (next) chairmanship change. Furthermore, a data exchange via USB devices as well as via mail will lead to immense security problems due to national regulations. These problems will arise more and more. Therefore, the idea to use the existing teamsite more intensively, as well as a digital data archive, were discussed in the Council. The German delegation will discuss the idea of a general digital GARTEUR data archive with DLR security officers and will develop a proposed solution. One solution could be to upload the archive data from the hard disc to a "cloud archive" with very restricted access. Access to the current data archive and a possible realisation will be developed in cooperation with Italy.

PEGASUS Paper:

V. Puoti presented a presentation about a possible PEGASUS collaboration between GARTEUR and PEGASUS. The Council is of the opinion that a collaboration could be a possibility to find younger people to work with GARTEUR. However, the Council is also of the opinion that it needs to be clarified exactly whether there is really a benefit in cooperation. Further discussions on this will take place in the coming year. For example, it is being considered to organise a joint workshop or to take part in PEGASUS workshops or meetings.

Further decisions:

In the C76 meeting, it was decided to find a wording of a mandatory reference for reports to show the involvement of GARTEUR. In the discussion of the last XC173 meeting, the XC members have agreed to adapt only the template and to add the following sentence: "This research was carried out within the Group for Aeronautical Research and Technology in Europe (GARTEUR)".

Figure 8: Discussion-Dinner at the Swedish Air Force Museum

3.5 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

Groups of Responsables (GoRs). Contact details and information on how to be involved in GARTEUR research are also provided, along with links to the national strategic documents of the GARTEUR countries.

For the use of the Council & GoRs, DLR has arranged a TeamSite to be used as a repository for minutes and other documents. That TeamSite is accessible directly by the Council and GoR members.

4. European aeronautics RTD environment

As a unique forum of aeronautical experts from Ministries, Academia, Research Establishments and Industry fostering research initiatives for the benefits of all the member countries, GARTEUR actions are aimed to support the European aeronautical community, both in the civil and in the defence domain. Hence, GARTEUR directly or indirectly interacts with other entities or fora, such as the *European Union*, the *Association of European Research Establishments in Aeronautics* (EREA), the *European Defense Agency* (EDA), the *Advisory Council for Aviation Research and Innovation in Europe* (ACARE). Further details can be found in the previous annual report 2023.

The following sections present the coordination with other European and global research networks from 2024.

4.1 GARTEUR and ICAS

At the end of 2024, GARTEUR and the International Council for the Aeronautical Sciences (ICAS) formally adopted a Memorandum of Understanding (MoU) during GARTEUR's Annual Meeting. The agreement establishes a structured framework for cooperation and represents a significant step toward strengthening the international visibility and impact of GARTEUR's collaborative research.

Memorandum of Understanding between GARTEUR and ICAS

Figure 9: Illustration for collaboration between GARTEUR and ICAS

The cooperation is initially agreed for a duration of ten years and provides GARTEUR with the opportunity to participate in the ICAS Congress, which takes place every two years. Within this framework, GARTEUR may present and publish selected research contributions in the form of oral presentations, based on recommendations issued by GARTEUR.

- These contributions will be accepted without undergoing the standard ICAS peer-review process, while maintaining high scientific standards through GARTEUR's internal quality assurance.

- In addition, GARTEUR will be invited to contribute its expertise to the ICAS Technology Forum and to participate in the ICAS Programme Committee, further strengthening the strategic and technical exchange between both organisations.

Through this cooperation, ICAS will benefit from direct access to GARTEUR's extensive scientific and technical expertise, contributing to a measurable enhancement of the overall quality and relevance of future ICAS congress programmes. At the same time, the partnership provides GARTEUR with a long-term, high-profile international platform to showcase its research results to the global aeronautics community.

The MoU reflects GARTEUR's commitment to fostering excellence in collaborative research, increasing its attractiveness and visibility, and actively shaping the international aeronautics research agenda in the years ahead.

The next ICAS Congress is scheduled for 13th - 17th September 2026.

Figure 10: ICAS Congress 2026 (https://icas2026.com/.

4.2 GARTEUR and PEGASUS

The Partnership of a European Group of Aeronautics and Space Universities (PEGASUS[1]) is a network of aeronautical universities in Europe created in order to facilitate student exchanges and collaborative research between universities. It has been originally created by the "Groupement des écoles aéronautiques françaises" (group of French aeronautical grandes écoles) (ENAC, ENSMA and ISAE) in 1998. PEGASUS currently has 31 members, and 3 associate partners, in 13 different European

[1] https://www.pegasus-europe.org/

countries and has an organisational structure quite similar to GARTEUR, both characterised by a Council and a rotating Chairman.

In 2023 GARTEUR has contacted the Chairman of PEGASUS in order to start having some interactions to understand whether a collaboration between the two entities was possible or not. GARTEUR Council Chairman, Dr. Piergiovanni Renzoni, invited the PEGASUS Vice-Chairman, Prof. Emmanuel Zenou, to the Council in Amsterdam. There a presentation of the PEGASUS Consortium was given to the Council members and a very interesting and fruitful discussion started.

The PEGASUS representative in Italy, Prof. Francesco Franco from the University of Naples "Federico II", was then invited to participate in the event in Pozzuoli in order to have a closer look at the GARTEUR research activities.

Dott. Michele Mazzola, Director of Office III (Internationalization of Research) of the Italian Ministry of University and Research, during the 50th anniversary event pointed out how the membership of Italian universities in PEGASUS is crucial because this partnership aims to offer highly relevant educational and research programmes, thereby attracting the best students and scientists. He emphasised how achieving these goals will require coordinated changes, staff and student exchanges and innovation.

Contacts with PEGASUS continued in 2024 in order to check further the conditions for a more stable collaboration on themes of mutual interest. The Council discussed in 2024 several options for a possible cooperation. This is to be further concretised in the coming reporting period 2025.

5. Summary of GARTEUR technical activities

During 2024 the five GARTEUR Groups of Responsables (GoRs) continued facilitating and delivering 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 (GoRs). 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;
- aerothermodynamics;
- aeroacoustics;
- 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

Four action groups have finished their activities in 2023 and delivered their reports in 2024.

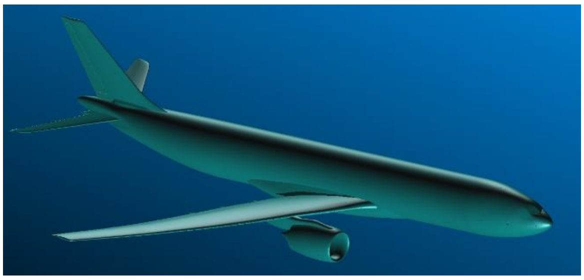
Two Action Groups and five Exploratory Groups have been running throughout 2024. One group has finished its exploratory phase, while four groups have continued their exploratory phases.

Action groups (AG)

The following groups have provided their conclusions in 2024:

AD/AG-56

Coupled Fluid Dynamics and Flight Mechanics Simulation of Very Flexible Aircraft Configurations



The CAD geometry of the XRF-1.

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. A second aim of AG-56 is to derive 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 flexible aircraft structure,
- ✓ Fluid-structure interaction procedures that are capable of modelling large translations and finite rotations.

The chairperson is Richard van Enkhuizen (NLR).

AD/AG-57

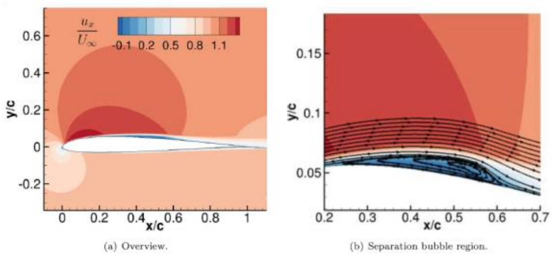
Secondary inlets and outlets

Aircraft captures the outside air with secondary air inlets for air conditioning, ventilation and cooling. The objectives of this group are to study numerically various types of secondary inlets & outlets.
The submerged air intake (NACA type) is predominantly selected for application on the fairing of transport aircraft (civil and military) whereas the hidden inlet is utilized for application inside the engine air intake of combat aircraft in order to reduce the radar signature.

The chairperson is Antonio Carozza (CIRA).

AD/AG-59

Improving the Modelling of Laminar separation bubbles



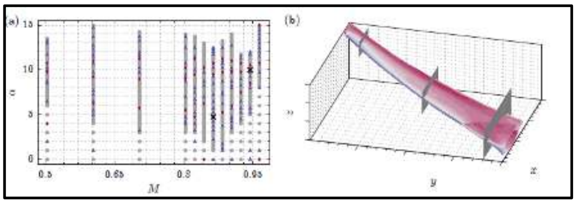
The main goal of the action group has been to improve the modelling of the numerical methods used in the reproduction of the laminar separation bubbles. Incompressible flows in a wide range of Reynolds numbers have been analysed.

An investigation of the main issues that flows at low Reynolds numbers could present in transonic conditions has also been performed.

The chairperson is Pietro Catalano (CIRA).

AD/AG-60

Machine Learning and Data-Driven Approaches for Aerodynamic Analysis and Uncertainty Quantification



Test case used for Machine Learning training and selected test cases

The objectives of the 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.);

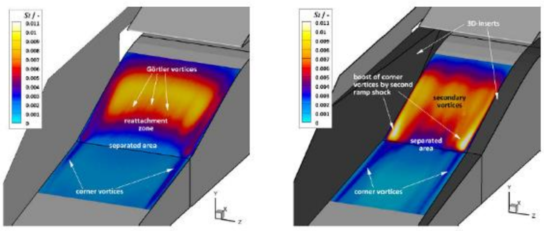
- ✓ Objective 3: Exploration of the potential of machine-learning and data-driven techniques for uncertainty quantification and management.

The chairperson is Esther Andrés (INTA).

The following Action Groups were active throughout 2024:

AD/AG-58

Supersonic Air Intakes



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

The main objective for the 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.

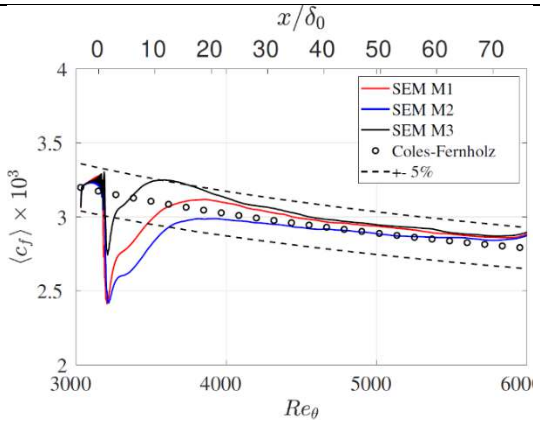
The chairperson is Christophe Nottin (MBDA).

AD/AG-61

WMLES and Embedded LES

RANS CFD has shown many merits but fails to model turbulence in adverse-pressure-gradient boundary layers and in separated flows. Turbulent scale-resolving simulations are needed, but DNS and wall resolved LES are not affordable yet for industrial daily needs.

Thus, this group investigates the hybrid RANS-LES strategies. In order to extend previous activities family II strategies are of



Test case 4: flat plate (SAAB)

interest (where only the inner part of the attached boundary layer is modelled in RANS whereas the outer region of the boundary layer is resolved by LES). Such strategies belong to the more general Wall-Modeled LES approaches. A substantial cost reduction is gained (over wall resolved LES) and improved turbulent dynamics is simulated (over DES-like, or family I simulations where the attached boundary layer is treated fully in RANS). The use of LES can thus be restricted to the regions of interest in a so called embedded LES strategy.

The activities of the group aim at facilitating the introduction of family II in industry. The several turbulent relative topics are investigated through 4 test cases.

The chairperson is Nicolas Renard (ONERA).

Exploratory Groups (EG)

One Exploratory Group has finished its exploratory phase in 2024:

AD/EG-83	*Hydrogen combustion* The exploratory group will address use of hydrogen in aeronautic combustion engine. Three different lines of activities have been identified: 1. To create a validated software tool suitable for use in design of future aero-engines employing hydrogen combustion. The work will proceed by conducting a series of simulations on a set of flames and comparing the numerical results with experiment. 2. To model heat fluxes associated with hydrogen leakage within a future aircraft hydrogen powered propulsion system 3. To explore potential alternative of hydrogen combustion aero-engine turbine technology: The Rotating Detonation Engine A very strong consortium has been formed, partners are: CIRA, CERFACS, CRANFILD Un., ENEA, FOI, IMFT,

INTA, Piaggio, Tu Darmstadt, Un. of Beira Interior, Politecnico di Bari

The following Exploratory Groups were active throughout 2024:

AD/EG-79	*Hypersonics* EG-79 Hypersonic flows was active since 2022. Partners of the EG are: DLR, CIRA, NLR, FOI, VKI, MBDA France and University of Munich. The EG has started with email communication and online meetings in order to discuss the potential topics for a future AG. Topics currently under discussion are ablation, radiation heat flux measurements, thermal fluid structure interaction, and shock wave boundary layer interaction. Each topic is discussed both with respect to numerical and experimental activities.
AD/EG-80	*Morphing for load control of high aspect ratio wings* Partners of the EG are: CIRA, DLR, NLR, ONERA. The objective of EG-80 will be to investigate both aerodynamic efficiency and load control & alleviation capabilities of a High Aspect Ratio wing concept equipped with morphing devices while limiting weight increase and mechanical complications due to morphing technology. The proposal research will focus on the strut braced wing aircraft, referred to as U-HARWARD reference model, that will be made available by ONERA
AD/EG-81	*Virtual certification* For new civil transport aircraft program, the certification phase is critical in terms of planning and

	costs. In 2019, a common paper by Airbus and Boeing indicated how CFD could contribute to the certification of civil transport aircraft for off-design flight characteristics. The purpose of this EG is to have more physics-based analysis tools, less empirical and/or sub-scale methods, fully-integrated multi-physics and multi-scale aircraft modelling and minimize usage of ground test rigs. The objective of the proposed activity is to foster scientific activities in collaboration with industrial leaders and EASA towards a larger usage of CFD in the certification process.
AD/EG-82	*Corner flows for turbulence model development* The understanding and the prediction of the development of flows at the junction of two orthogonal surfaces is still an important topic in the different aspects of aircraft design, e.g. in the design of the wing-fuselage junction, the intersection of horizontal and vertical tail planes or the pylon-fuselage junction which exists in a rear engine aircraft configuration. The idea of this GARTEUR initiative is to form a working group dealing with the investigation of aircraft related junction flows (both civil and military applications), the comparison and validation of state-of-the-art transition and/or turbulence modelling approaches for such flows as well as the improvement of the physical modelling. For this purpose, experimental data is needed for comparison and potential partners are encouraged to share WT data if available. Furthermore, potential partners are equally encouraged to bring in their expertise in transition and turbulence modelling as well as in the application of different CFD tools and modelling approaches.

New topics under consideration are:

- Grid adaptation
- Thermal management for electric propulsion

- Measurement techniques for wind tunnel test and flight test
- Reduced scaled model flight test
- CFD and optimization
- Advanced Air Mobility with RC-GoR and others
- Sloshing for hydrogen fuels
- Quantum computing for aerodynamics
- Plasma for flow control

5.1.3 GoR-AD Membership

The membership of GoR-AD in 2024 is presented in the table below. Several changes have occurred.

Chairperson		
Jean-Luc Hantrais-Gervois	ONERA	France
Vice-Chairperson		
Magnus Tormalm	FOI	Sweden
Members		
Giuseppe Mingione	CIRA	Italy
Kai Richter	DLR	Germany
Fernando Monge	INTA	Spain
Drewan Sanders	Cranfield University	The United Kingdom
Bambang Soemarwoto *replaces Harmen van der Ven*	NLR	The Netherlands
Industrial Points of Contact		
Peter Eliasson	SAAB	Sweden
Riccardo Gemma	Leonardo Company	Italy
Michel Mallet	Dassault Aviation	France
Didier Pagan	MBDA	France
Luiz 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, industries and other relevant European Entities (e.g. National Civil Aviation Authority, MoD, Military entities, etc.) involved in security for aviation through collaborative research activities, and through identification of future projects for collaborative research.

The GoR-AS initiates, organises and performs research on detection and mitigation of unlawful interferences against aviation. Both physical and digital interferences are considered. Topics such as Cybersecurity, Unauthorized drones, Laser Dazzling, Chemical, Biological & Explosive detection are addressed by the GoR.

5.2.2 GoR-AS Activities

Two high priority research topics were identified a few years ago following discussions with various industrial, institutional and academic stakeholders. GoR-AS is focusing on the investigation of these two topics: detection and mitigation of unauthorized drones, assessment of security risks caused by AI in Aviation.

Unauthorized Drones

Since the end of European ASPRID (Airport System Protection from Intruding Drones) project, ONERA, INTA and CIRA have kept on collaborating on this topic. In 2024, four scientific publications were written in order to disseminate the new results obtained on this topic.

In 2024, the group investigated drone attacks in areas managed by U-space, the European framework designed to safely manage low-altitude traffic, particularly drone activities. The group proposed a preliminary concept for improving the safety and the security of a U-space system by means of a novel service, named DARS (Drone Attack Resilience Service). The group also investigated threat scenarios that combine drone physical intrusions with cyber-attacks on U-space remote identification service. The group started to investigate attacks performed by drone teams and swarms. An enhanced version of the SESAR Security Risk Assessment Methodology (SecRAM) was used to assess the risk linked with a network of multiple drones performing a monitoring operation. The same methodology was also used to automatically investigate the threat scenarios associated with U-space services in general.

This topic was discussed by researchers of CIRA, INTA, ONERA and University of Campania (I), University of Salerno (I) as well as members of Eurocontrol Civilian/Military coordination team (EU), ENAC (I), SmartTesting (F) and FEMTO-ST (F). A new SESAR proposal on this topic could be submitted by the GoR members in 2025.

AI and Aviation Security

AI Assistant cybersecurity is another topic that GoR-AS continued to explore in 2024.

Members of the GoR as well as members of other GoR are investigating the use of digital assistant based on Machine Learning in various domains of aviation. For instance, AI assistant was developed to help Air-Traffic controllers detect and correct aircraft trajectory conflicts. AI assistant should also be hosted on-board the aircraft. For instance, FM/AG-20 is investigating the use of AI techniques for flight control fault detection. Due to the critical role played by AI assistants, their cybersecurity has to be investigated.

In 2024, the group identified that AI Digital Assistants could also help perform cybersecurity risk assessment. The Digital Assistant could monitor the quickly evolving cybersecurity threat landscape and continuously update the risk assessment when important new threats appear. The Digital Assistant might also contribute to the design of the protection architecture by helping the designer to select the most relevant and robust security mechanisms.

The AI Assistant cybersecurity topic was discussed by researchers of CIRA, DLR, ONERA, TUM (D), RISE (S) and industrial partners Collins (I) and Leonardo (I).

Research and Innovation Roadmaps

The AS-GoR has also monitored the main research and innovation roadmaps applicable to Aviation Security. EASA Roadmaps were mainly used for the definition of past and future topics: Counter-Drone Task-Force, AI Certification Roadmap, and more generally the European Plan for Aviation Safety (EPAS). EASA published in 2024 the “Aviation Authorities Research Agenda 2024” that includes a topic about “*Interaction between artificial intelligence and cybersecurity*” that is addressed by the current GoR activities. It also includes a topic about “*Risk assessment methodology for air operators to address conflict zones risks based on open-source data*” that is not currently covered by the GoR activities.

In 2024, an update of SESAR JU ATM Master Plan was produced, it includes a Cybersecurity vision for the years 2025 to 2030. Some topics such as cyber-resilience and dynamic risk assessment are addressed by the GoR activities. Other topics such as Quantum computing are not currently covered and they will be analysed in 2025.

5.2.3 GoR-AS Membership

The membership of this GOR in 2024 is presented in the table below:

Chairperson		
Pierre Bieber	ONERA	France
Vice-Chairperson		
Tim Stelkens-Kobsch	DLR	Germany
Members		
Angela Vozella	CIRA	Italy
Domenico Pascarella	CIRA	Italy
Rene Wiegers	NLR	The Netherlands
Jaime Cabezas	INTA	Spain

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 Rotorcraft GoR leads.

5.3.2 GoR-FM Activities

In 2024, two virtual GoR meetings took place. It was decided to focus the effort in 2024 on assisting EG-30 "AI for fault detection" chairs and members for its transition into the AG-20 with the same name.

The EG co-chairs Philippe Goupil (Airbus) and Gustav Öman-Lundin (ONERA) organized several virtual meetings to discuss about the state of the art, detailed objectives, contributions from the partners, the work plan and the partners' interest to participate during 2024. The EG came finally up with a proposal for FM/AG-20 "AI for fault detection" with participation of CIRA, FOI, INTA, Airbus under the lead of ONERA which was presented at Council C77 in Linköping including the letters of adherence and acceptance of 3 partners already received at that time. In the meanwhile, we received the approval to launch AG-20 as soon as we will have received the letters of the 2 missing partners. Up to now, we received the letters of one of the missing partners and we are assisting the last missing partner to accelerate their signature process in order to organize the KoM of AG-20 end of quarter 1, beginning of quarter 2 of 2025.

Exploratory Groups (EG)

The following Exploratory Group was active in 2024:

FM/EG-30	*AI for fault detection* The idea is to investigate the feasibility AI technics for fault detection on-board aerospace vehicles. The current state of practice generally implies a dedicated algorithm (a.k.a. monitoring) to detect a specific fault, and does not rely on AI technics. A more precise objective of the group is to train AI technics on the availability of data within nominal conditions and to analyse their capabilities to detect then any abnormal behaviour.

5.3.3 GoR-FM Membership

The membership of GoR-FM in 2024 is presented in the table below.

Chairperson		
Carsten Döll	ONERA	France
Members		
Marinus Johannus van Enkhuizen	NLR	The Netherlands
Antonio Vitale	CIRA	Italy
Bernd Korn	DLR	Germany
Martin Hagström	FOI	Sweden
Maria Izquierdo Sanchez	INTA	Spain (new member)
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 (interim)

5.4 Group of Responsables – Rotorcraft (RC)

5.4.1 GoR-RC Overview

The GoR-RC 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.

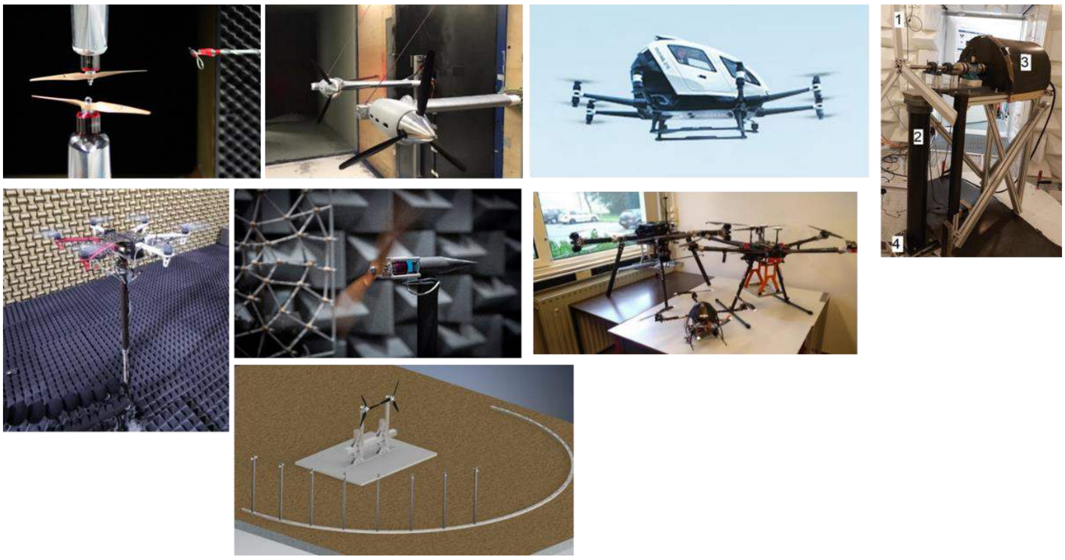
The GoR-RC initiates, organises and monitors basic and applied, computational and experimental multidisciplinary research in the context of application to rotorcraft vehicles (helicopters and VTOL aircraft such as: tilt rotors; compounds and multi-copters) and systems technology.

The field for exploration, analysis and definition 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/medium-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, UAM e VTOLs, advanced technologies for surveillance, rescue and recovery;
    - flight mechanics, flight procedures, human factors, new commands and control technologies;
    - increase crashworthiness, ballistic protection, …;
- better integrate rotorcraft into the air traffic (ATM, external noise, flight procedures, requirements/regulations);
- tackle environmental issues:
    - greening, pollution;
    - visual pollution (for UAM applications);
    - 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 multi-copter aircraft 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.



Overview of experimental activities in RC/AG-26

5.4.2 GoR-RC Activities

Action groups (AG)

The following Action Groups were active throughout 2024:

RC/AG-26	*Noise Radiation and Propagation for Multirotor System Configurations* The objective is to investigate, both numerically and experimentally, the noise radiation and propagation (installation effect) of multirotor systems and to gain knowledge in the physics of noise generation and near-field noise propagation of multirotor systems under

	the influence of the installation effects and to establish tools for the noise prediction. 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 AG started in February 2022. Both, a common validation study and a common experiment are foreseen. The common validation study aims at evaluating and improving the prediction accuracy of different simulation methods.
RC/AG-27	*Analysis and Decomposition of the Aerodynamic Force Acting on Rotary Wings* The technology for drag analysis of CFD solutions of fixed wing configurations has reached a mature stage. Conversely, applications in rotary wing aerodynamics are still very limited, if not absent. However, recent progresses obtained in unsteady flow analysis are promising for both parasite force calculations and thrust extraction. The objective of this AG is to study the application to rotary wings of aerodynamic force analysis and decomposition methods. The kick-off meeting of this AG was held on April 2023.

Exploratory Groups (EG)

The following Exploratory Group were active in 2024:

RC/EG-40	*eVTOL aircraft Vortex-Ring-State investigations* The general aim of this Exploratory Group is to investigate the potential impact of the Vortex-Ring-State (VRS) phenomenon on the safety and operational characteristics of new eVTOL aircraft architectures integrating multirotor/propeller systems as well as fixed wings. The main objectives of the future Action Group are: • to enrich knowledge on the risk of VRS in general for aircraft with rotating wings and in

particular on the new configurations for Advanced Air Mobility, such as UAM aircraft;

- potentially provide recommendations for the developers of these new configurations and for certification agencies (EASA, DGAC, etc.).

New topics under consideration are:

Drone impact on Helicopters (rotating parts)

To gain insight in the severity level of drone/rotor blade interactions. This topic is important for both civil and military applications.

Helicopter Icing & De-Icing

To improve the assessment of performance degradation when flying with rotorcraft in icing conditions, and to identify suitable de-icing systems for rotary wing applications.

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, e-VTOLS...)

To assess the potential and the limitations of these pressure and temperature sensitive paint-based measurement techniques in rotorcraft wind tunnel tests applications.

Perception and public acceptance of UAM and Noise propagation in urban environment (high RPM with high frequency noise)

These two NIs have much in common. These topics are currently having the biggest attention from the rotorcraft community and investigations about them are of utmost importance.

Installation effect of propeller noise (wing, ducts)

The development of eVTOL architectures require a deeper understanding of the noise generated by propellers when ducted or installed in close proximity to wings or airframe.

Verification & Validation: defining metrics for the quality of simulations.

There is an international interest about this topic, especially related to VTOL applications.

5.4.3 GoR-RC Membership

The membership of RC-GoR in 2024 is presented in the table below. Alvaro Cuerva has joined as the Spanish RC-GoR member. Barbara Ohlenforst was a member for part of the year and has been replaced by Marthijn Tuinstra (NLR). There is new UK Industry representation through Florent DeHaeze from Leonardo Helicopters (UK).

Chairperson		
Mark White	Univ. Liverpool	United Kingdom
Vice-Chairperson		
Arnaud Le Pape	ONERA	France
Members		
Rainer Heger	Airbus Helicopters (D & F)	Germany
Florent DeHaeze	Leonardo Helicopters	United Kingdom
Klausdieter Pahlke	DLR	Germany
Antonio Visingardi	CIRA	Italy
Marthijn Tuinstra	NLR	The Netherlands
Barbara Ohlenforst	NLR	The Netherlands
Alvaro Cuerva	Universidad Politécnica de Madrid	Spain
Industrial Points of Contact		
Rainer Heger	Airbus Helicopters (D&F)	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 (Group of Responsables in Structures and Materials) is active in initiating and organizing aeronautics-oriented research on structures (configuration, topology, optimization), modelling and simulation procedures (strength, fatigue, structural dynamics, etc.), and different type of materials for structural applications.

Materials oriented research is related to material systems primarily for the airframe; it includes specific aspects of polymers, metals including Additive Manufacturing (AM), and different kinds of composite systems.

Structural research is devoted to computational mechanics, loads, and design methodologies. 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 upstream research intended to discover valuable areas of future activity; in this context, many new ideas were proposed and explored during the year 2020.

The work and activities of the SM GoR covers a variety of aspects related to novel structural concepts, new materials, improved manufacturing technologies, new design and verification criteria.

Recent, current and upcoming work is devoted to:

- Additive Layer Manufacturing of metals;
- Characterization and Optimization of shock absorbers for civil aircraft fuselages;
- Characterization and modelling of Composites with Ceramic Matrix submitted to severe thermo-mechanical loading;
- Structural Health Monitoring for hydrogen aircraft tanks;
- Multifunctional Metamaterials for Aerospace applications;
- Non-traditional laminates.

5.5.2 GoR-SM Activities

In 2024, the GARTEUR GoR-on SM monitored two Action Groups (AG) and three Exploratory Groups (EG):

Action groups (AG)

The following Action Groups were active throughout 2024:

SM/AG-36	*Additive layer Manufacturing* This AG started in March 2022 and it is a result from SM/EG-47. AG-36 deals with new Aluminium alloys (ScanCromal and AlMg1Cr1.5Mo0.5Sc0.5Zr0.25) suitable for processing by Additive Manufacturing (AM) techniques. There is an increasing need for high strength aluminium alloys that can be processed by AM procedures, for products and applications requiring low weight combined with high specific strengths. Process optimizations are investigated for processing by Laser Powder Bed Fusion (LPBF) and Directed Energy Deposition (DED) techniques.
SM/AG-37	*Characterization and optimization of shock absorbers for civil aircraft fuselages* Commonly adopted shock absorbers and, in general, crashworthy structural components, based on sandwich structural concepts and/or complex dumping mechanisms, are, generally, characterized by high volumes and significant additional mass. The main objective of the proposed work consists in the investigation of the feasibility and effectiveness of novel thin additive manufactured hybrid metal/composite lattice structures as lightweight shock absorbing devices for application to structural key components in impact events. The topics of this AG-37 are:

- Investigation on the key components which require the integration with shock absorber;
- identification and classification of the shock absorbers (material and geometry);
- material investigation (Alternative materials, Hybridization);
- integration strategies;
- analytical methods for designing hybrid shock absorber;
- numerical analysis and design;
- unit cell optimization (weight minimization and/or shock absorbing capability maximization);
- thermal stress analysis;
- experimental tests and validation;
- certification issues;
- definition of guidelines for an effective integration in each scenario.

Exploratory Groups (EG)

The following Exploratory Groups were active throughout 2024:

SM/EG-45	*Characterization and modelling of CMC submitted to severe thermo-mechanical loading* The main objectives of the EG consist in: • understanding of the damage and failure mechanisms under static and fatigue loading at very high temperatures;

		• definition of standard tests to measure 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 simulating CMC composite structures under static or fatigue loading (evaluation of predictive capabilities of models).
SM/EG-48		*Structural health Monitoring for hydrogen aircraft tanks* In order to drastically reduce CO2 emissions, hydrogen is an alternative solution for the production and storage of energy. Regarding the storage, the best option consists in liquefying the hydrogen at a temperature below -253°C. Composite materials are being considered for the cryogenic tank but the issue related to the development of a composite tank is the ability to detect initiation of any damage. Structural Health Monitoring (SHM) methods, consisting of integrating sensors in or on the structure, are then used. However, few studies are dedicated to SHM methods under such temperatures. The AG objective would be to work on the design of SHM systems dedicated to composite parts under cryogenic temperatures, including the study of the durability of such systems.
SM/EG-49		Multifunctional Metamaterials for Aerospace applications Multifunctional Metamaterials (MM) is a promising state of the art topic with multiple and multifunctional applications, and suitable for Aerospace applications. During last GoR meetings, several discussions have been held between the partners in the topic, and a lot of interest between the partners has been raised:

- INTA has a team working in MM lattice-based structures, focused on dynamic response: vibration attenuation for primary structures, functionally graded structures, optimization, etc.

- NLR has also a research line in the MM topic. NLR interests includes static crashworthiness for ballistic applications, 3D printing, MM grids definition, energy absorption application, Titanium auxetic sandwiches, etc.

- UNICAMPANIA is interested in the topic: Nanoshapes, multifunctional MM sandwiches, etc.

- ONERA is interested: Light structures, and Static/Fatigue improved properties from 3D printed MM.

Therefore the SM/EG-49 was created, and one of the first things to set could be the Benchmarks definition.

5.5.3 GoR-SM Membership

The membership of GoR-SM in 2024 is presented in the table below:

Chairperson		
Francisco Javier San Millan	INTA	Spain
Vice-Chairperson		
Aniello Riccio	UNICAMPANIA	Italy
Members		
Florence Roudolff	ONERA	France
Joachim de Kruijk	NLR	Italy Netherlands
Peter Wierach	DLR	Germany
Andrew Foreman	QinetiQ	United Kingdom
Mats Dalenbring	FOI	Sweden
Industrial Points of Contact		
Thomas Ireman	SAAB	Sweden
Christian Weimer	Airbus Operations	Germany
Thomas Körwien	Airbus Defence and Space	Germany

6. List of abbreviations

ACARE: Advisory Council for Aviation Research and Innovation in Europe

AG: Action Group

AREANA: Aviation Research Ecosystem Advanced Novel Approach

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

SM: Structures & Materials

RC: Rotorcraft

ICAS: International Council of the Aeronautical Sciences

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

PEGASUS: Partnership of a European Group of Aeronautics and Space Universities

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 31st December 2024

GARTEUR Chair Country 2024-2025: Germany
Counil Chair: J. Bode

XC Chair: B. Hammer
Secretary: J. Fröhling

GARTEUR COUNCIL							
Function	**France**	**Germany**	**Italy**	**Netherlands**	**Spain**	**Sweden**	**United Kingdom**
Head of Delegation	J.S. Martinez De Castilla	J. Bode	P. Renzoni	vacant	R. Gonzalez Armengod	R. Stridh	P. Griffiths
XC Member	O. Vasseur	B. Hammer	V. Puoti	O. Bartels	J.J. Fernandez Orio	A. Wahlström	R. Gardner
Other Members of Delegation	P. Beaumier	H. Hemmer A. Manecke		B. Thuis	J.F. Reyes-Sánchez R. Garcia	M.O. Olsson I. Eriksson J. Rignér	C. Low

GROUPS OF RESPONSABLES									
Aerodynamics (AD)		**Aviation Security (AS)**		**Flight Mechanics, Systems & Integration (FM)**		**Rotorcraft (RC)**		**Structures & Materi**	
GoR AD members		**GoR AS members**		**GoR FM members**		**GoR RC members**		**GoR SM memb**	
J.-L. Hantrais-Gervois	FR	**P. Bieber**	FR	**C. Doll**	FR	**M. White**	UK	**F.J. San Millan**	ES
M. Tormalm	SE	T. Stelkens-Kobsch	DE	M.J. van Enkhuizen	NL	A. Le Pape	FR	A. Riccio	IT
G. Mingione	IT	A.Vozella	IT	A. Vitale	IT	A. Visingardi	IT	F. Roudolff	FR
K. Richter	DE	R. Wiegers	NL	B. Korn	DE	K. Pahlke	DE	J. de Kruijk	NL
F. Monge	ES	D. Pascarella	IT	M. Hagström	SE	B. Ohlenforst	NL	P. Wierach	DE
D. Sanders	UK	J. Cabezas	ES	M.I. Sanchez	ES	M. Tuinstra	NL	A. Foreman	UK
B. Soemarwoto	NL			A. Rae	UK	A. Cuerva	ES	M. Dalenbring	SE
Industrial Points of Contacts		**Industrial Points of Contacts**		**Industrial Points of Contacts**		**Industrial Points of Contacts**		**Industrial Points of C**	
L.P. Ruiz-Calavera	ES			P. Goupil	FR	R. Heger	DE	T. Ireman	SE
P. Eliasson	SE			L. Goerig	FR	F. DelHaeze	UK	C. Weimer	DE
R. Gemma	IT			M. Hanel	DE			T. Korwien	DE
M. Mallet	FR			P. Rosander	SE				
D. Pagan	FR								

APPENDICES

AND GO TO https://garteur.org/annual-reports/

Appendix A: Annex GoR-Aerodynamics (AD)

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AERODYNAMICS"

Remit

The GoR (AD) is active in initiating and organising basic and applied research in aerodynamics and aerothermodynamics. Aerothermodynamics is closely related to space operations and flight through the earth's atmosphere at very high speeds.

Aerodynamics is a cornerstone of aeronautics and one of the primary design disciplines to determine the shape of the aircraft. Environmental issues are of great concern in aeronautics for civil aircraft and advanced aerodynamic design will have a significant impact on fuel consumption and the noise of aircraft. For military aircraft, the requirements of stealthy operation require new aircraft shapes to be considered and these shapes must be aerodynamically effective. The GoR(AD) area of activity covers aerodynamics, aeroacoustics, and aeroelasticity. The GoR(AD) is supporting a multi-disciplinary cooperation with the other GARTEUR Groups in areas where a mono-disciplinary approach is not meaningful.

The Group is active in experimental, theoretical, analytical, as well as in numerical fields of aerodynamics to support the development of methods and procedures. Work in experimental areas is performed mainly to obtain valuable data for the validation of methods. Measurement techniques are developed and refined to increase accuracy and efficiency of experimental investigations. Other numerical studies give insight in the mechanisms of basic flow phenomena.

GoR-AD Overview

GoR Activities

The GoR AD initiates and organises basic and applied aerodynamic research in the field of aeronautics. Both experimental and numerical activities are considered ranging from research on basic flows to dedicated applied aeronautical applications, passing through methodological aspects (measurements, numerical techniques). The close collaboration of experimental and numerical activities is of great benefit and enables enhanced progress in aeronautical research.

Management

Two meetings have been held:

AD/A- 114 Meeting FOI, Stockholm (Sweden) March 5th - 6th 2024

AD/A- 115 Meeting at Göttingen (Germany), October 23rd-24th 2024

A third unformal online meeting has been organized in June 2024.

Next GoR-AD meetings are planned on March 4th and 5th at NLR (Amsterdam) and on the 30th of September and 1st of October (Meudon).

Dissemination of GARTEUR activities and results

No specific dissemination activity in 2024.

Status of Action Groups and Exploratory Groups

Four groups finished their activities in 2023 and proposed their reports in 2024. Two Action Groups have been running throughout 2024. In this period one EG finished its exploratory phase. Four exploratory group have been active (no new EG has been launched).

Action groups (AG)

Four groups had finished their activities and produced their reports in 2024:

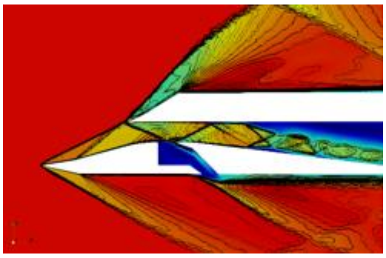
- AD/AG-56: *Coupled Fluid Dynamics and Flight Mechanics Simulation of Very Flexible Aircraft Configurations*
- AD/AG-57: *Secondary Inlets and Outlets*
- AD/AG-59: *Improving the Simulation of Laminar Separation Bubbles*
- AD/AG-60: *Machine Learning and Data-Driven Approaches for Aerodynamic Analysis and Uncertainty Quantification*

The following Action Groups were active throughout 2024:

AD/AG-58

Supersonic Air Intakes

The main objective for the 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.

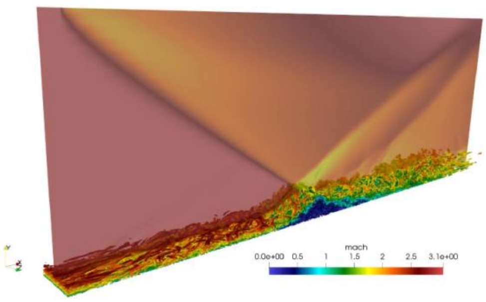
It is expected to support each theme with recent and detailed experimental data as well as CFD modelling and/or validation.

Due to COVID crisis that complicated organisation and priorities in 2020 for many companies, the collaborative work planned last year has been postponed for a year. Some other priorities in 2022 have lead to other delays. Collaboration has been restarted and the group is expected to prepare its final report by end of 2025.

The chairperson is Christophe Nottin (MBDA).

AD/AG-61

WMLES and Embedded LES



RANS CFD has shown many merits but fails to model turbulence in adverse-pressure-gradient boundary layers and in separated flows. Turbulent scale-resolving simulations are needed, but DNS and wall resolved LES are not affordable yet for industrial daily needs.

Thus, this group investigates the hybrid RANS-LES strategies. In order to extend previous activities (see AD/AG-54 for instance), family II strategies are of interest (where only the inner part of the attached boundary layer is modelled in RANS whereas the outer region of the boundary layer is resolved by LES). Such strategies belong to the more general Wall-Modeled LES approaches. A substantial cost reduction is gained (over wall resolved LES) and improved turbulent dynamics is simulated (over DES-like, or family I simulations where the attached boundary layer is treated fully in RANS). The use of LES can thus be restricted to the regions of interest in a so called embedded LES strategy.

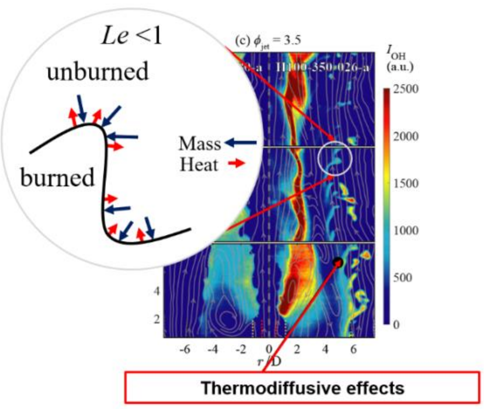
The activities of the group aim at facilitating the introduction of family II in industry. The several turbulent relative topics are investigated through 4 test cases.

The chairperson is Nicolas Renard (ONERA).

Exploratory Groups (EG)

The following Exploratory Group has finished its exploratory phase in 2024 and prepared its report. The group will be active in 2025.

AD/EG-83 → AD/AG-62 *Hydrogen Combustion*



The objectives of the group are to understand basic phenomena linked to hydrogen combustion and to model them in numerical tools.

The following investigation themes will be tackled both experimentally and numerically:

- understand the dynamics of hydrogen combustion in the presence of turbulence
- develop reliable and validated software design tool for future hydrogen combustion engines and hydrogen storage
- concept feasibility study of a rotating detonation engine

The group will be launched in 2025 for a duration of 3 years.

The chairperson is Ainslie French (CIRA).

The following Exploratory Groups were active throughout 2024:

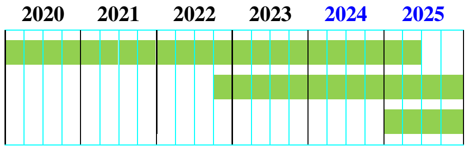
AD/EG-79 *Hypersonics*

	Partners of the EG are: DLR, CIRA, NLR, FOI, VKI, MBDA France and University of Munich. In 2024, the group has selected its topics: • ablation on generic materials • thermal fluid structure interaction • shock wave-boundary layer interaction in hypersonic/high temperature flow Each topic is discussed both with respect to numerical and experimental activities. The AG proposal should be proposed in the beginning of 2025.
AD/EG-80	*Morphing for load control of high aspect ratio wings* Partners of the EG are: CIRA, DLR, NLR, ONERA. The objective of EG-80 will be to investigate both aerodynamic efficiency and load control & alleviation capabilities of a High Aspect Ratio wing concept equipped with morphing devices while limiting weight increase and mechanical complications due to morphing technology. The proposal research will focus on the strut braced wing aircraft, referred to as U-HARWARD reference model that will be made available by ONERA. The group did not exchange in 2024.
AD/EG-81	*Virtual certification* For new civil transport aircraft program, the certification phase is critical in terms of planning and costs. In 2019, a common paper by Airbus and Boeing indicated how CFD could contribute to the certification of civil transport aircraft for off-design flight characteristics. The purpose of this EG is to have more physics-based analysis tools, less empirical and/or sub-scale methods, fully-integrated multi-physics and multi-scale aircraft modelling and minimize usage of ground test rigs. The objective of the proposed activity is to foster

	scientific activities in collaboration with industrial leaders and EASA towards a larger usage of CFD in the certification process. Several online discussions in 2024 gathered several partners interested in the subject. As the team is not settled yet, it is not indicated here. The topics eligible for a GARTEUR activity need to be elaborated in 2025.
AD/EG-82	*Corner flows for turbulence model development* The understanding and the prediction of the development of flows at the junction of two orthogonal surfaces is still an important topic in the different aspects of aircraft design, e.g. in the design of the wing-fuselage junction, the intersection of horizontal and vertical tail planes or the pylon-fuselage junction which exists in a rear engine aircraft configuration. The idea of this GARTEUR initiative is to form a working group dealing with the investigation of aircraft related junction flows (both civil and military applications), the comparison and validation of state-of-the-art transition and/or turbulence modelling approaches for such flows as well as the improvement of the physical modelling. For this purpose, experimental data is needed for comparison and potential partners are encouraged to share WT data if available. Furthermore, potential partners are equally encouraged to bring in their expertise in transition and turbulence modelling as well as in the application of different CFD tools and modelling approaches. The group did not exchange in 2024. There are interested partners, but the group lacks a chair person.

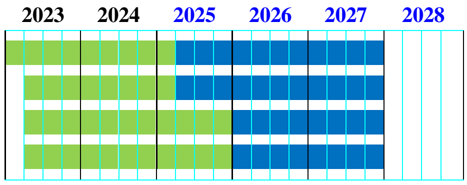
Rolling plan

Nº	Topic
AG58	Supersonic air intakes
AG61	WMLES and Embedded LES
AG62	Hydrogen combustion



Closed Active Status December 2024

Nº	Topic
EG79	Hypersonic flows
EG80	Morphing
EG81	Virtual certification
EG82	Corner flows



Closed Active Status December 2024

GoR membership

This year France (ONERA) has chairmanship and Sweden (FOI) vice-chair. This will also be the case in 2025.

After years of active contribution in the GoR-AD, Harmen Van Der Ven withdrew from the GoR. The GoR-AD members thank him for everything he brought to the group, both on the scientific and personal levels. As NLR representative Harmen Van Der Ven has been replaced by Bambang Soemarwoto.

The GoR-AD also appreciates the arrival of Drewan Sanders (Cranfield University).

Bruno Stefes being involved in other activities has passed the full Airbus perimeter to Luiz Ruiz-Calavera.

Chairperson		
Jean-Luc Hantrais-Gervois	ONERA	France
Vice-Chairperson		
Magnus Tormalm	FOI	Sweden
Members		
Giuseppe Mingione	CIRA	Italy
Fernando Monge	INTA	Spain
Kai Richter	DLR	Germany
Drewan Sanders	Cranfield University	The United Kingdom
Bambang Soemarwoto	NLR	The Netherlands

Industrial Points of Contact		
Peter Eliasson	SAAB	Sweden
Riccardo Gemma	Leonardo Company	Italy
Michel Mallet	Dassault Aviation	France
Didier Pagan	MBDA	France
Luiz P. Ruiz-Calavera	AIRBUS	Spain

Table of participating organizations

	AG-58	AG-61	AG-62
Research Establishments			
CIRA		□	■
Cranfield University			□
DLR	□	□	
FOI	□	□	□
INTA			□
NLR		□	
ONERA	□	■	
Industry			
Airbus Defence & Space			
Airbus Operations GmbH			
Airbus Operations S.A.S.			
Leonardo Company			
Dassault Aviation			
MBDA-F	■		
MBDA-D	□		
Piaggio Aero.			□
SAAB	□	□	
OPTIMAD			
Academic Institutions			
Imperial College			
Technical Univ. Munich			
Technical Univ. Darmstadt			□
Univ. of Cambridge			□
Univ. of Southampton			
Univ. of Manchester		□	
Univ. of Napoli “Federico II”			
Poli. Bari			□
Univ. of Strasbourg		□	
ENEA			□
IMFT			□
CERFACS			□

Univ. Beira Interior			☐

AD/AG-56	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations
Monitoring Responsable:	H. Van der Ven NLR
Chairman:	M.J. van Enkhuizen NLR

- **Activity concluded**

See report GARTEUR TP–201 (Open).

- **Synthesis**

Climate change is currently one of the major issues facing humanity. Within this context, the aircraft industry has publicly been at the receiving end of a large amount of criticism due to the extensive use of fossil fuels. Many proposed solutions exist to lower or completely remove the need for fossil fuels. These solutions include increasing the aircrafts efficiency using lighter weight, yet more flexible a wing tip deflection of around 10% of the semi-span is targeted. This condition includes trimming for thrust, pitching moment and a target lift coefficient. The second case is a steady, 2.5g pull-up manoeuvre following the subsonic trim condition. Finally, a gust disturbance as specified by certification requirements is defined as an unsteady test.

NLR uses in-house CFD simulation software (ENFLOW) and a third-party software based on the vortex-lattice method (ZAERO) to perform the aeroelastic simulations. CIRA uses an in-house, block-structured CFD solver (ZEN) and ONERA uses the well-known elsA CFD code to perform the simulations within this work.

The rigid trim simulations performed by ZEN, ENFLOW & ZAERO show generally good agreement between the different trim parameters, where the differences could be explained by a difference in thrust. For the flexible trim simulations (see Figure 11), there are some very good agreements between final trimmed values of the angle-of-attack and expected tip displacement between elsA and ENFLOW. Unfortunately, there has not been enough time to thoroughly investigate the root cause for these differences. The 2.5g pull-up manoeuvre was simulated by ENFLOW, showing deflections up to 22% of the wing semispan (see Figure 12). elsA is not able to converge the 2.5g condition due to large amounts of

materials and higher aspect ratio wings. The use of these materials and more efficient aerodynamic configurations, result in the increased importance of robust and accurate aeroelastic simulations for a wider range of topics in aircraft design. Classical aeroelastic simulation methods have often relied on small deformation assumptions. However, it is yet unknown whether it is possible to maintain the use of such methods for the aforementioned highly flexible structures.

The goal of AG56 is to enhance each partner's (NLR, CIRA, ONERA and Airbus) capabilities in aeroelastic simulations pertaining to very flexible aircraft and to define and develop a common test case in terms of aircraft and manoeuvre. This is done by increasing the flexibility of the wing of the XRF1 model provided by Airbus and subsequently defining three load cases with increasing complexity. The first of which is a simple 1g trim condition at both a subsonic and transonic Mach number, where

flow separation. Finally, rigid gust simulations were performed by ZEN, ENFLOW and ZAERO. The response from ZAERO and ENFLOW match up quite well. The results from ZEN cannot be compared to the other two simulations as there is a difference in gust definition. Finally, the flexible gust shows a maximum of 2.1% tip deflection for this specific gust, which supports the use of small deflection methods for aeroelastic gust simulations.

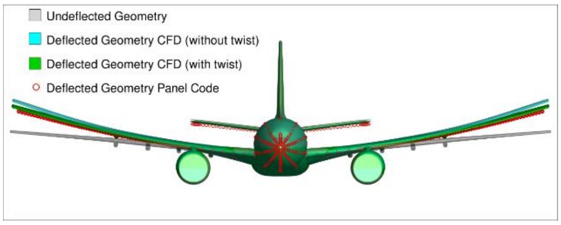


Figure 11: Deformed structured as calculated using CFD and panel code computations (M = 0.50 trim case)

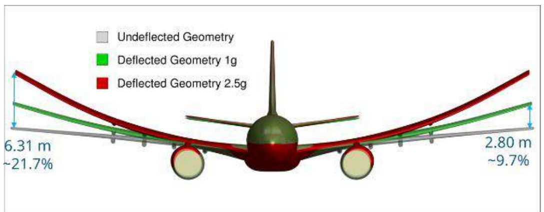


Figure 12: Deformed structure as calculated by CFD (M = 0.50, 2.5g pull up manoeuvre)

- **Recommendations**

All simulations presented here are performed using a linear structural model, which is not justified for the large deflections encountered in the obtained results. The structural model contained elements which are not suitable for nonlinear analysis however. It is therefore recommended in the future to replace elements that are solely applicable to nonlinear analysis, with elements that can be used in simulations that include nonlinear structural effects.

Moreover, the conclusion from the gust analysis is that the linear, modal analysis is sufficient to accurately resolve the dynamic structural effects. This conclusion is encouraging, however, is based on the smallest gust width required from the certification. Larger gust widths will result in longer periods of increased local angle-of-attack and as such, longer periods of increased loading. This will result in larger deflections. Hence, the conclusions here cannot be used as final, definitive justification for using modal analysis, yet provide some good initial evidence. It is therefore recommended to repeat these simulations with larger gust widths.

Finally, there are some differences between the results of different partners that could not be fully explained. Therefore, it is recommended to more thoroughly investigate where the differences in simulation results come from.

- **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

AD/AG-57	Secondary inlets and outlets
Monitoring Responsable:	G. Mingione CIRA
Chairman:	A. Carozza CIRA

- **Activity concluded**

See report GARTEUR TP–199 (Limited).

- **Synthesis**

Aircraft captures the outside air with secondary air inlets for air conditioning, ventilation and cooling. Their shapes differ widely depending on integration possibilities, performance requirements and minimization of interference effects (including drag). In the case of transport aircraft (civil and military), the capabilities of secondary air inlets have to collect more and more air from the outside to replace the bleed air provided by the main engines, 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 the 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 onboard 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.

The group activities concern the application of secondary air inlets on multiple aircraft platforms, both transport aircraft (civil and military) and combat aircraft. The submerged air intake (NACA type) is predominantly selected for application on the fairing of transport aircraft (civil and military) whereas the hidden inlet is utilized for application inside the engine air intake of combat aircraft in order to reduce the radar signature.
The group focused its efforts on the following items:

1. Belly fairing NACA standard intake,
2. Piaggio P180 aircraft air cooler air intake,
3. Airbus A320 VTP flapped air intakes,
4. An integrated secondary inlet in the main engine air intake of a combat aircraft

The main objective of the project was to analyse the efficiency of various air intake types for using the state-of-the-art CFD and the performance evaluation methods.

Inside the first work package, NLR investigated the drag and performance of the NACA submerged intake together with CIRA. Airbus Defence and Space and CIRA have also investigated the performance of the Piaggio P180 oil cooler with different approaches. The codes appear to predict well the behaviour of the aerodynamic solutions with comparable results with some differences. Those differences are likely due to the assumptions within the codes and the different grids and levels of discretization in the computational domain.

In the second work package the design of secondary inlets for two military configurations has been accomplished. Mesh generation process and entire CFD process were stable, fast, and efficient. The report provides comparisons of the two inlets (total pressure recovery, distortion, design considerations...).

- **Recommendations**

A Python tool environment for automatic extraction of total pressure recoveries, DC60, and swirl is recommended for future investigations.

A higher secondary inlet mass flow rate reduces the mass flow spilled by the engine and in fact the intake sizing should consider it. Nevertheless, considering only one engine setting and a very limited number of boundary conditions and flight conditions requires much deeper investigations (off design conditions). Due to lack of resources passive flow control design have not been addressed.

- **AD/AG-57 membership**

Member	Organisation
A. Carozza	CIRA
I. J. Rodriguez Hidalgo	AIRBUS
U. Krause	AIRBUS
J. Himisch	DLR
C. Gonzales Biedma	Airbus D&S
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AD/AG-58	Supersonic Air Intakes Aerodynamics
Monitoring Responsable:	D. Pagan MBDA
Chairman:	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 their design heavily relies on numerical simulations (CFD).
An Action Group on supersonic air intakes was completed in 2007 (AG34). 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 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 proposed 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.

WP1: Management

In 2024, some computations were performed both by MBDA, ONERA and FOI but still need to be gathered and analysed in common. For the WP2 case, ZDES was finalized by ONERA. For WP3, DLR reported that it was not possible to gather the missing experimental data. This case will be completed with the available published data and the simulations already performed by MBDA and FOI.
More detailed measurements were gathered and shared by DLR for the WP4, especially regarding thermal fluxes. This task will require more common work in 2025.
The final report will be postponed by the end of 2025.

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 $Re\delta2 \approx 6000$ 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 AG58 but with well-known flow conditions at boundaries, see Figure 13.
Several RANS computations were performed by ONERA. Inlet flow profiles are now available to all partners, see Figure 14. 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, RSM, …).

- **Main achievements**

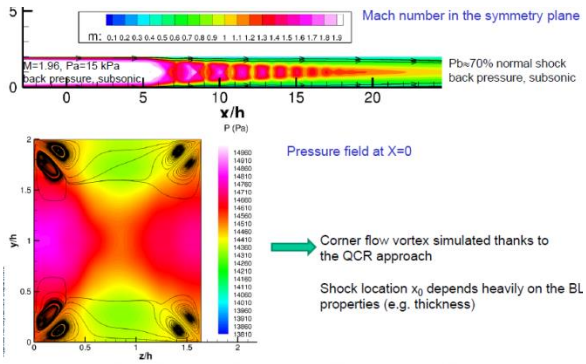


Figure 13: Shock train in a rectangular cross-section channel. ONERA test-case

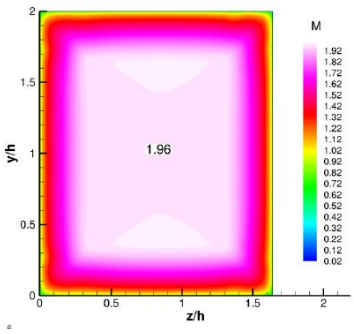
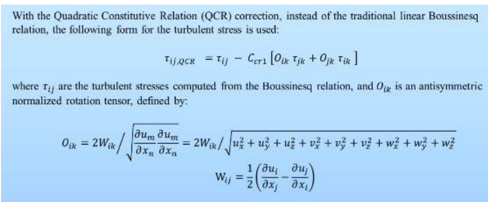


Figure 14: Inlet flow field proposed by ONERA for shock train case computations.

RANS computations were performed by ONERA and also MBDA using Spalart-Allmaras (SA) and a non linear closure variant (SA-QCR).

QCR generic formulation is detailed below.



With the Quadratic Constitutive Relation (QCR) correction, instead of the traditional linear Boussinesq relation, the following form for the turbulent stress is used:

$$\tau_{ij,QCR} = \tau_{ij} - C_{cr1}\left[O_{ik}\,\tau_{jk} + O_{jk}\,\tau_{ik}\right]$$

where τ_{ij} are the turbulent stresses computed from the Boussinesq relation, and O_{ik} is an antisymmetric normalized rotation tensor, defined by:

$$O_{ik} = 2W_{ik} \Big/ \sqrt{\frac{\partial u_m}{\partial x_n}\frac{\partial u_m}{\partial x_n}} = 2W_{ik} \Big/ \sqrt{u_x^2 + u_y^2 + u_z^2 + v_x^2 + v_y^2 + v_z^2 + w_x^2 + w_y^2 + w_z^2}$$

$$W_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} - \frac{\partial u_j}{\partial x_i}\right)$$

Figure 15: Principle of QCR non linear closure for turbulence models.

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. Figure 16).

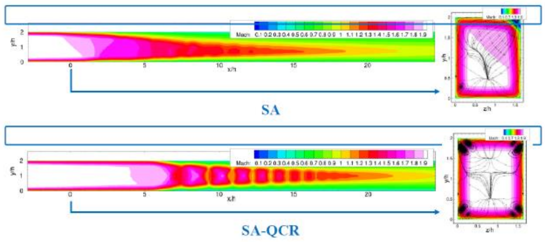


Figure 16: Effects of QCR closure with the Spalart-Allmaras model on corner flows and shock train development for WP2 test-case (ONERA).

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. Figure 17 and Figure 18).

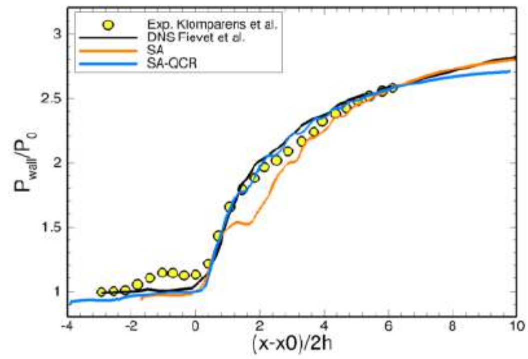


Figure 17: Effects of QCR closure with the Spalart-Allmaras model and comparison with wall pressure measurements (ONERA).

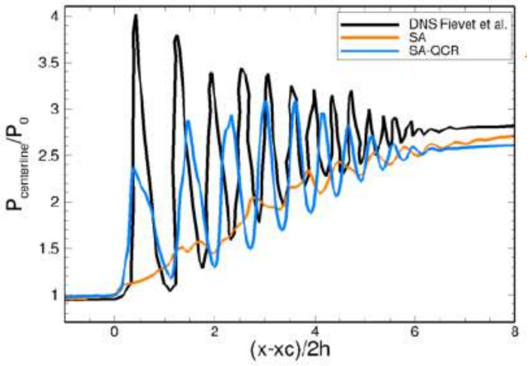


Figure 18: Effects of QCR closure with the Spalart-Allmaras model and comparison with axial pressure computations from DNS published by Fiévet et al. (ONERA).

Further investigations were performed by ONERA and MBDA on QCR correction applied to k-omega SST model.

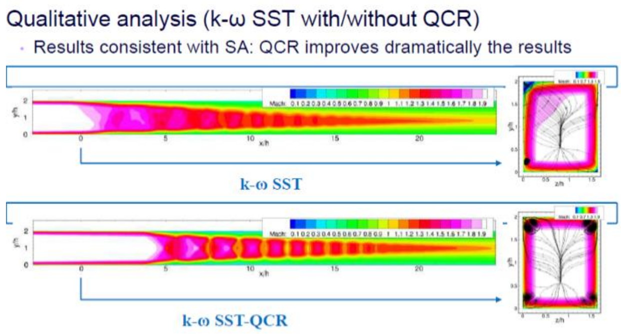


Figure 19: Effects of QCR closure with the k-omega SST model on corner flows and shock train development for WP2 test-case.

These results (see Figure 19) confirm the trends from previous results obtained with SA model.

QCR correction leads to strong improvement regarding corner flow effects (see Figure 20).

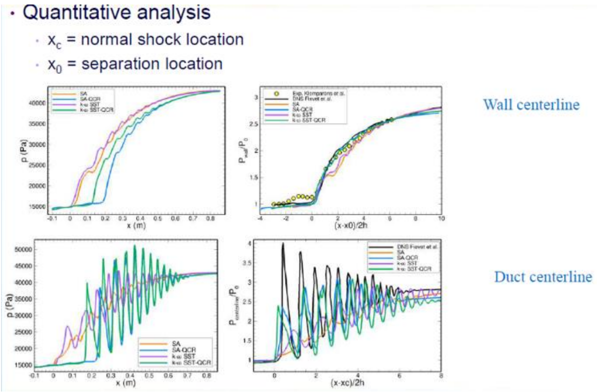


Figure 20: Effects of QCR closure with the k-omega SST model and comparison with wall pressure measurements and SA/SA-QCR results.

Further investigations will be made on Reynolds Stress Model (RSM) and ONERA has completed ZDES computations (see Figure 21).

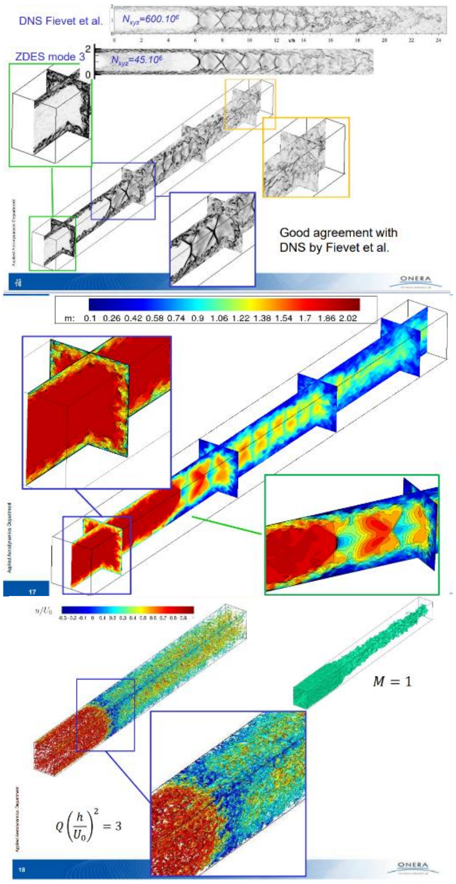


Figure 21: ZDES simulations (ONERA) on WP2.

Preliminary comparisons between RANS and ZDES computations show significant improvements on shock train prediction as illustrated by Figure 22.

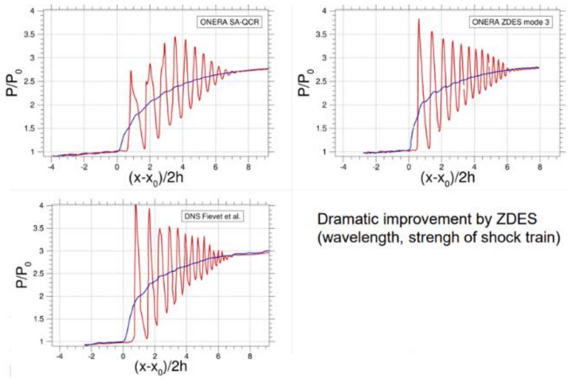
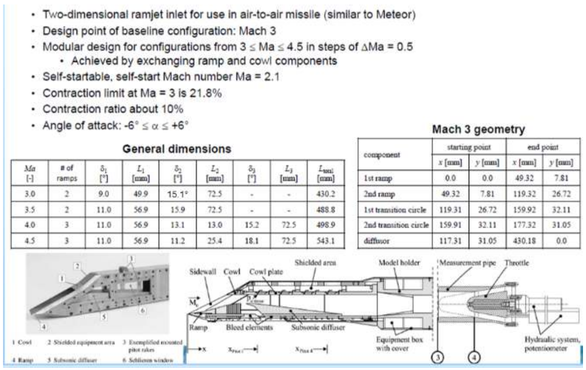


Figure 22: RANS vs ZDES simulations (ONERA) on WP2.

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 23.



General dimensions

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

Mach 3 geometry

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

Figure 23: 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 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. Figure 24):

- 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
  - Instationary pressure 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
  - 2 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.

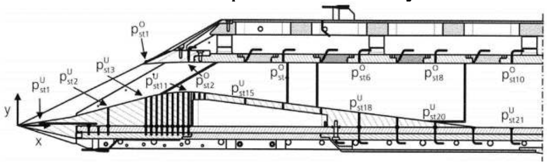


Figure 24: DLR experiments with measurements and rakes location.

Accuracy on the air intake performance 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 last teleconference meeting.
Regarding boundary conditions, DLR will assess by 2D computations the potential effect of wind-tunnel walls on the bleed mass flow rate, as the internal bleed has no sonic outlet as illustrated by Figure 25.

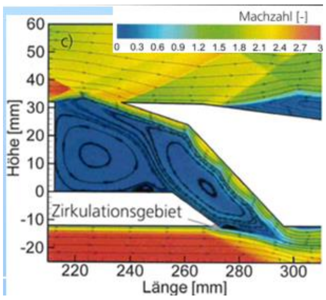


Figure 25: Illustration of Mach number of the internal flow inside the bleed (DLR).

The 3D CAD file, ready to mesh, has been provided to all members (see. Figure 26)

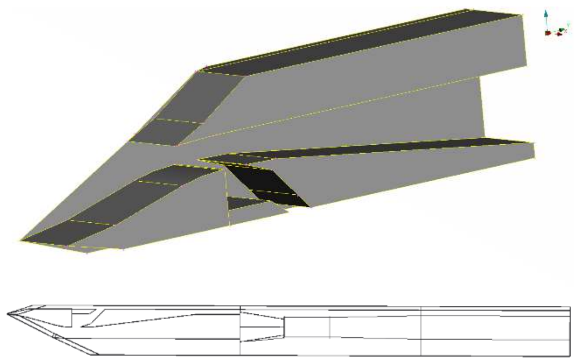


Figure 26: CAD provided by DLR for the WP3 computation (open bleed case).

The CAD extension down to the throttling device (plug) has been provided as an option so that throattling 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 measurements will be provided shortly by DLR to all members.
Computations efforts will be focused on RANS approach with same turbulence models effects as those proposed in WP2 as well assessing adaptive grid refinement improvements.

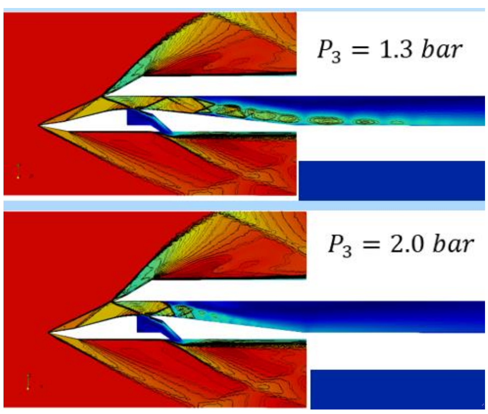


Figure 27: Characteristic curves at Mach 3.0 using CEDRE code.

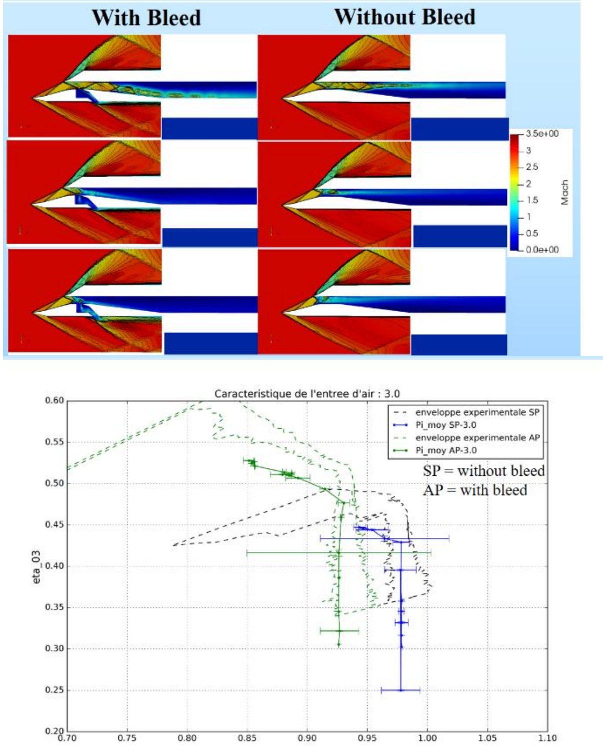


Figure 28: Fig.15 Preliminary investigation of internal bleed effect at Mach 3.0, using CEDRE code with k-omega SST turbulence model.

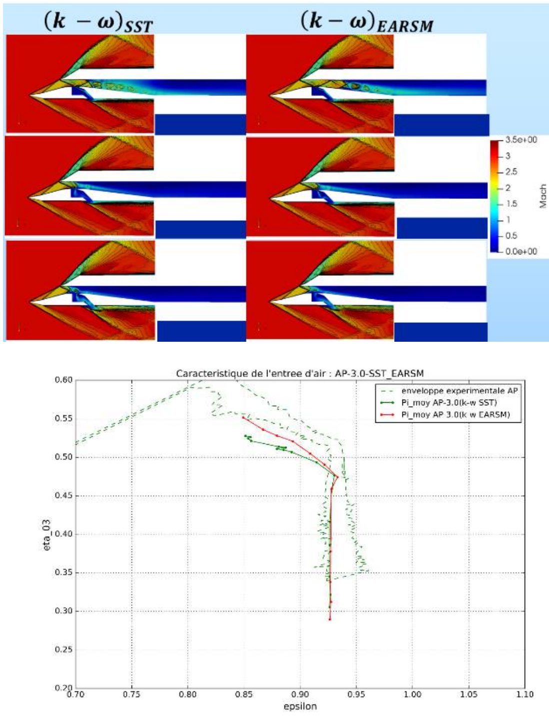


Figure 29: Preliminary investigation of turbulence model effect at Mach 3.0, using CEDRE code with k-omega SST turbulence model vs EARSM

WP4: Mach 7 scramjet intake

The proposed test-case is illustrated on the Figure 30.

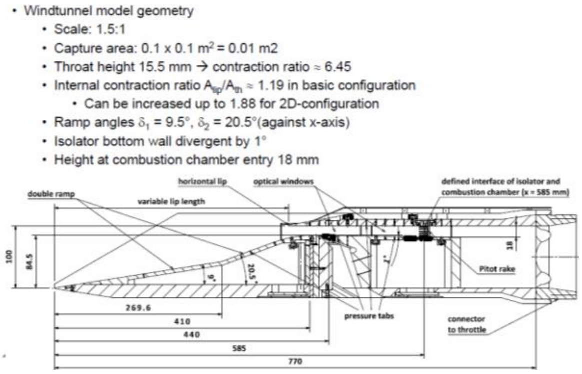


Figure 30: DLR experimental model for the scramjet Mach 7 intake.

One topic for WP4 will be the aerothermal fluxes prediction and effects of sidewalls compression, see some examples of experimental results on Figure 31.

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 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).

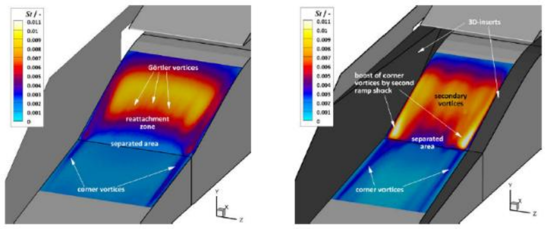


Figure 31: DLR experiments on the scramjet intakes, with IR thermography. Effect of sidewalls compression on heat fluxes and corner flow.

The CAD, ready to mesh, provided by DLR is presented on the Figure 32. The exit plan is located downstream the isolator Pitot rake.

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

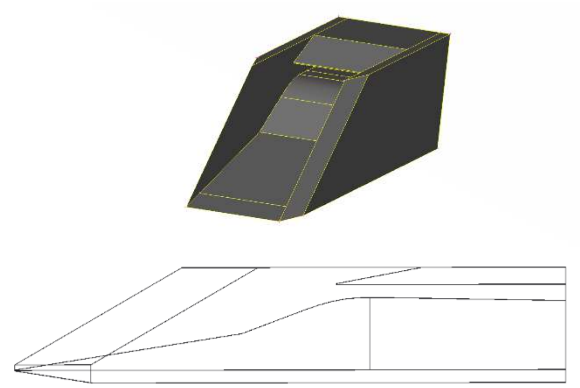


Figure 32: CAD provided by DLR for the WP4 computation (closed bleed case).

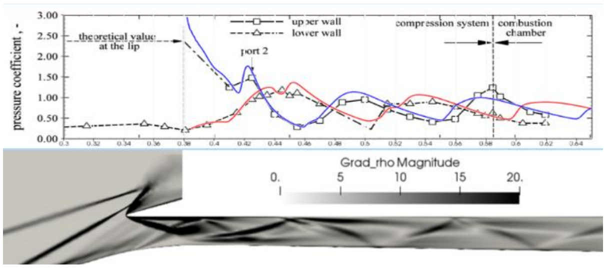


Figure 33: Preliminary computation, using CEDRE code.

- **Expected results/benefits**

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

- **AD/AG-58 membership**

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AD/AG-59	Improving the simulation of laminar separation bubbles
Monitoring Responsable:	G. Mingione CIRA
Chairman:	P. Catalano CIRA

- **Activity concluded**

See report GARTEUR TP–198 (Open).

- **Synthesis**

The main goal of the action group has been to improve the modelling of the numerical methods used in the reproduction of the laminar separation bubbles. Incompressible flows in a wide range of Reynolds numbers have been analysed. An investigation of the main issues that flows at low Reynolds numbers could present in transonic conditions has also been performed.

The focus is placed on the methods based on the Reynolds Averaged Navier-Stokes (RANS) equations. A crucial point in applying the RANS approach is the turbulence modelling. The most critical issues to be addressed are the determination of the transition location and the production of the turbulent kinetic energy. In fact, the presence of separation bubbles means that the separation is laminar and the transition points are very difficult to be set. The turbulence models are instead calibrated for separation in the turbulent flow regime, and need the transition points to be known "a priori". The other critical point is represented by the levels of turbulence inside the recirculation region of the bubble. A proper modelling of the production of the turbulent kinetic energy inside the recirculation region of the bubble should ensure a better reproduction of the pressure recovery and of the bubble length.

Common test cases have been performed by AG-59 participants and the comparison of the different methods and models has allowed to individuate the advices for the numerical simulation of the laminar separation bubbles. The quantities of interest are:

- The determination of the transition location;
- 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 for the treatment of laminar separation bubbles.

The attention of the AG has been also devoted to low-Reynolds number flows in transonic regime. These flows have an unusual specification that could occur in non-Earth (i.e. Martian) atmosphere. The execution of a common test-case with available models has allowed for the assessment of the current methods and for the individuation of the main issues to be addressed for this kind of flows.

Boundary layer instability analysis tools have also been compared with the RANS results to ascertain deficiencies of the turbulent onset point; moreover, the RANS embedded turbulence/transition models have also provided significant insight into the efficacy of the boundary-layer instability and hence transition criteria.

The importance of employing turbulence models making use of transition functions (γ, and/or $Re\Theta$) has been highlighted. Interesting approaches based on functions for the boost of the turbulent kinetic energy have been proposed. Good results have been achieved by employing the Spalart-Allmaras model with transition functions, especially the version modified for decreasing the destruction term of the model. This has as a consequence the enhancement of the skin friction levels in the recovery region of the flow. The same effect can be obtained by a function that multiplies the production term of the kinetic turbulence equation as shown by the $\kappa - \omega$ LSST model.

A function for the boost of the turbulent kinetic energy has also been coupled to the transition $\kappa - \omega$ SST model retrieving the beneficial effect of a transition function and, at the same time, ensuring the enhancement of the friction levels. These remarks apply to the laminar bubbles analysed at low Reynolds numbers. At high Reynolds number the use of transition functions has allowed to obtain satisfactory results in good agreement with the experimental data.

The study of laminar separation bubbles in the compressible regime has evidenced the same issues encountered by the numerical methods for incompressible flows. In fact, the main troubles are related to the reproduction of the bubbles and of separated regions. The Mach number does not critically influence the flow field. It seems, on the contrary, that the increase of Mach energizes the flow that is more able to withstand with the adverse pressure gradients and becomes less prone to the separation. It is worth noting that this regime is of particular interest for the flight in the Martian atmosphere whose conditions of low pressure, density, and temperatures produce flight conditions characterized by very low Reynolds numbers, about 2% of those on the Earth, in combination with high

Mach numbers, about 1.5 times higher than the terrestrial ones.

A further work package has been devoted to explore the use of instability analysis methods for pressure-induced laminar separation bubbles and to assess their capability for predicting the transition. The methods have been applied to two airfoils also in the turbulent flow region. LES data has been used as basic flow. It has been shown that the PSE methodology is well suited for the linear stability analysis of convectively unstable LSBs. The N-factor envelope curves by PSE well compare with the more expensive AHLNS ones. The N-factor based prediction of the transition is consistent with the field of the turbulent kinetic energy coming from the large eddy simulations. All traced modes reach a maximum close to the reattachment point (averaged in time and space) and tend to become neutrally stable downstream.

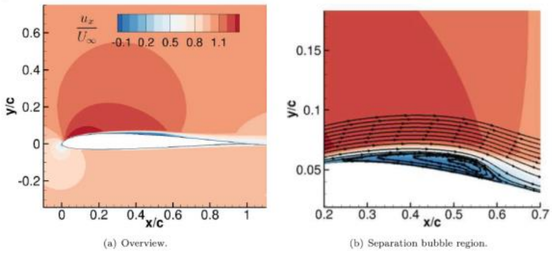

Figure 34: Basic flow around the SD7003 airfoil for M = 0.10, Re = 60,000 and α = 4.0°

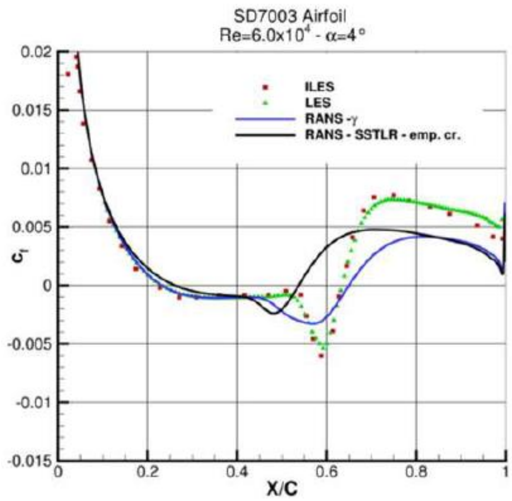

Figure 35: Skin friction coefficients for the SD7003 airfoil for M = 0.10, Re = 60,000 and α = 4.0°

- **AD/AG-59 membership**

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A. Marouf	Uni. Strasbourg	
M. Righi	Uni. Strasbourg	

AD/AG-60	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

- **Activity concluded**

See report GARTEUR TP–202 (Open).

- **Synthesis**

The GARTEUR AD/AG60 explored the application of machine learning (ML) and data-driven methodologies for aerodynamic analysis and uncertainty quantification. Key findings demonstrated the effectiveness of advanced ML models, such as Multi-layer Perceptrons, Graph Neural Networks, and Autoencoders, in predicting aerodynamic behaviors, particularly under nonlinear conditions like shock waves and flow separation. These models showed significant potential for industrial applications, with approaches like Proper Orthogonal Decomposition (POD) and Isomap providing efficient reduced-order representations. Additionally, data fusion techniques integrating multi-fidelity datasets from CFD, wind tunnel tests, and other sources proved valuable for synthesizing diverse information into consistent aerodynamic predictions. Uncertainty quantification methods highlighted challenges in handling incomplete datasets, successfully addressing these through innovative multi-fidelity and adaptive modeling approaches.

The conclusions emphasize the scalability of these methodologies for industrial configurations, such as the Airbus XRF1, demonstrating reduced computational costs while maintaining accuracy. Techniques like physics-based regularization and Physics-Informed Neural Networks (PINNs) were identified as critical for improving generalization and reducing data requirements. Adaptive learning and incremental model refinement emerged as promising strategies for optimizing surrogate models in complex aerodynamic scenarios. Future research will focus on enhancing robustness, particularly in highly nonlinear regimes, and integrating uncertainty management for broader industrial adoption.

Overall, the findings underscore the transformative potential of ML and data-driven approaches in aerospace design, offering scalable, efficient, and accurate solutions for aerodynamic analysis and optimization. These advancements pave the way for more effective integration of computational and experimental data in the design and evaluation of next-generation aerospace systems.

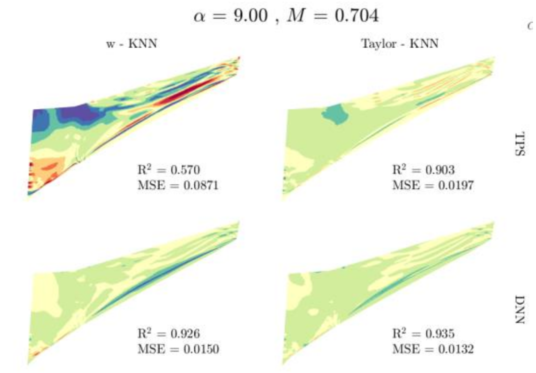

Figure 36: INTA results, cp prediction using Isomap+DNN

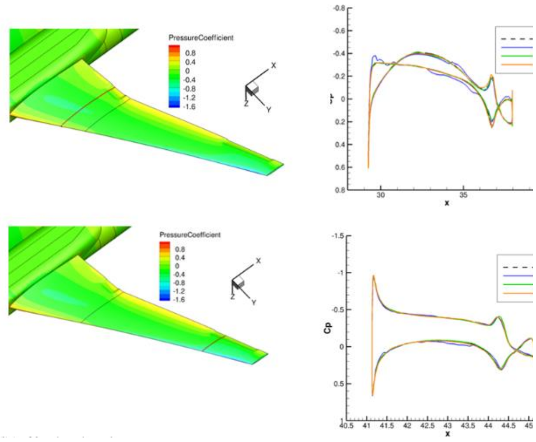

Figure 37: DLR results, cp prediction comparison of PODi, GNSR and DNNN methods

- **AD/AG-60 membership**

Member	Organisation	E-mail
Robert Maas	NLR	
Jacques Peter	ONERA	
Matthias De Lozzo	IRT	
Anne Gazaix	IRT	
Angelo Iollo	INRIA	
Domenico Quagliarella	CIRA	d.quagliarella@cira.it
Pietro Catalano	CIRA	p.catalano@cira.it
Mattia Barbarino	CIRA	m.barbarino@cira.it
Haysam Telib	OPTIMAD	
Alessandro Alaia	OPTIMAD	
Angela Scardigli	OPTIMAD	

Philipp Bekemeyer	DLR	
Olivier Amoignon	FOI	
Boban Pavlovic	FOI	
Sergio de Lucas Bodas	Airbus Military	
Daniel González	Airbus Miltary	
Daniel Redondo	AIRBUS	
Marta Gonzalez	AIRBUS	
Blanca Martinez	AIRBUS	
Esther Andrés	INTA	
Andrea Ianiro	UCM3M	
Stefano Discetti	UCM3M	

AD/AG-61 Hybrid RANS/LES methods for WMLES and Embedded LES

Monitoring Responsable: J.-L. Hantrais-Gervois ONERA

Chairpersons: N. Renard ONERA

- **Objectives**

RANS CFD has shown many merits but fails to model turbulence in adverse-pressure-gradient boundary layers and in separated flows. Turbulent scale-resolving simulations are needed, but DNS and wall resolved LES are not affordable yet for industrial daily needs.
Thus, this group investigates the hybrid RANS-LES strategies. In order to extend previous activities (see AD/AG-54 for instance), family II strategies are of interest (where only the inner part of the attached boundary layer is modelled in RANS whereas the outer region of the boundary layer is resolved by LES). Such strategies belong to the more general Wall-Modelled LES approaches. A substantial cost reduction is gained (over wall resolved LES) and improved turbulent dynamics is simulated (over DES-like, or family I simulations where the attached boundary layer is treated fully in RANS). The use of LES can thus be restricted to the regions of interest in a so called embedded LES strategy.
The activities of the group aim at facilitating the introduction of family II in industry. The several turbulent relative topics are investigated through 4 test cases.

- **Main achievements**

The following four test cases serve the modelling development and validation objectives:

- Test case 1: Mixing co-flow of wake and Boundary Layer;
- Test case 2: Shock Wave-Boundary Layer Interaction;
- Test case 3: Shallow flow separation from a smooth surface;
- Test case 4: Fundamental WMLES test case – ZPG flat-plate boundary layer.

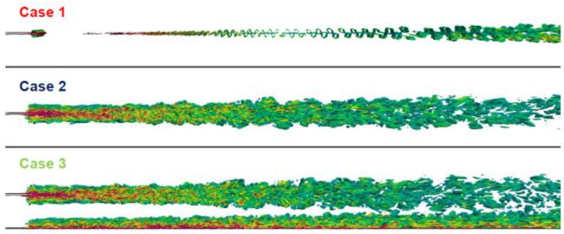

Figure 38: TC1 mixing co-flow (SAAB)

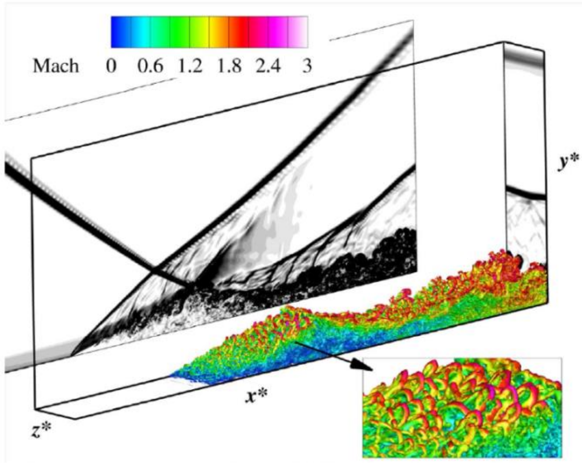

Figure 39: TC2 shock / BL (ONERA)

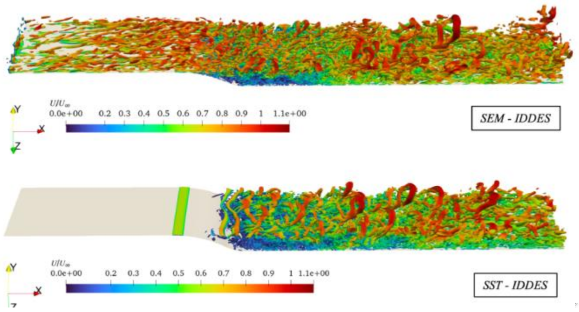

Figure 40: TC3 shallow separation (UNIMAN)

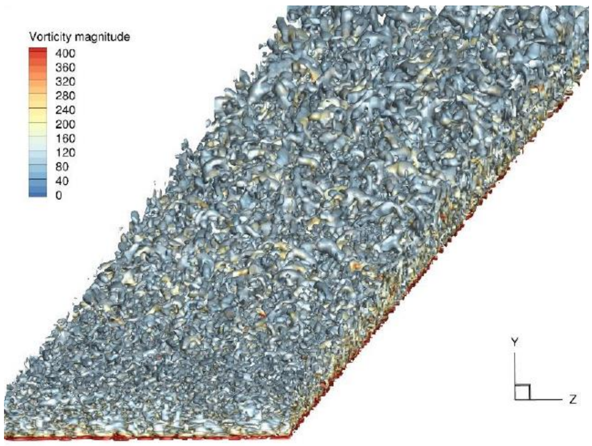

Figure 41: TC4 flat plate (NLR)

- **Management issues**

The group is active since April 2022 (distance kick off meeting) and a distance progress meeting has

been held in February 2023. Due to the COVID crisis, the kick-off foreseen in 2021 had been delayed to 2022. The end date was initially planned at the end of 2024 and a 1-year extension to end 2025 has been granted (at constant budget). Following the departure of S.-H. Peng from FOI without replacement, S. Rezaeiravesh (UniMan) has accepted to become the new co-chairman of the group. An in-person progress meeting has been hosted by UniMan on April 17-18, 2024 in Manchester, which has enabled fruitful discussions. The next in-person meeting will be hosted by CIRA in spring / summer 2025 (the exact time slot is under discussion).
Some encouraging results are already available and the group is well organised to work actively.
Because of the delay in the group progression, there is a need to extend AG61 to the end of 2026.

- **Expected results/benefits**

Thanks to the simulations and comparisons between the partners, the group aims at achieving progresses in:

- resolved turbulence injection prediction of mild flow separation;
- improved accuracy in shock wave / boundary layer interaction (for supersonic and transonic flows);
- prediction of wall pressure fluctuations for acoustics (RANS region permeable to fluctuations);
- applicability (and robustness) to multi-domain and curvilinear geometries;
- interaction between modelled and resolved turbulence;
- mitigation of the log layer mismatch.

- **AD/AG-61 membership**

Member	Organisation	E-mail
Nicolas Renard (c)	ONERA	nicolas.renard@onera.fr
Sébastien Deck	ONERA	sebastien.deck@onera.fr
Yannick Hoarau	Université de Strasbourg	hoarau@unistra.fr
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Magnus Tormalm (observer)	FOI	magnus.tormalm@foi.se
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Pietro Catalano	CIRA	p.catalano@cira.it

Appendix B: Annex GoR-Aviation Security (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, industries and other relevant European Entities (e.g. National Civil Aviation Authority, MoD, Military entities, etc.) involved in security for aviation through collaborative research activities, and through identification of future projects for collaborative research.

The GoR-AS initiates, organises and performs research on detection and mitigation of unlawful interferences against aviation. Both physical and digital interferences are considered. Topics such as Cybersecurity, Unauthorized drones, Laser Dazzling, Chemical, Biological & Explosive detection are addressed by the GoR.

GoR-AS Overview

GoR-AS Activities

Two high priority research topics were identified a few years ago following discussions with various industrial, institutional and academic stakeholders. GoR-AS is focusing on the investigation of these two topics:

- detection and mitigation of unauthorized drones,
- assessment of security risks caused by AI in Aviation.

Unauthorized Drones

Since the end of European ASPRID (Airport System Protection from Intruding Drones) project and AG-AS-1, ONERA, INTA and CIRA have kept on collaborating on this topic. In 2024, four scientific publications were written in order to disseminate the new results obtained on this topic.

In 2024, the group investigated drone attacks in a large geographical area managed by a U-space service provider. In Europe, the U-space framework is designed to safely manage low-altitude traffic, particularly drone activities. While most aircraft are expected to be authorized and cooperative, U-space must also address unauthorized, non-cooperative, or malicious aircraft to protect persons and goods on the ground as well as other aircraft in the airspace. The management of all the risks potentially caused by drones is essential to achieve the safety and security objectives of U-space in regard to the drone ecosystem. This requires the exploration of technical feasibility for managing non-cooperative drones and the analysis of their impact on the current U-space system services. In 2024, the group proposed a preliminary concept for improving the safety and the security of a U-space system by means of a novel service, named DARS (Drone Attack Resilience Service). The service explicitly would be based on resilience-driven features and would be powered by artificial-intelligence capabilities. The preliminary concept was investigated in terms of U-space impacts, context and functional architecture.

In 2024 the group also investigated threat scenarios that combine drone physical intrusion with cyber-attacks on U-space services. Two challenging scenarios that combine drone intrusion with cyber-attacks on U-space remote identification messages were considered: simultaneous emission of multiple false remote identification messages in order to hide drone intrusions, replay of previously recorded messages in order to help a drone to masquerade as a legitimate emergency helicopter. These scenarios highlight the need to enhance current defence strategies against drone intrusions in order to deal with cyber-attacks.

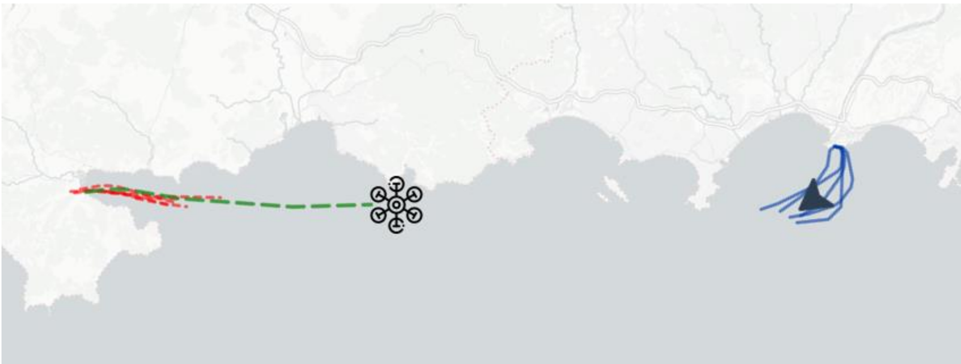

Illustration of cybersecurity attack on U-space Remote Identification Service

In 2024, the group started to investigate attacks performed by drone teams and swarms. An enhanced version of the SESAR Security Risk Assessment Methodology (SecRAM) was used to assess the risk linked with a network of multiple drones performing a monitoring operation. The same methodology was also used in order to automatically investigate the threat scenarios associated with U-space services.

This topic was discussed by researchers of CIRA, INTA, ONERA and University of Campania (I), University of Salerno (I) as well as members of Eurocontrol Civilian/Military coordination team (EU), ENAC (I), SmartTesting (F) and FEMTO-ST (F). A new SESAR proposal on this topic could be submitted by the GoR members in 2025.

AI and Aviation Security

AI Assistant cybersecurity is another topic that GoR-AS continued to explore in 2024. Members of the GoR as well as members of other GoR are investigating the use of digital assistant based on Machine Learning in various domains of aviation. For instance, AI assistant was developed to help Air-Traffic controllers detect and correct aircraft trajectory conflicts. AI assistant should also be hosted on-board the aircraft in order, for instance, to detect unstabilized approach. FM/AG-20 is investigating the use of AI techniques for flight control fault detection.

Due to the role played by AI assistants in safety critical tasks, their safety and certification are extensively investigated by EASA as well as the industrial and academic community. EASA AI Roadmap[2] recognizes the important role of cybersecurity but it provides by now limited guidance on this topic. ENISA, the European agency in charge of cybersecurity has investigated generic cyber-threats against Machine Learning[3] but the relevance of these threats to AI Assistants in the Aviation remains to be established.

In 2024, the group identified that AI Digital Assistants could also help perform cybersecurity risk assessment. The Digital Assistant could monitor the quickly evolving cybersecurity threat landscape and continuously update the risk assessment when important new threats appear. The Digital Assistant might also contribute to the design of the protection architecture by helping the designer to select the most relevant and robust security mechanisms.

The AI Assistant cybersecurity topic was discussed by researchers of CIRA, DLR, ONERA, TUM (D), RISE (S) and industrial partners Collins (I) and Leonardo (I).

Management

Bi-Monthly virtual meetings were organized to explore the GoR Aviation Security research topics. A face-to-face meeting was organised on November, 14 2024 at CIRA facilities in Capua.

Dissemination of GARTEUR activities and results

The main dissemination event during 2024 was the organisation of a special session on "Innovative Security Concepts and Applications in Aerospace Systems" during the second IEEE International TechDefense[4] Workshop in Naples on November 11-13, 2024. Several papers related with GARTEUR Aviation Security were written and presented during this workshop.

On November 4th, D. Pascarella from CIRA participated to Eurocontrol High-Level Workshop on the Current State of Counter Unmanned Aerial Systems (C-UAS)[5] and presented the results of GoR AS on this topic.

Documentation issued

Four scientific papers were prepared in 2024 by members of the AS GoR and presented at the TechDef conference.

D. Pascarella et al., "A Preliminary Concept for a Resilience Service to Manage Drone Cyber-Physical Attacks," 2024 IEEE International Workshop on Technologies for Defense and Security (TechDefense), Naples, Italy, 2024, pp. 351-356, doi: 10.1109/TechDefense63521.2024.10863264.

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[2] EASA AI Roadmap 2.0, https://www.easa.europa.eu/en/downloads/137919/en
[3] AI Cybersecurity Challenges, https://www.enisa.europa.eu/publications/artificial-intelligence-cybersecurity-challenges/@@download/fullReport
[4] https://techdefense.org/techdefense2024/
[5] https://www.eurocontrol.int/event/high-level-workshop-current-state-counter-uas-systems

P. Bieber and T. Dubot, "Drone Intrusions in U-Space: Risk Analysis and Modeling of Cyber-Physical Attacks," 2024 IEEE International Workshop on Technologies for Defense and Security (TechDefense), Naples, Italy, 2024, pp. 334-339, doi: 10.1109/TechDefense63521.2024.10863471.

R. Elia, M. Rak and D. Pascarella, "Preliminary Concept Design of an Ontology for the Security Risk Assessment of U-Space Solutions," 2024 IEEE International Workshop on Technologies for Defense and Security (TechDefense), Naples, Italy, 2024, pp. 340-345, doi: 10.1109/TechDefense63521.2024.10863476.

G. P. Rimoli, M. Ficco, D. Pascarella and V. U. Castrillo, "Security Assessment of Drone Teams and Swarms Using an Extended SecRAM Methodology," 2024 IEEE International Workshop on Technologies for Defense and Security (TechDefense), Naples, Italy, 2024, pp. 328-333, doi: 10.1109/TechDefense63521.2024.10863721.

Status of Action Group

One original aspect of Aviation Security is that new threats are constantly emerging. Knowing threats that are applicable to the Aviation domain is a prerequisite for almost all the research performed in the Aviation Security domain. GARTEUR AS-GoR is a good forum in order to identify and assess threats to Aviation Security.

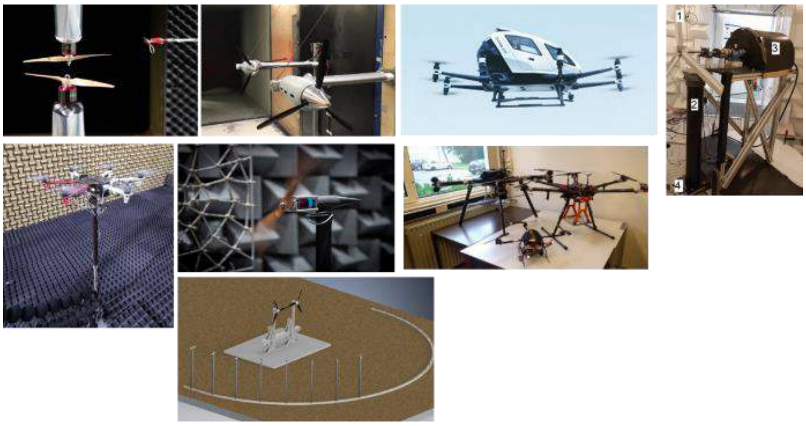
AS-GoR plans to organize in 2024-25 several workshops about new threats to Aviation Security. The aim of this workshop is to produce an up-to-date threat landscape that could foster further research projects.

Prior to a workshop, AS-GoR members will compile a list of potential generic threats extracted from the scientific literature. The workshop will gather experts from AS-GoR as well as invited attendees from industry and academia, they will assess the generic threats. In particular, they will identify the generic threats that are applicable to the Aviation domain. They will also evaluate the impact of the threats on the Aviation domain. The conclusions of the workshop will be published as a GARTEUR paper in order to disseminate broadly the produced Threat Landscape.

The various papers presented by the GoR members as well as other organisations during the 2024 IEEE TechDef workshop special session provided a lot of interesting contributions in terms of threat assessments. It would be interesting to organize another similar session in future editions of this workshop or similar conferences.

Appendix C: Annex GoR-Rotorcraft (RC)

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "ROTORCRAFT"



Experimental tests in RC/AG-26

Remit

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

The GoR-RC initiates, organises and monitors basic and applied, computational and experimental multidisciplinary research in the context of application to rotorcraft vehicles (helicopters and VTOL aircraft such as tilt rotors, compounds, multi-copters) 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, UAM eVTOLs, advanced technologies for surveillance, rescue and recovery;
    - flight mechanics, flight procedures, human factors, new commands and control technologies;
    - increase crashworthiness, ballistic protection, …;

- integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations);
- tackle environmental and public acceptance issues:
    - greening, pollution;
    - visual pollution (for UAM applications);
    - 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, tiltrotor, compound and multi-copter 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-RC, wherever practicable, informs, seeks specialist advice and participation where appropriate, and interacts with activities in other GARTEUR Groups of Responsables.

GoR-RC Overview

GoR Activities

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

This membership enables the GoR to act as a highly effective forum in its primary function of promoting collaborative research through Exploratory Groups and Action Groups. It has been successful in establishing collaborative research programmes, at a non-competitive level, to the benefit of the European rotorcraft community, including both governmental and industrial interests. In addition, the 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 GoR-RC is a kernel for ideas for new research projects and supports the preparation of several EU proposals, despite in the last few years no project dedicated to rotorcraft has been funded by Clean Aviation. The GoR-RC is concerned by the fact that rotorcraft topics are not included in the working program for Clean Aviation and that opportunities of a European project dedicated to rotorcraft in Horizon Europe are limited.

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

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

Finally, the GoR-RC 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 was transferred to Mark White (Univ. Liverpool) in 2024 with the role of Vice Chairman transferring to Arnaud Le Pape (ONERA). There are two new members in the Rotorcraft GoR, Dr Florent DeHaeze (Leonardo Helicopters, UK) and Professor Alvaro Cuerva (Universidad Politécnica de Madrid, Spain).

Generally speaking, the rotorcraft community in Europe is rather small. Indeed, 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 were active in Calls for Proposals. In the view of the RC-GoR, this aspect is advantageous for all, GARTEUR and EU, industry and research establishments. In practice, the 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 RC-GoR held two meetings:

- 89th GoR Meeting: 13th – 14th February 2024, at ONERA, Palaiseau (F);
- 90th GoR Meeting: 9th October 2024, Online

The main business of the meetings was to discuss 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) and the Asian/Australian Rotorcraft Forum (ARF) was harmonized and supported.

In the year 2024 two Action Groups and one Exploratory Group were active.

Dissemination of GARTEUR activities and results

Results coming from AGs are traditionally prone to publication either in Journals or in Conferences. In the field of Rotorcraft, the two conferences having the greatest impact are the ERF and the Annual Forum of the VFS.

Documentation issued

Reports

- F. De Gregorio; J. Yin, K-S. Rossignol; A. Zanotti; S. Luesutthiviboon, “Matrix on common numerical simulation”, RC-AG26 Delivery (Updated Version)
- F. De Gregorio, Manuel Keßler, A. Zanotti, B. COTTÉ, S. Luesutthiviboon, K-S. Rossignol, J. Yin, “Specifications on common simulation”, RC-AG26 Delivery (Updated Version)
- M. Muth, “CFD Best practice GARTEUR RC-AG 26 numerical setups”, AG26 Delivery
- Y. Beausse, B. Cotté, “Report on the wooden DLR propeller test”, AG26 Delivery
- G. Qiao, G Barakos, “CIRA-Cusano configurations”, RC-AG26 Delivery

Theses

- Manuel Iannotta, “Improvement of a Free-wake Model for the Analysis of a Small-scale Two-bladed Propeller in Hover with Manufacturing-produced Dissimilarities in the Blade Geometries,” Politecnico di Milano, Dec. 2024
- Technische Universität München: Tonal Noise Prediction for the 2-bladed Accid 13x7 Propeller
- Florian Fausel, “Aerodynamic and acoustic investigations of the influence of phase shift on rotors as part of the GARTEUR project”, University of Stuttgart, 2024
- A. Cavalli, “Mid-fidelity numerical approach to aeroacoustic investigation of side-by-side propellers in hover” POLIMI M.Sc Thesis
- Chambergo Venegas, Jose Carlos, “Numerical investigation of noise radiation from a 2-bladed propeller”. (Term paper) in Master of Aerospace at SOED, TUM, 2024.
- Villasante, Jaime Manjon, “Numerical flow simulation and noise prediction for a 2 bladed propeller in tandem configuration”, MSc thesis in Master of Aerospace at SOED, TUM, 2024

Publications

- Kostek, Anna, Braukmann, Johannes N., Lößle, Felix, Visingardi, Antonio, Boisard, Ronan, Gardner, Anthony D., "Aerodynamic Interactions in Quadcopter Configurations with Vertical Rotor Spacing," READ (Research & Education in Aircraft Design) 2024, Warsaw (PL), 6-8 Nov. 2024, - (RC/AG-25);

- Anna A. Kostek, Johannes N. Braukmann, Felix Lößle, Sebastian Miesner, Antonio Visingardi, Ronan Boisard, Vasilis Riziotis, Manuel Keßler, Anthony D. Gardner, "Experimental Investigation of Quadrotor Aerodynamics with Computational Cross-Validation," Journal of the American Helicopter Society, 69, 022009 (2024), DOI: 10.4050/JAHS.69.022009, - (RC/AG-25);

- Iannotta, M., Visingardi, A., Quagliarella D., De Gregorio, F., Barbarino, M., Zanotti, A., "Improvement of a Free-wake Model by using PIV Measurements for the Analysis of a Small-scale Propeller with Dissimilar Blade Geometries," AIVELA XXXII National Meeting, Forlì (I), 19-20 Dec. 2024, - (RC/AG-26);

- Yin, J., De Gregorio, F., Rossignol, K.S., Rottmann, L., Ceglia, G., Reboul, G., Barakos, G., Qiao, G., Muth, M., Kessler, M., Visingardi, A., Barbarino, M., Petrosino, F., Zanotti, A., Oberti, N., Savino, A., Bernardini, G., Poggi, C., Abergo, L., Caccia, F., Guardone, A., Testa, C., Zaghi, S., "Acoustic and aerodynamic evaluation of DLR small-scale rotor configurations within GARTEUR AG26," CEAS Aeronautical Journal, Oct. 2024, https://doi.org/10.1007/s13272-024-00790-2,- (RC/AG-26);

- Antonio Visingardi, Mattia Barbarino, Fabrizio De Gregorio, Luca Greco, Claudio Testa, Stefano Zaghi, Jianping Yin, Gabriel Reboul, Andrea Cavalli, Daniele Granata, Luca Abergo, Alberto Guardone, Alex Zanotti, Giovanni Bernardini, Caterina Poggi, Paolo Candeloro, Tiziano Pagliaroli, George Barakos, Geng Qiao, Florian Fausel, Manuel Keßler, Moritz Muth, "Analysis of the Aeroacoustic Performance of Twin Propellers in Hover by Using the CIRA-CUSANO Test Rig," presented at the 50th European Rotorcraft Forum, Marseille (F), 10-12 Sept. 2024, - (RC/AG-26);

- De Gregorio, F., Candeloro, P., Del Duchetto F., Pagliaroli T., "Experimental Flowfield and Aeroacoustic Investigation of Twin Rotors in Hover Conditions", 50th European Rotorcraft Forum, Marseille, France, 10-12 September, 2024, (RC/AG-26);

- A. Zanotti, D. Granata, A. Savino, F. Caccia, L. Abergo, A. Guardone, J. Yin, R. Wickersheim, M. Kessler, A. Visingardi, M. Barbarino, A. Haas, H.-J. Kaltenbach, G. Reboul, G. Bernardini, C. Poggi, "Acoustic and Aerodynamic Evaluation of POLIMI Tandem Propellers Configurations within GARTEUR AG26," presented at the 50th European Rotorcraft Forum, Marseille (F), 10-12 Sept. 2024, - (RC/AG-26);

- Karl-Stéphane Rossignol, Jianping Yin, Fabrizio De Gregorio, Antonio Visingardi, Giuseppe Ceglia, Mattia Barbarino, Francesco Petrosino, "Aeroacoustics of Small Contra-Rotating Co-

Axial Rotors in Hover and Forward Flight," presented at 30th AIAA/CEAS Aeroacoustics Conference (2024), June 4-7, 2024, Rome, Italy, https://doi.org/10.2514/6.2024-3336, - (RC/AG-26);

- Visingardi Antonio; Barbarino Mattia; Ceglia Giuseppe; De Gregorio Fabrizio; Luca Greco; Claudio Testa; Stefano Zaghi; Paolo Candeloro; Tiziano Pagliaroli; Giovanni Bernardini; Caterina Poggi; Federico Porcacchia, "Aeroacoustic Investigations of a Three-bladed Single- and Twin-propeller Test Rig," presented at the DICUAM 2024 congress, Delft (NL), 20-22 March 2024- (RC/AG-26);

- Alex Zanotti; Daniele Granata; Donato Grassi; Ilaria Savoldi; Luca Riccobene; Alberto Savino "Experimental Aeroacoustics Investigation of Interacting Tandem Propellers in Hover", 30th AIAA/CEAS Aeroacoustics Conference (2024), June 4-7, 2024, Rome, Italy, (RC/AG-26)

- Tiziano Pagliaroli; Paolo Candeloro; Fabio Del Duchetto; Karl-Stéphane Rossignol; Jianping Yin; "Exploring the effects of phase delay on propeller noise: an experimental study in tandem configuration INTER-NOISE and NOISE-CON Congress and Conference Proceedings, INTER-NOISE24, Nantes, France, (RC/AG-26)

- Pagliaroli Tiziano; Candeloro Paolo; Del Duchetto Fabio; Rossignol Karl-Stephane; Yin Jianping "An experimental characterization of phase delay effect on the noise emitted by propellers in tandem configuration", QUIETDRONES 2024, Manchester, 8 - 11 September 2024, (RC/AG-26)

- Fabrizio De Gregorio; Karl-Stephane Rossignol; Karl-Stephane Rossignol; Giuseppe Ceglia; Jianping Yin; "Aerodynamic and acoustic investigations of rotor-rotor wake interaction", 21st International Symposium on Applications of Laser and Imaging Techniques to Fluid Mechanics, Lisbon, Portugal, July 08-11, 2024, (RC/AG-26)

- J., Yin,;"Broadband noise simulation of small coaxial rotor configurations", DGLR STAB-Symposium, 13./14. November 2024, Regensburg

- Daniele Granata, Alberto Savino, Donato Grassi, Luca Riccobene and Alex Zanotti; "Aerodynamic and aeroacoustics investigation of tandem propellers in hover for eVTOL configurations", Aerospace Science and Technology 155 (2024), Available online 16 Nov. 2024, https://doi.org/10.1016/j.ast.2024.109740

- Minervino M. and Tognaccini R. "Aerodynamic force by Lamb vector integrals in unsteady compressible flows", International Journal of Numerical Methods for Heat & Fluid Flow, 34(7): 2654–2687 (2024). DOI: https://doi.org/10.1108/HFF-06-2023-0350. (RC/AG-27)

- Nadal, M., Fournis, C. and Lewis, D. "Unsteady Far-Field Drag Analyses of the ONERA HAD-1 Propeller," AIAA 2024-4345. AIAA Aviation Forum and Ascend 2024. July 2024. (RC/AG-27)

Status of Action Groups and Exploratory Groups

Action groups (AG)

The following Action Groups were active throughout 2024:

RC/AG-26	*Noise Radiation and Propagation for Multirotor System Configurations* The objective is to investigate, both numerically and experimentally, the noise radiation and propagation (installation effect) of multirotor systems and to gain knowledge in the physics of noise generation and near-field noise propagation of multirotor systems under the influence of the installation effects and to establish tools for the noise prediction. 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 AG started in February 2022. Both, a common validation study and a common experiment are foreseen. The common validation study aims at evaluating and improving the prediction accuracy of different simulation methods.
RC/AG-27	*Analysis and Decomposition of the Aerodynamic Force Acting on Rotary Wings* The technology for drag analysis of CFD solutions of fixed wing configurations has reached a mature stage. Conversely, applications in rotary wing aerodynamics are still very limited, if not absent. However, recent progresses obtained in unsteady flow analysis are promising for both parasite force calculations, and thrust extraction. The objective of this AG is to study the application to rotary wings of aerodynamic force analysis and decomposition methods. The kick-off meeting of this AG was held on April 2023.

Exploratory groups (EG)

The following Exploratory Groups were active throughout 2024:

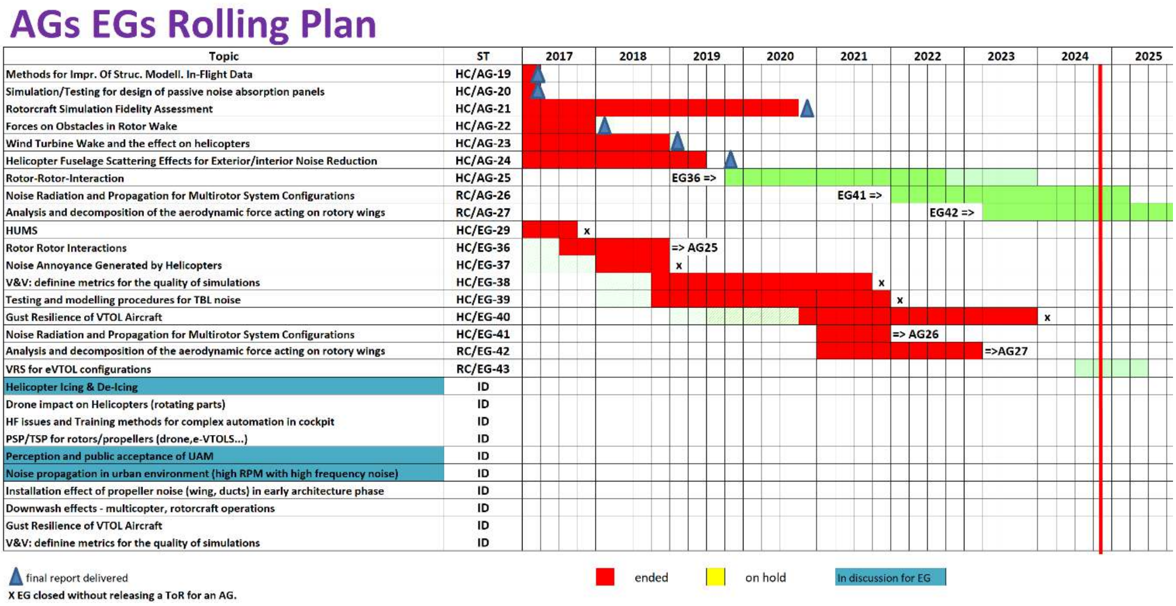
RC/EG-43	*eVTOL aircraft Vortex-Ring-State investigations* The general aim of this Exploratory Group is to investigate the potential impact of the Vortex-Ring-State (VRS) phenomenon on the safety and operational characteristics of new eVTOL aircraft architectures integrating multirotor/propeller systems as well as fixed wings. The main objectives of the future Action Group will be:

- To enrich knowledge on the risk of VRS in general for aircraft with rotating wings and in particular on the new configurations for Advanced Air Mobility, such as UAM aircraft;
- Potentially provide recommendations for the developers of these new configurations and for certification agencies (EASA, DGAC, etc.).

Rolling plan

The 3-to-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 2024 GoR meetings, several topics of mutual interest have been discussed and their potential for GARTEUR collaborative programmes has been examined. Some New Ideas were added, some others were cancelled because of lack of interest or manpower unavailability.



Rolling Plan

GoR membership

Chairperson		
Mark White	Univ. Liverpool	United Kingdom
Vice-Chairperson		
Arnaud Le Pape	ONERA	France
Members		
Antonio Visingardi	CIRA	Italy
Klausdieter Pahlke	DLR	Germany
Barbara Ohlenforst (to mid-2024)	NLR	The Netherlands
Marthijn Tuinstra	NLR	The Netherlands
Arnaud Le Pape	ONERA	France
Alvaro Cuerva	Universidad Politécnica de Madrid	Spain
Industrial Points of Contact		
Rainer Heger	Airbus Helicopters	Germany
Florent DeHaeze	Leonardo Helicopters	United Kingdom
Observer		
Richard Markiewicz	Dstl	United Kingdom

Total yearly costs of AG research programmes

	Person Months	Other Costs (k€)
2015	88.70	103.10
2016	79.50	102.90
2017	55.00	54.00
2018	26.50	20.00
2019	10.00	27.00
2020	22.50	29.10
2021	42.00	64.50
2022	78.00	144.60
2023	62.25	135.10
2024	63.25	140.90
TOTAL	**527.70**	**821.20**

Table of participating organisations

	AG26	AG27	EG43
RESEARCH ESTABLISHMENTS			
CIRA (I)	□		□
CNR-INSEAN (I)	□		
DLR (D)	■		□
DSTL (UK)			
ENSTA Paris (F)	□		
NLR (NL)	□		
ONERA (F)	□	□	■
SOPHRODYNE AEROSPACE			□
INDUSTRIES			
Airbus Helicopters, France			□
Airbus Helicopters, Germany			
CAE (UK)			
IMA Dresden (D)			
Leonardo Helicopters (I, UK)			
LMS (B)			
MICROFLOWN (NL)			
Thales (F)			
VOLOCOPTER (D)			□
ZF Luftfarhttechnik GmbH (D)			
ACADEMIC INSTITUTES			
Institut Superieur de l'Aeronautique et de l'Espace (F)			
National Technical University of Athens (GR)			
Netherland Defence Academy (NL)			
Politecnico di Milano (I)	□	□	□
Politecnico di Torino (I)		□	
Technical University of Delft (NL)	□		□
Technical University of Munich (D)	□		□
Università Telematica Cusano (I)	□		
University of Cranfield (UK)		■	□
University of Glasgow (UK)	□		□
University of Liverpool (UK)			□
University of Nottingham (UK)			□
University of Magdeburg (D)			
University of Napoli Federico II (I)		□	
University of Roma Tre (I)	□		
University of Stuttgart IAG (D)	□		□
University of Twente (NL)			

= Chair □ = Member

Action Group Reports

For further information about GARTEUR please contact:
secretariat@garteur.org or go to **www.garteur.org**

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

HC/AG-26: Noise Radiation and Propagation for Multirotor System Configurations

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

Background

Multirotor propulsion systems are increasingly applied to lift Vertical Take-Off and Landing (VTOL) configurations as well as to small scale drones used for surveillance, monitoring, search, aerial surveying and photography. In recent years multirotor systems have been scaled up and are today typical designs for person carrying eVTOL configurations for Urban Air Mobility. Many different options exist in designing multirotor systems, for example single or co-axial rotors or rotors with ducts as well as the positioning of the propulsion units relatively to each other.

A major concern with drones, and vehicles for Urban Air Mobility in particular, is their noise emission. In order to be publicly accepted, the noise of Urban Air Vehicles must be barely audible compared to the city's background noise. Therefore, Urban Air Vehicles must be designed from the beginning to meet stringent noise standards.

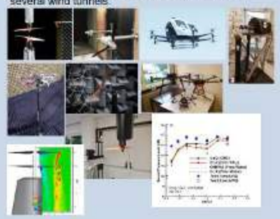
The design of low noise multirotor rotorcraft requires an in depth understanding of the physics related to noise sources, especially multi-interactions and near field sound propagation. Compared to conventional helicopters the importance of the various noise sources and the influence of noise scattering can be totally different. The main noise sources for conventional helicopters are well known, for example blade vortex interaction noise (BVI) in descent flight. But by using distributed single or co-axial rotors, the multiple interactions among rotors and the rotor-wake interactions (Figure 1b) may play an important role in the total noise signal. Ducts, wings or the fuselage may shield or scatter the noise during its propagation. In addition, broadband noise may become a dominant noise source for rotors with low tip Mach number or disturbed rotor inflow.

Programme/Objectives

Objectives

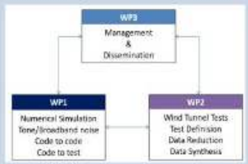
The present research work will investigate noise radiation and propagation (installation effect) of multirotor systems. The objective of the proposed GARTEUR group is therefore to gain knowledge in the physics of noise generation and near-field noise propagation of multirotor systems under the influence of the installation effects and to establish tools for the noise prediction. The focus is put on rotors in steady hover and forward flight but other operating states and configurations could also be considered. The partners will contribute with wind tunnel experiments as well as with numerical simulations. Both, a common validation study and a common experiment are foreseen. The common validation study aims at evaluating and improving the prediction accuracy of different simulation methods.

The data sets for the numerical studies validation will be provided by either existing or new experiments by the partners. The common experiment aims at using the dedicated capabilities of the partner's wind tunnels to improve the validation data base for the simulations and at the same time will validate the experimental accuracy by performing the same experiments in several wind tunnels.



The work programme is structured in three work packages:

- WP 1: Numerical Simulation on the acoustic tone/broadband noise and scattering effect
  - Code adaptation & prediction
  - Code validation & improvement of prediction tools
  - Post-test predictions & code to test comparison
- WP 2: Wind Tunnel Tests & Synthesis
  - Model preparation
  - Test preparation
  - Model setup and installation
  - Test matrix & instrumentation
  - Test conduct
  - Test data compilation & distribution
  - Test data analysis
- WP 3: Management & Dissemination
  - Action group Management
  - Exploitation & Info dissemination



Results

The duration of action group is 3 years and the AG started the activities since February 2022.

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

1. Description on existing test data and numerical tools for proposal on common test and numerical simulation in AG, 2022;
2. Existing test cases as well as common test will be used in the code validations;
3. AG26 common simulations with continuing update according to common test program defined and are under going;
4. Common test for CIRA/DLR defined and test matrix established for CIRA/DLR and tests conducted in Nov. 2022 by CIRA/DLR and the analysis of the test data are under going;
5. Common tests by using DLR und Uni-CUSANO setup and rotors are planned among DLR,Ensta-Paris, ONERA and Uni-CUSANO
6. 2 ERF papers with respect to the common simulation and common test between CIRA/DLR are submitted and under preparation;

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

Francesco Petrosino	CIRA	[illegible]
Jianping Yin	DLR	[illegible]
Benjamin Cotté	ENSTA Paris	[illegible]
Harry Brouwer	NLR	[illegible]
Gabriel Reboul	ONERA	[illegible]
Alex Zanotti	Politecnico di Milano (PoliMi)	[illegible]
Giovanni Bernardini	Roma TRE University (RomaTRE)	[illegible]
Michael Schmähl	TU Munich (TUM), Institute of Aircraft Design (LLS)	[illegible]
Hans-Jakob Kaltenbach	TU Munich (TUM), Flow control and aeroacoustics group (FKA)	[illegible]
Tiziano Pagliaroli	Uni Cusano	[illegible]
Manuel Keßler	Uni Stuttgart, Institute of Aerodynamics and Gas Dynamics (IAG)	[illegible]
George Barakos	School of Engineering, University of Glasgow (UoG)	[illegible]
Daniele Ragni	TU Delft	[illegible]
Claudio Testa	CNR-INM	[illegible]

GARTEUR Responsable:
K. Pahlke DLR

CIRA · Marine Technology Research Institute INSEAN · DLR · ENSTA IP PARIS · NLR · ONERA · Politecnico di Milano · Roma TRE · Technische Universität München · TUM · TU Delft · Università Cusano · University of Glasgow · University of Stuttgart Institute of Aerodynamics and Gas Dynamic

RC/AG-26	"Noise Radiation and Propagation for Multirotor System Configurations"
Monitoring Responsable:	K. Pahlke DLR
Chairman:	J. Yin DLR

- **Objectives**

The present research work will investigate noise radiation and propagation (installation effect) of multirotor systems. The objective of the proposed GARTEUR group is therefore to gain knowledge in the physics of noise generation and near-field noise propagation of multirotor systems under the influence of the installation effects and to establish tools for the noise prediction. The focus is put on rotors in steady hover and forward flight but other operating states and configurations could also be considered. The partners will contribute with wind tunnel experiments as well as with numerical simulations. Both, a common validation study and a common experiment are foreseen. The common validation study aims at evaluating and improving the prediction accuracy of different simulation methods.

The data sets for the numerical studies validation will be provided by either existing or new experiments by the partners. The common experiment aims at using the dedicated capabilities of the partner's wind tunnels to improve the validation data base for the simulations and at the same time will validate the experimental accuracy by performing the same experiments in several wind tunnels.

The main innovation of the AG comprises:

- An experimental data base for multirotor acoustics based on experimental data from the partners;
- improved understanding on multirotor noise emissions by analysis of experimental data and numerical simulations considering effects of interaction tone noise installation effects and broadband noise;
- validated prediction tools for multirotor noise including Assessment of different noise modelling approaches;
- validation of the partner's wind tunnels for experimental investigation of multirotor aerodynamics and acoustics by a common experiment.

- **Activities**

The AG consists of 3 work packages:

WP1: Numerical Simulation on the acoustic tone/broadband noise and scattering effect:

This work package deals with the activities to perform a literature survey for possible existing databases for evaluating and improving partner's numerical tools, to collect available test data from all partners, to conduct pre- & post-test predictions & code to code comparison and to validate the improved numerical tools against the experimental data produced or collected during the project wind tunnel test campaigns.

WP2 – Wind Tunnel Tests:

This work package deals with the performance of individual tests done by each partners and common tests where a common (or partly common) test setup can run in a partner's facility. The common test may also include common test teams involving different partners. The individual tests planned by each partner. The resulting experimental databases are used in WP1 for the final validation of the numerical tools proposed by the partners.

WP2 – Wind Tunnel Test Campaigns:

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 wake 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.

WP3 – Management & Dissemination:

The nature of a GARTEUR project requires a limited, yet necessary effort for a good project development and successful outcome. This work package is focussed on the fulfilment of all the management obligations and it is mainly performed by DLR, with contributions from all participating partners.

- **Results/benefits**

The duration of action group is 3 years and the AG started the activities since February 2022. 4 meetings including three technical review meetings were conducted since the beginning of the action group. The following results were achieved during this period:

1. The description of the AG26-Matrix-Numerical-Common-Simulations was updated;
2. the specifications on common simulations were updated;
3. common tests for CIRA/DLR test campaign on DLR test rig defined, test matrix established and tests conducted;
4. common tests for CIRA/Uni-CUSANO test campaign on CIRA/Uni-CUSANO test rig defined, test matrix established and tests conducted;
5. common tests for PoliMi test campaign on PoliMi test rig defined, test matrix established and tests conducted;
6. 3 ERF papers with respect to the common simulation and common test between CIRA/DLR were produced;
7. 2 more papers were produced concerning the: ENSTA database (Forum Acusticum 2023) and the CIRA/UniCusano database (AIVELA 2023);
8. one thesis was produced by Technical University of Munich regarding DLR test rig.

- **RC/AG-26 membership**

Only point of contact persons are listed here

Member	Organisation	e-mail
F. Petrosino	CIRA	f.petrosino@cira.it
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C. Testa	CNR-INM	Claudio.testa@cnr.it

- **Resources**

Person month resources were confirmed during the kick-off meeting and were tentatively split in years.

Partners	WP1	WP2	WP3	Total
CIRA	6	5	3	14
DLR	9	4	2	15
Ensta-Paris	5	3	1	9
NLR	5	5	1	11
TU Delft	4	6	2	12
ONERA	5	6	1	12
Polimi	7	7	1	15
RomaTre	9	6	1	16
CNR-INM	9	0	1	10
TUM-IAD	3	3	1	7
TUM-SBA	4			4
TUS-IAG	6	1	0	7
UniCusano	5	3	1	9
UoG	5	2	1	8
Total	82	51	16	149

RC/AG-27	**"Analysis and Decomposition of the Aerodynamic Force Acting on Rotary Wings"**
Monitoring Responsable:	A. Visingardi CIRA
Chairman:	D. Sanders (Univ. Cranfield)

- **Objectives**

Far-field methods have been shown to be highly valuable in the performance assessment and design of fixed wing aircraft, by relating phenomenological wake decompositions to aircraft forces, thereby enabling improved accuracy, mitigating uncertainty, and enhancing the understanding of relevant mechanisms. A brief review into rotor aerodynamics has also shown the sensitivity of rotor loadings to wake properties, and much effort has gone into improving the modelling accuracies of wake structures. However, in rotor flows, the wake mechanisms have only been related to the near-field loads implicitly and/or qualitatively. Adapting and improving fixed-wing far-field methods for implementation to rotor aerodynamics, offers the possibility to explicitly relate wake phenomena directly to near-field loads. This would enable enhanced understanding of rotor aerodynamics and provide an aid in mitigating uncertainty and improve modelling accuracy. However, due to the complexities of rotor flows, the adaptation of far-field methods requires incremental steps.

Subsequently, the aim of this project is to lay the foundations for the development of rotor applicable far-field methods, by fully developing the generalised theory and showcasing its potential based on strategic benchmark test cases. To this end, the AG aim at pursuing the following objectives:

1. Develop and generalise the theoretical formulations of thermodynamic, vortical and energy/exergy far-field decomposition methods for unsteady flows and curvilinear non-inertial reference frames;produce standardised numerical and experimental benchmarking cases for testing, validation and comparison of the methods;
3. apply the methods to benchmark test cases and provide a critical analysis along with a projected roadmap and requirements for future development and best practice guidelines.

To enable a stepped approach toward the development and evaluation of the decomposition methods, the consortium has identified two flow scenarios to focus on:

- 2D Pitching and Heaving Aerofoils;
- 3D Rotors in Axial Flight.

- **Activities**

The AG consists of 6 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 – Theoretical Development of Decomposition Methods: is aimed at identifying and providing critical reviews of the state-of-the-art in aerodynamic performance decompositions. The primary outcomes will be to highlight the advantages and disadvantages of each approach, as well as to identifying opportunities for further theoretical development and synergies / unification. The theoretical decomposition formulations need to be developed in a systematic way to be able to account for unsteady, inertial and rotational reference frames.

WP2 – Experimental Datasets of Pitching and Heaving Aerofoils: The first necessary steps to developing decomposition methods appropriate for rotary wings is to consider 2D pitching and heaving aerofoils. This experimental work is required to validate the unsteady CFD with respect to the cartesian unsteady decomposition methods developed in WP1, as well as evaluate the required level of CFD modelling fidelity.

WP3 – Numerical Datasets for Pitching and Heaving Aerofoils: This WP is aimed at providing numerical datasets so that the unsteady extensions to the decomposition formulations (in an inertial reference frame) can be tested and further developed.

WP4 – Numerical Datasets for 3D Rotors in Axial Flight: The aim is to provide numerical datasets from RANS and URANS simulations, through which the decomposition formulations may be tested and examined in WP5, to investigate the implications of the decomposition extension to a rotational reference frame.

WP5 - Application & Evaluation of Decomposition Methods: This WP will review, investigate and trial various post-processing techniques that will enable the implementation of the decomposition Formulations applied to the test cases of (i) pitching heaving aerofoils, (ii) rotor in axial flight. The focus will be on utilising the methods to improve the understanding of fundamental rotary wing aerodynamics.

- **Results/benefits**

The duration of Action Group is 3 years and the AG has started the activities in April 2023.

The first technical review meeting of the AG was held on October 4th 2023. A revision of the WBS was made. In particular:

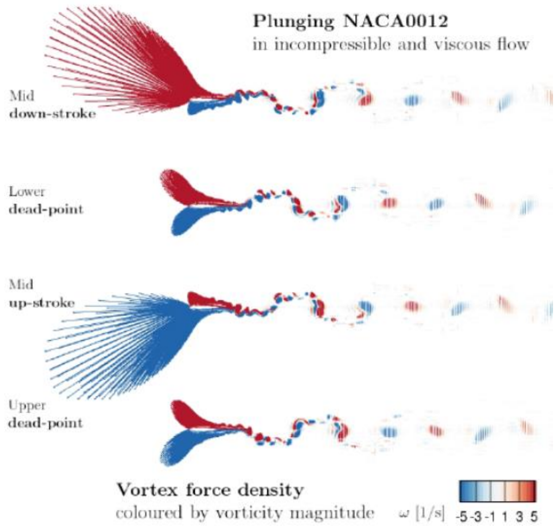
1. the partners agreed that the initial proposed work which included hover and advancing flight cases was too ambitious, and presents risk in spreading resources too thin. These WPs were removed.
2. Focus on propellers in axial flight was included as a new WP4 to replace the initial WP4 & WP5 as a necessary developmental step. There is now a total of 6 WPs.

A second bi-annual technical meeting was held online December 4th 2024.

Towards WP2 deliverables, Cranfield University presented preliminary experimental results obtained from their pitch/heave rig depicted below. The experiments will provide validation datasets for numerical modelling.

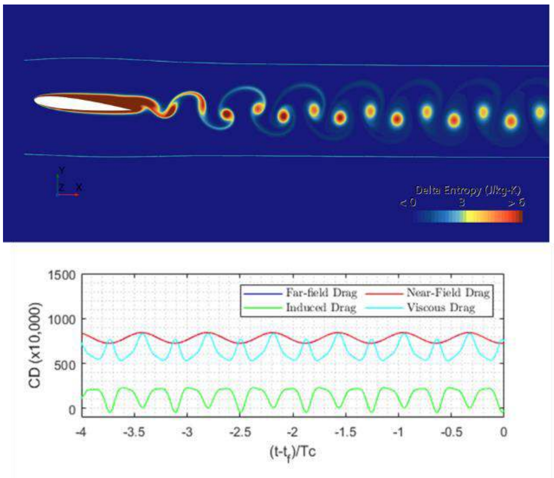
Cranfield University's Pitch/Heave Experimental Rig

In WP3, CIRA/UNINA have produced a number of numerical cases on plunging airfoils to which they applied vortex force decompositions as well as a unified approach to Lamb-vector and thermodynamic methods.



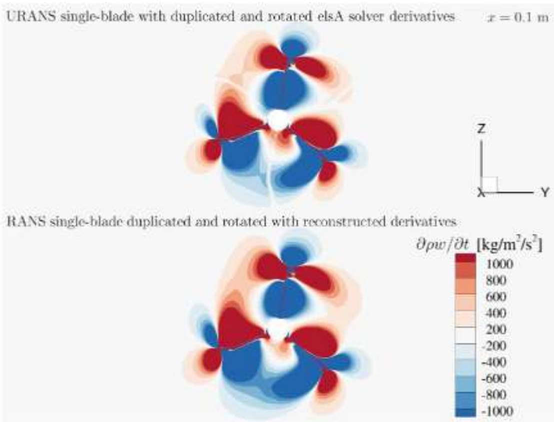
Vortex force density for a NACA0012 in heave motion, indicating the Lamb vector is a major contributor to thrust [Minervino, et al. 2024].

Also in WP3, PoliTo showed results of applying thermodynamic decomposition methods to unsteady vortex shedding cases.



Vortex shedding over a NACA0012, with thermodynamic decomposition method applied.

Towards WP4 deliverables, ONERA presented thermodynamic decompositions applied to simulations of the HAD-1 propeller [Nadal, M. et al., 2024] which is the geometry down-selected for the project. Time derivatives in the inertial frame of reference were reconstructed from RANS simulations in the rotating frame of reference and compared against URANS simulations in the inertial reference frame.



Time derivative reconstruction from RANS simulations in rotating reference frame, compared to time-derivatives computed from URANS in the inertial reference frame [Nadal, M. et al., 2024].

WPs 1 & 6 have seen a number of developments. Cranfield University has extended energy/exergy formulations to unsteady flows. ONERA continue to further develop thermodynamic methods via the Kutta-Joukowski-Maskell-Betz formulation, whilst CIRA/UNIN have achieved a meaningful unification between Lamb Vector and Thermodynamic methods.

- **RC/AG-27 membership**

The partner organisations of AG27 in 2024 include four universities: Cranfield University (UK), Politecnico di Milano (IT), Politecnico di Torino (IT), University of Naples Federico II (IT); two research institutions: ONERA (FR) and CIRA (IT). The members are listed below:

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Drewan Sanders	Cranfield University (Chairman)	d.s.sanders@cranfield.ac.uk
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Renato Tognaccini	UNINA	rtogna@unina.it

- **Resources**

Person month resources are currently being re-evaluated by each partner due to some changes in scope, members and WP structure.

	Year 1			Year 2			Year 3			Total		
Partner	PM	FC	TC	PM	FC	TC	PM	FC	TC	PM	FC	T
CU*	3	0	2	3	6.5	2	4	0	2	10	6.5	
ONERA	3	2	2	3	2	2	3	2	2	9	6	
CIRA-UNINA	3.5	2	2.5	3.5	2	2.5	3.5	2	2.5	10.5	6	7
PoliMi	5	2	2	7	12	2	6.5	4	2	18.5	18	
PoliTo	2	4	1.5	3	6	1.5	2.5	4	1.5	7.5	14	4
Total	**13.75**	**8**	**8**	**16.75**	**25.5**	**8**	**16.5**	**10**	**8**	**47**	**44.5**	**2**

Appendix D: Annex GoR-Structures and Materials (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 the operation costs low, reduce environmental impact, and improve passenger comfort. In many cases the research tasks are strongly interconnected so an optimum design can only be reached through balanced improvements in several fields.

The GoR-SM (Group of Responsables in Structures and Materials) manages and organizes aeronautics-oriented research on several fields like structures (configuration, topology, optimization, etc.), modelling and simulation procedures (strength, fatigue, structural dynamics, etc.), and different type of materials for structural applications.

Materials oriented research is related to material systems primarily for the airframe; it includes specific aspects of polymers, metals including those produced by Additive Manufacturing (AM), and different kinds of composite systems.

Structural research is devoted to computational mechanics, loads, and design methodologies. 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 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 upstream research intended to discover valuable areas of future activity; in this context many new ideas were proposed and explored during the year 2024.

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:

- Additive Layer Manufacturing of metals

- Characterization and Optimization of shock absorbers for civil aircraft fuselages
- Characterization and modelling of Composites with Ceramic Matrix submitted to severe thermo-mechanical loading
- Structural Health Monitoring for hydrogen aircraft tanks
- Multifunctional Metamaterials for Aerospace applications
- Non-traditional laminates

GoR-SM Overview

GoR Activities

The activities within the Action Groups (AGs) cover several aspects of new technologies, new structural concepts and new design and verification criteria.

In 2024 two AGs were active and were devoted to the following topics:

- **Additive layer Manufacturing (SM/AG-36)**

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 guidelines must be considered, and currently available CAD design tools are considered inadequate for designing when AM techniques are used.

At this moment it is still difficult for AM technologies to compete with traditional techniques on reliability and reproducibility, mainly because the quality of the 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 SM/AG-36 (which was launched in 2022) is to build up knowledge and skills in the field of metal AM processes and materials to support the manufacturing industry and increase its competitiveness. The work will more especially focus on novel Aluminium alloy like Scalmaloy and ScanCromal.

There is an increasing need for high strength aluminium alloys that can be processed by AM procedures, for products and applications requiring low weight combined with high specific strengths.

Process optimalisations are investigated for processing by Laser Powder Bed Fusion (LPBF) and Directed Energy Deposition (DED) techniques.

- **Characterization and optimization of shock absorbers for civil aircraft fuselages (SM/AG-37)**

Commonly adopted shock absorbers and, in general, crashworthy structural components, based on sandwich structural concepts and/or complex dumping mechanisms, are, generally, characterized by high volumes and significant additional mass. The main objective of the proposed work consists in the investigation of the feasibility and effectiveness of novel thin Additive Manufactured (AM) hybrid metal/composite lattice structures as lightweight shock absorbing devices for application to structural key components in impact events.

The topics of this AG-37 are:

- Investigation on the key components which require the integration with shock absorber.
- identification and classification of the shock absorbers (material and geometry).
- material investigation (Alternative materials, Hybridization).
- integration strategies.
- analytical methods for designing hybrid shock absorber.
- numerical analysis and design.
- unit cell optimization (weight minimization and/or shock absorbing capability maximization).
- thermal stress analysis.
- experimental tests and validation.
- certification issues.
- definition of guidelines for an effective integration in each scenario.

Management

In 2024, two GoR meetings were held:

1. 82nd GoR SM meeting, on February 14th (online meeting, by 3CX telecom)
2. 83rd GoR SM meeting (in-person meeting at INTA facilities at Torrejón de Ardoz) on September 27th. There was an additional 3CX telecom channel for those partners that couldn't attend in-person.

The measures taken in the past years to revitalize the Structures and Materials group were confirmed:

- Action Group SM/AG-36 progress well with an active collaboration and communication between the participants, and high-quality work is being achieved. During last GoR meeting it was proposed to explore the possibility of preparing a new EG on AM that could continue AG-36 work. The SM GoR thinks the work done in AG-36 is very good, and it should be considered for presenting proposals on European Calls on the topic.

- Regarding SM/AG-37 this first year has been critical in consolidating partners' knowledge of activities related to shock absorption. It is expected that the second year will focus more on numerical activities, with a proposal to increase the frequency of progress meetings to encourage greater collaboration among the various partners. The GoR thinks that the work done in AG-37 is quite promising, and the possibility of presenting proposals on the topic on European Calls should be explored.

- For SM/EG-44, SM/EG-45, and SM/EG48 several meetings were held. The progress and maturity of each EG is different but all of them seem likely to finish proposing new AGs.

Dissemination of GARTEUR activities and results

No presentation was given during 2024, covering specifically the GARTEUR GoR-SM. There was a presentation related to SM/AG-36 activities: a Conference paper plus a presentation, in the "European Conference on Spacecraft Structures Materials and Environmental Testing" (**ECSSMET**) 2024: Processing High-Strength Aluminium Alloy by Directed Energy Deposition, by Maria Montero-Sistiaga (NLR) et al.

Reports issued

No reports were issued in 2024.

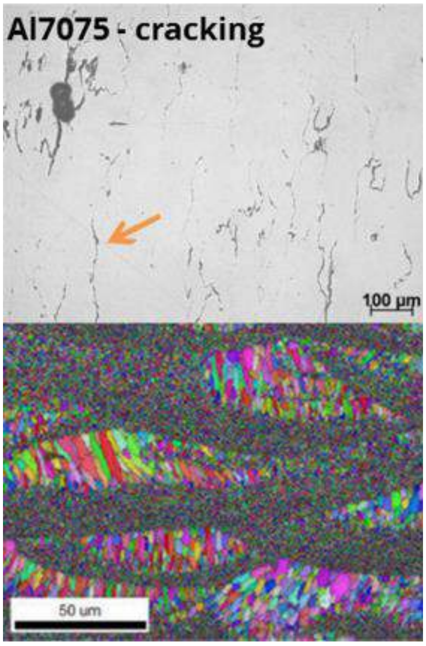
Status of Action Groups and Exploratory Groups

Two Action Groups (AGs) were active in 2024: AG-36, and AG-37.

Three Exploratory Groups (EGs) were active in 2024: EG-45, EG-48, and EG-49.

Action Groups (AG)

SM/AG-36	*Additive layer manufacturing*



Aluminium and its alloys are widely used in the aerospace sector due to their excellent mechanical performance in combination with their light weight. Their strength and low density are the main advantages of these materials. Fabricating components with complex geometries from high strength aluminium alloys by conventional processing techniques is challenging due to their low formability. In contrast, metal Additive Manufacturing (AM) techniques allow the production of near-net-shape and complex parts, adding value to the use of aluminium alloys in the aerospace sector. Even so, not all aluminium alloys are easy to process by AM.

Currently, there are several novel aluminium alloys being investigated for application in AM. Great advancements are being achieved on laser powder bed fusion (L-PBF) and also on directed energy deposition (DED). One of the focus points is to broaden the materials palette towards higher performance aluminium alloys. On one hand, the high-strength 7000 series have been investigated aiming at avoiding solidification cracking during the AM process.

Several works have focused on modifying the composition by additions of Zr, Sc or Si to avoid cracking and improve the mechanical properties. On the other hand, casting aluminium alloys have been widely investigated with addition of nano-/micron-sized particles such as TiB2 or TiC aiming at increased fatigue performance. Examples of these modifications have resulted in commercially available aluminium alloys such as A20X™ developed by Aeromet with Cu and TiB2, or Scalmalloy® developed by Airbus & commercialized by APWorks.

Besides the advancements on alloy development for AM, there is still a big gap with respect to the commercialisation of these novel alloys. Therefore, great efforts should be done to fully characterise these. In addition, aluminium processing is still a big challenge due to the laser related high reflectivity & unstable melting behaviour of the alloy.

Starting from the above considerations, AG-36 was launched in 2022. The AG chairman is Maria Montero from NLR, and the other participants are INTA, ONERA, and AIRBUS.

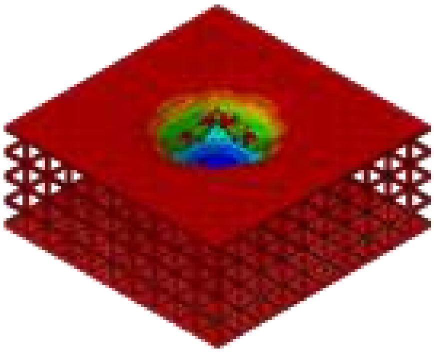
Update on technical progress during 2024:

- Process optimalisations have been carried out for processing high strength aluminium for Laser Powder Bed Fusion (LPBF) and Directed Energy Deposition (DED).
- The Test programme was defined. Test samples were prepared by NLR, and they are tested among the AG-36 partners.
- Several heat treatments were evaluated. The most promising ones have been selected.
- Processing high strength aluminium by DED was very challenging. Several thin walled and cube specimens were made by NLR. Cross sections were made, and porosity levels and surface roughness were determined to select the optimal process parameters.
- Ending of the AG will be extended to Q3/2025, because of some delays during the experimental activities: availability of powder (WP2), and in the selection of the Heat treatment (WP3). Accordingly, some deliverables have been postponed to 2025.
- There is an active collaboration and communication between the participants: high quality work is being achieved.
- During last GoR meeting it is proposed to explore the possibility of preparing a new EG on AM that could continue AG-36 work.
- The SM GoR thinks the work done in AG-36 is very good, and it should be considered for presenting proposals on European Calls on the topic.

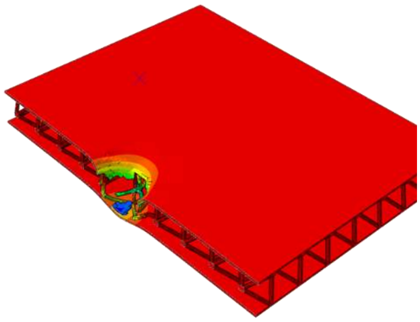
In 2024, there were two progress meetings, both online.

In addition, Maria Montero gave a presentation related to SM/AG-36 activities: a Conference paper plus a presentation, in the "European Conference on Spacecraft Structures Materials and Environmental Testing" (**ECSSMET**) 2024.

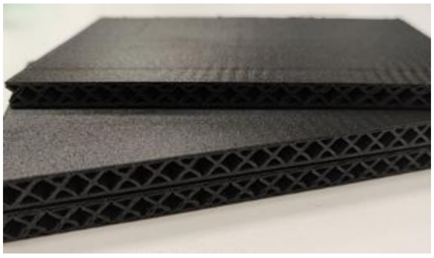
SM/AG-37	*Characterization and optimization of shock absorbers for civil aircraft fuselages*



FEM simulation of a Low velocity impact on a metallic lattice unit cell



FEM simulation of a Low velocity impact on a metallic sandwich panel with lattice core



Composite sandwich panels with lattice core

Commonly adopted shock absorbers and, in general, crashworthy structural components, based on sandwich structural concepts and/or complex dumping mechanisms, are generally characterized by high volumes and significant additional mass.

This research activity is focused on the investigation of the feasibility and effectiveness of novel thin Additive Manufactured (AM) hybrid metal/composite lattice structures as lightweight shock absorbing devices for application to structural key components in impact events.

These hybrid structures would represent a real step beyond the state of the art of shock absorbers being characterized by an AM metal lattice core, able to maximize the absorbed energy by plastic deformations and, at the same time, by a composite skin/cohesive coating, fully integrated with the internal metal lattice structure, able to lower the global weight and increase the stiffness and strength of the shock absorber. The hybrid shock absorbers must be able to reduce the peak acceleration transferred on the main structure, ensuring the integrity of the core structure and, eventually, the safety of the passengers.

Starting from the above considerations, AG-37 was launched at the beginning of 2023. The AG chairman is Andrea Sellitto from University of Campania (UNICAMPANIA), and the other participants are: NLR, DLR, ONERA, CIRA, and CNR (recently incorporated).

In 2024 the following activities were carried out:

- CIRA worked on design and optimization of metallic lattice structures developed using AM technologies. A custom-made numerical tool has been utilized, capable of generating and optimizing axisymmetric hybrid structures composed of metal and composite materials. The design focused on a shock absorber structure with an axial-symmetric architecture. Finite element models (FEM) were generated for simulation, including modal analysis to assess the resonance frequencies and global stiffness of the structure, demonstrating its robustness across different impact conditions.

- UNICAMPANIA focused on the characterization and optimization of hybrid sandwich structures for energy absorption in industrial applications. The structures incorporate metal or polymeric cores created using AM technologies: Fused Filament Fabrication (FFF) and Direct Metal Laser Sintering (DMLS). The outer skins of the sandwich panels are made of Carbon Fibre-Reinforced Composite through co-extrusion processes. Various core solutions were explored, including aluminium-based cores produced through DMLS and polymer-based cores. The study further explored the integration of sandwich panels into pre-existing structures for enhanced energy absorption.

- NLR contribution was focused on composite AM and lattice structure modelling for shock absorbers. It includes an investigation into various materials like nylon and PEEK reinforced with carbon fibre, focusing on different infill strategies for compression tests. Additionally, the modelling and simulation of metal and polymer lattice structures, particularly using ABAQUS and DIGIMAT software, were evaluated.

- DLR performed crash test activities on subfloor components for an eVTOL (Electric Vertical Take-Off and Landing) aircraft, evaluating different composite layups to enhance crashworthiness. The tests aimed to assess the energy absorption capabilities of the subfloor structure, providing valuable insights for the safety and performance of future eVTOL designs.

- ONERA's activities were primarily focused on the research and optimization of auxetic structures, with an emphasis on the optimization of unit cells and their dimensions. The goal of these structures is to enhance energy absorption. So far, quasi-static tests have been conducted, but the future objective is to perform high strain rate tests to assess the performance of the unit cells under more extreme conditions.

- As a summary, 2024 was critical in consolidating partners' knowledge of activities related to shock absorption, and to set different alternatives of numerical activities, with the aim of optimizing energy absorption.

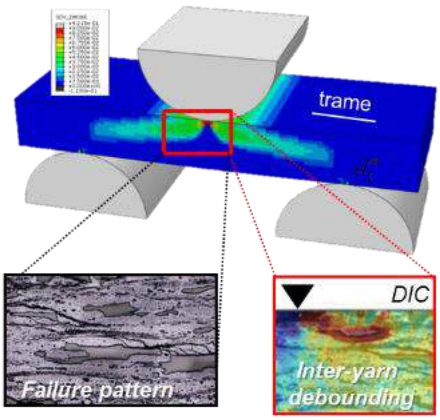
- The GoR thinks the work done in AG-37 is quite promising, and the possibility of presenting proposals on the topic on European Calls should be explored.

In 2024 there were continuous email contacts between the AG partners. An online progress meeting has been planned in January 2025

Exploratory groups (EG)

SM/EG-45

Characterization and modelling of CMC submitted to severe thermo-mechanical loading



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

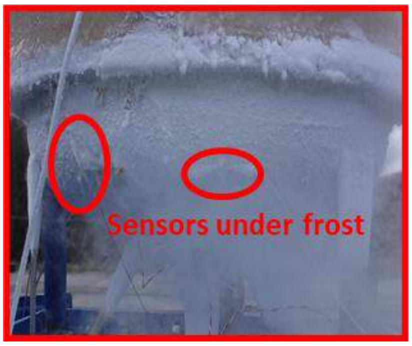
- Comprehension of the damage and failure mechanisms under static and fatigue loading at very high temperatures.
- Definition of standard tests for the measurement of mechanical properties (behaviour, damage, failure) at very high temperatures.
- Proposition of damage and failure models to predict behaviour 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 EG chair is Frédéric Laurin (ONERA), and the other participants are DLR, NLR, QinetiQ, UNICAMPANIA, and ONERA.

The EG status is quite advanced and, hopefully, it could be proposed as a new AG during this year 2025.

SM/EG-48

Structural Health Monitoring for hydrogen aircraft tanks



To drastically reduce CO_2 emissions, hydrogen is an alternative solution for the production and storage of energy. Regarding the storage, the best option consists in liquefying the hydrogen at a temperature below -253°C.

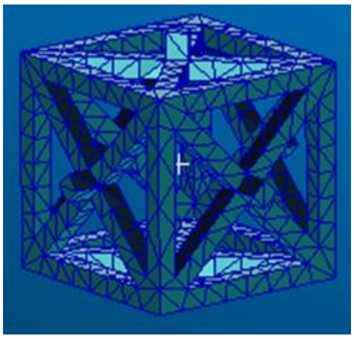
Composite materials are being considered for the cryogenic tank, but the issue related to the development of a composite tank is the ability to detect initiation of any damage.

Structural Health Monitoring (SHM) methods, consisting of integrating sensors in or on the structure, are then used. However, few studies are dedicated to SHM methods under such temperatures.

The objective of the group would be to work on the design of SHM systems dedicated to composite parts under cryogenic temperatures, including the study of the durability of such systems.

The expected chairman is Jean-Michel Roche from ONERA.

SM/EG-49 *Multifunctional Metamaterials for Aerospace applications*



3D FEM – Unit Cell of a MM structure

Multifunctional Metamaterials (MM) is a promising state of the art topic with multiple and multifunctional applications, and suitable for Aerospace applications. During last GoR meetings discussions have been held between the partners in the topic, and several interests have been raised:

- INTA has a team working in MM lattice-based structures, focused on dynamic response: vibration attenuation for primary structures, functionally graded structures, optimization, etc.
- NLR has also a research line in the MM topic. NLR interests includes static crashworthiness for ballistic applications, 3D printing, MM grids definition, energy absorption application, Titanium auxetic sandwiches, etc.
- UNICAMPANIA is interested in the topic: Nanoshapes, multifunctional MM sandwiches, etc.

- ONERA is interested: Light structures, and Static/Fatigue improved properties from 3D printed MM.

Therefore, the SM/EG-49 was created, and one of the first things to set could be the Benchmarks definition.

Rolling plans

The Rolling plan of GARTEUR SM GoR, for the last 5 years is shown below:

	AG/EG Title	2020	2021	2022	2023	2024
SM/AG-35	Fatigue and damage tolerance accesment of hybrid Structures					
SM/AG-36	Additive Layer Manufacturing					
SM/AG-37	Characterization and optimization of shock absorbers for civil aircraft fuselages					
SM/EG-43	Development of additive layer manufacturing for aerospace applications					
SM/EG-44	Characterization of composites with polymer matrix at high temperatures					
SM/EG-45	Characterization and modelling of CMC submitted to severe thermomechanical loading					
SM/EG-46	Characterization and optimization of shock absorbers for civil aircraft fuselages				* Resulted in **SM/AG-37**	
SM/EG-47	Additive Layer Manufacturing			* Resulted in **SM/AG-36**		
SM/EG-48	Structural Health Monitoring for hydrogen aircraft tanks					
SM/EG-49	Multifunctional Metamaterials for Aerospace applications					

AG or **EG active**
AG finished
EG inactive
EG stopped: lack of progress, non-enough interest, etc.
EG finished, it results into an **AG**

GoR membership

Chairperson		
Francisco Javier San Millan	INTA	Spain
Vice-Chairperson		
Aniello Riccio	UNICAMPANIA	Italy

Members		
Florence Roudolff	ONERA	France
Joachim de Kruijk	NLR	The Netherlands
Peter Wierach	DLR	Germany
Andrew Foreman	QinetiQ	United Kingdom
Mats Dalenbring	FOI	Sweden

Industrial Points of Contact		
Thomas Ireman	SAAB	Sweden
Christian Weimer	Airbus Operations	Germany
Thomas Koerwien	Airbus Defense and Space	Germany

Table of participating organisations

	AG-36 Started in 2022	**AG-37** Started in 2023	**EG-44** Stopped in 2023	**EG-45** Quite advanced	**EG-48** Under definition	**EG-49** Newly created
Research establishments						
CIRA		□			□	
DLR		□	■	□	□	
INTA	□				□	■
NLR	■	□		□	□	□
ONERA	□	□	□	■	■	□
CNR		□				
QINETIQ				□		
Industries						
Airbus	□				□	
Academia						
University of Campania		■		□		□

□ Participating institution ■ Chair

Action Group Reports

SM/AG-36	Additive Layer Manufacturing
Monitoring Responsable:	J. de Kruijk (NLR)
Chairman:	M. Montero (NLR)

- **Context and challenge:**

Aluminium and its alloys are widely used in the aerospace sector due to their excellent mechanical performance in combination with their light weight. Their strength and low density are the main advantages of these materials. Fabricating components with complex geometries from high strength aluminium alloys by conventional processing techniques is challenging due to their low formability. In contrast, Metal Additive Manufacturing (AM) techniques allow the production of near-net-shape and complex parts, adding value to the use of aluminium alloys in the aerospace sector. Even so, not all aluminium alloys are easy to process by AM.

Currently, there are several novel aluminium alloys being investigated for application in AM. Great advancements are being achieved on laser powder bed fusion (L-PBF) and also on directed energy deposition (DED). One of the focus points is to broaden the materials palette towards higher performance aluminium alloys. On one hand, the high-strength 7000 series has been investigated aiming at avoiding solidification cracking during the AM process. Several works have focused on modifying the composition by additions of Zr, Sc or Si in order to avoid cracking and improve the mechanical properties. On the other hand, casting aluminium alloys have been widely investigated with addition of nano-/micron-sized particles such as TiB2 or TiC aiming at increased fatigue performance. Examples of these modifications have resulted in commercially available aluminium alloys such as A20XTM developed by Aeromet with Cu and TiB2, or Scalmalloy® developed by APWorks.

- **Scope:**

The main objective of this proposal is 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

- **Expected Impact:**

Development of an AM-process for high-performance novel aluminium alloys opening up the advantages of additive manufacturing for this class of materials, particularly for the aerospace industry, but also elsewhere.

Refinement of the AM process to achieve mechanical performance (static and/or dynamic) for the 3D printed parts that equals or exceeds the current high-performance aluminium alloys allowing the initial steps to be taken towards certification.

- **Main achievements:**

AG-36 started its activities in 2022. In that year, the alloy was selected: AlMg1Cr1.5Mo0.5Sc0.5Zr0.25. Airbus provided Scancromal powder to get familiar with the characterisation techniques.

In 2023, the study of the new alloy started: powder characterization and parameters optimization. In September 2023, the 1st physical meeting took place.

In 2024, process optimizations have been carried out for LPBF and DED methods. The Test programme was defined, and several heat treatments were evaluated. Porosity levels and surface roughness were determined for optimal process parameters.

- **SM/AG-36 membership**

Member	Organisation	e-mail
M. Montero	NLR	
M. de Smit	NLR	
A. Pastor	INTA	
M. Thomas	ONERA	
A. Morel	ONERA	
F. Palm	AIRBUS	

SM/AG-37	Characterization and optimization of shock absorbers for industrial applications
Monitoring Responsable:	Aniello Riccio (UNICAMPANIA)
Chairman:	A. Sellitto (UNICAMPANIA)

- **Background:**

The most important characteristic of any transportation system lies in its ability to ensure passenger safety. To this end efforts have been directed toward the advancement of innovative shock-absorbing devices, capable of increasing safety by reducing acceleration peaks and enhancing energy absorption during crash scenarios.
Beyond safety requirements, shock absorber devices have weight constraints aimed at cost reduction, and environmental sustainability. Optimising hybrid aluminium/composite shock emerges as an approach to mitigate vehicle weight and fuel consumption without compromising crash resistance.
The use of cutting-edge manufacturing technologies eases the creation of efficient shock absorbers. Additive Manufacturing (AM) technologies offer notable advantages, enabling the production of complex microstructures with superior impact energy absorption capabilities impossible through traditional manufacturing processes. Consequently, this production technique may be preferred for crafting highly efficient shock absorber cores.
Indeed, the utilization of a metal core maximizes energy absorption through plastic deformations, while the integration of a composite skin reduces weight while increasing the stiffness and strength of the shock absorber device.

- **Scope:**

In response to emerging needs related to the use of hybrid shock absorbers in aerospace applications, the **primary scope** of this AG is as follows:

To design and verify composite/metal hybrid structures for shock absorbers capable of enhancing absorbed energy and mitigating acceleration peaks during crash events.

This objective requires addressing the following **key issues**: Classification of shock absorbers, Material investigations, Integration strategies, Design of hybrid shock absorbers, FE analysis, Unit cell optimization, and Experimental tests and validation.

The expected **outcomes** include reduction of acceleration peaks in the component, integration with pre-existing components, low weight characteristics, and compact volume requirements.

- **Expected Impact:**

The development of hybrid shock absorbers aims to mitigate peak acceleration transferred to the main structure, ensuring the integrity of the core structure and, ultimately, passenger safety. The design of the developed shock absorber should facilitate the integration with pre-existing structures in a minimally intrusive manner.
Furthermore, the knowledge gained in this work will enable GARTEUR to advance its exploration of the energy absorption and crashworthiness capabilities of aeronautical structures. This exploration will consider technological advancements such as AM, which plays a pivotal role in the design of efficient energy absorption devices.

- **Main achievements:**

AG-37 started its activities in the beginning of 2023. In 2024 different FEM alternatives have been considered to optimize energy absorption. Detailed discussions on demonstrators, and FEMs have been done, to validate numerical models.

- **SM/AG-37 membership**

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