GARTEUR

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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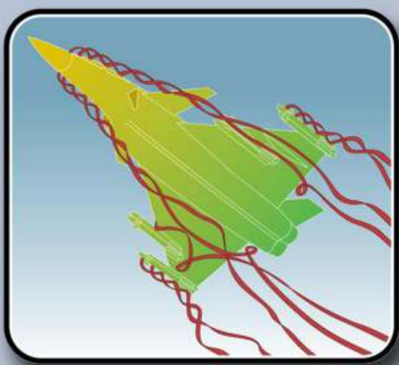
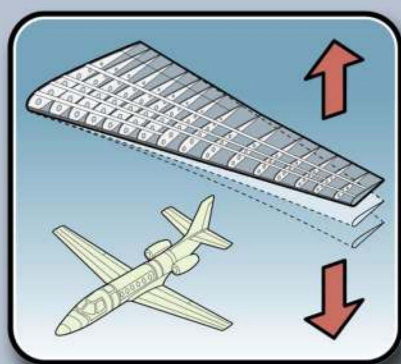
GARTEUR Annual Report 2015





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www.garteur.org

GARTEUR ANNUAL REPORT 2015

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1. EXECUTIVE SUMMARY

Air transport is an essential sector in the more and more globalized world meeting the needs of societies by giving means to connect markets and people. It has been continuously growing these last 45 years and it is expected to continue over the next 20 years.

The European aviation industry is currently world leading and contributes very positively to European economic welfare. To reinforce this position it is therefore vitally important to be ready to meet future major economical and societal challenges. Industrial competition is fierce and increasing, not only from established regions but also from new and strong challengers. Protecting the environment and ensuring safety and security are other key challenges. Hence, the entire sector must improve its performance in order to maintain its global leadership and meet the needs of citizens. Top level objectives of European aviation industry are addressed in the vision document "Flightpath 2050" presented in 2011. ACARE[1] stakeholders also come together to develop the "Strategic Research and Innovation Agenda" (SRIA) presented in 2012. Both these documents define the civil aviation policy in which the GARTEUR action is placed. At present, the aeronautic community is involved in the process of the update of this SRIA.

Research, technology and innovation are essential catalysts for a competitive and sustainable future and efforts have to be pursued to remain effective. Aviation operates on long timescales for exploitation of technology and innovation both because of the complexity of the systems involved and because of the necessary safety requirements and certification processes. This leads to the need for a long term research plan to initiate research on new promising technologies in time.

Likewise, the European Military Aircraft Industrial base has been and is very strong, and several Air Power Systems are being taken into service as well as being upgraded. Many of the technologies developed for these programmes have also been the basis for the successful commercial aircraft industry and other industrial sectors. Conversely, technologies developed for civil aviation are more and more beneficial to military aviation.

The declining defence budgets mean that it is no longer economically viable to retain non-controlled redundant development capabilities in Europe. This necessitates a harmonised approach between Governments, their agencies, industry and research institutions, to enable European Governments to have access to affordable European Air Power solutions, meeting future defence and security requirements. Through various European collaboration projects and studies European countries are paving the way for the next generation of Future Air Systems (manned and unmanned).

More generally, the GARTEUR Council is a unique forum of R&T aeronautical experts from relevant government ministries and research establishments. The Groups of Responsables (GoR), the scientific management bodies and think-tank of GARTEUR, are composed of representatives from government departments, national research establishments and industry.

[1] ACARE: Advisory Council for Aviation Research and innovation in Europe

GARTEUR is the only framework for both civil and military R&T collaboration in Europe. It has been working successfully for numerous projects over the past decades and has continuously adapted to meet new challenges. This Annual Report includes a summary overview of GARTEUR projects (Action Groups) as well as new topics under consideration. The activities and projects of the Groups of Responsables are described in more detail in a separate report (GARTEUR X/D 52 - Annexes to the Annual Report 2015). These annexes, which can also be downloaded from the GARTEUR website, well demonstrate the added value of the cooperation to improve the technology base of the contributing actors.

Beyond that, GARTEUR can take advantage and stimulate R&T activities in the aeronautical framework programmes at both national and European levels. Several examples show that GARTEUR projects are often continued in more application-orientated EU-funded projects, complementing national R&T efforts.

Regarding the EU funded ERA-Net AirTN[2] project, for which GARTEUR was the initiator, the activities are now pursued in the AirTN NextGen project, which will end in September 2016. The AirTN team has successfully established and maintained an extensive network of European aeronautics stakeholder groups that include ACARE and GARTEUR along with universities and research institutes.

The reports on national situations in aeronautics, in both civil and military domains, are presented at each GARTEUR Council meeting, reflect the changing situation and show that the Governments of the GARTEUR countries are closely following and adapting to the developments described above. Over the past years some of the GARTEUR countries have formulated new national strategy plans and R&T programmes. These are made available at the GARTEUR website.

Members of the GARTEUR Council are involved with several other European organizations so that GARTEUR Council meetings act as an effective forum for information exchange. Senior scientific or technical managers from large aerospace companies are invited to give specific presentations at each Council meeting to pursue contacts with the industry.

In the aeronautic community the development of autonomous vehicles and related technologies as well as the growth of cybersecurity technologies are becoming increasingly important topics. For this reason a GoR on Aviation Security was created in 2014. The GARTEUR White Paper on Aviation Security topic, which was published in 2015, outlines four initial topics of strong interest and acts as a guide for future research. The industrial partners who are involved in this field were invited in November 2015 to join the GoR discussions and activities.

France has been the GARTEUR Chair Country from January 2013 to December 2015 and has handed the GARTEUR Chairmanship over to the United Kingdom for 2016-2017.

Hervé Consigny
GARTEUR Council
Chairman
(2013-2015)

[2] AirTN: Air Transport Net

2. INTRODUCTION

The GARTEUR Annual Report 2015 has been prepared by the Executive Committee for the 60th Council meeting held in Stockholm March 17-18, 2016.

The Report provides a summary of all the ongoing activities at scientific and technical levels as well as at the management level, according to the Action Plan agreed by the Council in March 2015.

All matters directly connected to Council activities or decisions are addressed in the next chapter on GARTEUR Council.

Chapter 4 provides an overview of the European aeronautics RTD environment, within which GARTEUR nations continue to account for the vast majority of aeronautical activities.

The GARTEUR scientific and technical activities are summarised in Chapter 5, where ongoing activities are presented as one page posters. More details about the scientific and technical activities are presented in a separate report prepared by the Groups of Responsables (GARTEUR X/D 52 - Annexes to the Annual Report 2015). These annexes can also be downloaded from the GARTEUR website. Data and statistics for GARTEUR activities are provided in the Appendices to this report.

3. GARTEUR COUNCIL

3.1. Chairmanship and membership

Following the transfer of the GARTEUR Chairmanship from Sweden on 1st January 2013, France chaired GARTEUR for a 3-year period ending on 31st December 2015.

During this period Dr. Hervé Consigny was the Chairman of the Council, Dr. Olivier Vasseur the Chairman of the Executive Committee (XC) and Mrs Anne-Laure Delot the GARTEUR Secretary, all of them being employed by ONERA, the French Aerospace Lab.

Several changes to the national delegations took place in 2015:

- in the Dutch Delegation M. van Weelderen (from the Ministry of Defence of The Netherlands) succeeded to T. de Laat as the Head of Delegation;
- in the Italian Delegation L. Paparone (CIRA) replaced M. Amato as the Executive Committee representative for Italy;
- in the Swedish Delegation A. Blom (from FOI and formerly a Member of the Swedish Delegation) replaced G. Hult (FHS) as Head of Delegation, E. Bernhardsdotter (FMV) replaced B. Jonsson as the Executive Committee representative for Sweden, E. Lindegren (VINNOVA) succeeded to E. Lindencrona as a member of the Swedish Delegation and J. Stjernfalk (FMV) completed the Delegation;
- in the Delegation of the United Kingdom L. Barson (BIS) became the Head of Delegation (in replacement of R. Kingcombe who retired in September 2014), M. Scott (ATI) was appointed Executive Committee representative for the UK, S. Weeks and S. Pendry (both from ATI) being the other members of the British Delegation.

The composition of the GARTEUR Council at the end of December 2015 is presented in Figure 11 in Appendix 1.

3.2. Meetings

3.2.1. General points

The GARTEUR Council met twice in 2015:

- C58 meeting in Stockholm, Spain on 19-20 March 2015,
- C59 meeting in Sevilla, Spain on 19-20 November 2015.

The Council meetings followed the usual meeting agenda with the main focus on recurring agenda topics i.e. the GoR chairpersons report about the activities in the Action/Exploratory Groups on their 3-5 years rolling plans and the XC Chairman reports about the status of ongoing and planned GARTEUR actions with respect to the GARTEUR Action Plan.

Furthermore a meaningful point on the Council meeting agendas is the reports on the national situations in aeronautics, on both civil and military sides. Additionally, members of the GARTEUR Council are involved in several other European organisations and hence the GARTEUR Council meetings act as an effective forum for exchange of information. Several member countries have published strategy documents on aeronautics, the public versions of which are included on the GARTEUR website.

Since March 2014 "open discussions" have been proposed in the agendas of the Council meetings so that Council members informally exchange opinions about current programs and questions arising in Europe and brainstorm on how to further develop GARTEUR to be a good instrument for coordinated actions. In 2015 Council members shared ideas on topics such as:

- How to run across the Valley of Death,
- Future EDA and EC projects in the field of defence or dual-use technologies,
- Place of GARTEUR in the evolution of the aerospace market,
- Critical technology in aerospace,
- Impact of Big Data revolution in the Aeronautics R&T community,
- Mid-Term Review of Horizon 2020.

The Executive Committee (XC) met twice in 2015:

- XC155 meeting in Bonn, Germany on 3rd February 2015,
- XC156 meeting in Cranfield, UK on 22nd September 2015.

In addition the Executive Committee held short meetings together with GoR chairpersons in the morning before the Council meetings.

The latest version of GARTEUR Basic documents is available on the GARTEUR website. The most recent alteration to the GARTEUR Basic documents was made at the Council meeting of November 2015 with the addition of the GoR on Aviation Security in the list of Groups of Responsables.

3.2.2. White Paper on Aviation Security: meetings with EC representatives & contacts with industry

Aviation Security represents a growing challenge to the aerospace industry (cf. ACARE/SRIA/Challenge 4) and as such, a new GARTEUR Group of Responsables on "Aviation Security" was formed in March 2014 with the purpose of actively contributing ideas and developing technologies that will assist in making aviation more secure. This GoR has worked on analysing the field of aviation security and has identified important fields of research activities such as Cybersecurity, CBE (Chemical, Biological and Explosive) detection, Dazzling and Malevolent use of RPAS, as described in the *GARTEUR White Paper on Aviation Security* published in 2015.

Meetings with EC representatives from the "Secure Societies program" at DG HOME and the "Aviation Security Unit" at DG MOVE were held on 12th October 2015 to inform the European Commission about the GARTEUR initiative on Aviation Security and to get a better knowledge of the EC organization regarding "Aviation Security". The meetings showed that security topics are scattered in several different European initiatives. The AS-GoR could take advantage of the knowledge of these different initiatives.

In November 2015 the GARTEUR Council sent an official letter to potential partners from institutions and industrial companies to invite them to support and participate in the Group of Responsables on "Aviation Security", in one or several initial topics outlined in the *GARTEUR White Paper on Aviation Security*. This letter raised a significant interest and allowed to identify interested industrial partners that are potential IPoCs for the AS-GoR. An AS-GoR meeting involving industrial partners will be organised at the beginning of 2016.

3.2.3. Contacts with EREA

In order to discuss and coordinate common strategy issues between EREA and GARTEUR the GARTEUR Chairman was invited at the EREA Board meeting in December 2015. During that meeting Hervé Consigny gave the EREA Board an overview of activities taking place in GARTEUR, tackling research achievements in the fields of military aviation as well as purely civil aviation. He informed on the recently created GARTEUR Group of Responsables on Aviation Security and highlighted that GARTEUR prepared a *White Paper* on this matter. The GARTEUR Chairman pointed out that EREA and GARTEUR could exchange on the Aviation Security topic. He added that the GARTEUR French Chairmanship would end in December 2015 and that the next GARTEUR Chairmanship would be under UK responsibility. He highlighted that specific presentations about GARTEUR were given during international conferences (AIAA SciTech 2014 and CEAS 2015) and that GARTEUR activities were quoted in the *ACARE* booklet on "*15 years of Research & Innovation Success Stories*".

3.2.4. Contacts with industry

In order to strengthen the links with industry, top level representatives from aeronautical industries and interest groups are regularly invited to attend the Council meetings to give presentations on their organisations and activities.

At the Council 58 meeting in Stockholm in March 2015, H. Runnemalm (Research Director at GKN) was invited to give a specific presentation about GKN, focusing on engine activities, from R&D, innovation up to market. During his presentation H. Runnemalm informed GARTEUR members about the GKN Research and Innovation strategy and gave examples of novel technologies currently studied at GKN: innovative propulsion concepts (build of the 1st open rotor in CleanSky) and different types of additive manufacturing techniques.

Additionally S. Andersson, Program Manager Future Combat Air System at SAAB, was invited at the Council 58 meeting to give a presentation on "SAAB Future Combat Air System - Long Term Study". In his presentation S. Andersson gave an overview of the SAAB FCAS program and roadmap, before providing information about the FCAS System-of-System and about the FCAS Work Breakdown Structure and activities.

At the Council 59 meeting in Sevilla in November 2015, S. Calvo (Head of Development Flight Test department and Head of Acceptance and Delivery Flight Test department of Airbus D&S) was invited to give a presentation on Airbus Defense & Space. In her presentation S. Calvo gave information about the RTD strategy of Airbus D&S and pointed out that activities were oriented towards mainstream and low-TRLs technologies. Additionally she provided information on different Research & Developments topics such as C295 firefighter, Green Regional Aircraft (GRA) cockpit demonstrator (participation of Airbus D&S in Clean Sky with activities up to TRL 5), FT4B (Future Turboprop Transport Technological Test Bench) and the Collaboration program AERION.

Finally a visit of the A400M FAL (Final Assembly Line) was arranged in Sevilla at the end of the Council 59 meeting.

Figure 1: Visit of the A400M Final Assembly Line in Sevilla at the end of the Council 59 meeting.

3.2.5. European Commission

The Strategic Research and Innovation Agenda (SRIA) - a roadmap for aviation research, development and innovation developed by ACARE - was published in 2012 (more in Chapter 4). This agenda was very useful to launch the Aviation Security initiative and to determine the preliminary needs in this field.

On 20 October 2015 ACARE called for an update of the Strategic Research and Innovation Agenda (SRIA) it published in 2012. The Target Date for the 2nd edition of the SRIA is the 30 June 2017.

The budget line for "Aeronautics/Aviation" is contained under "Smart, green and integrated transport" within "Horizon 2020".

3.2.6. Strategy discussions

At each Council meeting the status for ongoing and planned GARTEUR actions with respect to the GARTEUR Action Plan is discussed. A specific time slot is systematically devoted to strategic discussions with the aim to strengthen the role of GARTEUR projects within the European R&T environment.

A key asset of GARTEUR is its unique collaboration mechanism which can be used for both civil and military, as well as for dual-use projects. Hence, this provides a straightforward mechanism to increase collaboration on dual use projects without introducing new procedures. Partners with either civil or military funding can therefore easily work together.

The Groups of Responsables (GoRs) are the key bodies for GARTEUR success. The enthusiasm and competence of GoR members and GoR chairs are essential for the set up of new GARTEUR Action Groups. It is an important role for Council to facilitate and stimulate the process, which has been the focus of some of the 2015 GARTEUR activities.

There is an increased focus on dual use in light of growing budget pressures. In this context it is noted that GARTEUR projects are of different types:

1. Benchmarking of codes and methods;
2. Experimental data for validation of codes and criteria;
3. Initial studies of new technologies with potential for future applications in aeronautics. This type of projects implies a potential special role for GARTEUR since lower TRL projects have difficulties to fit within EU-FP projects as well as within applied military projects. Hence it could be a good role for GARTEUR to make sure that these needed projects are performed.

3.3. External communication

The contacts and relations to other European fora are followed up at all GARTEUR Council meetings:

- in the field of civil aeronautics: contacts with EU, ACARE, EREA, JTI and AirTN NextGen;
- in the field of defence related organizations: contacts with EDA, ETAP, ASD, NATO/STO and NATO/IST.

An overview of GARTEUR activities was presented at the CEAS conference in Delft, The Netherlands, in September 2016 (see paragraph 3.3.3 for details).

3.3.1. GARTEUR Website and archive

Concerning the GARTEUR website (www.garteur.org) dedicated pages to the five Groups of Responsables present information on the technical programme of each GoR, current Action and Exploratory Groups and a list of all issued GARTEUR Technical Reports. These pages are regularly updated and the Annual Reports from the GoRs are also included.

"GARTEUR Open" Technical Reports are available on the website after 3 years if not otherwise specified by the Action Group.

Some national strategy documents on aeronautics are included or linked from the GARTEUR website.

Additional documents can be found on the GARTEUR website such as the GARTEUR brochure, GARTEUR presentations given during conferences or special events (ICAS 2004, Aerodays 2011, 2014 AIAA SciTech conference, 2015 CEAS conference, etc) or links on specific websites dedicated to specific GARTEUR Actions Groups.

3.3.2. AirTN NextGen

The AirTN third phase started in December 2013 with the new EU project: AirTN NextGen.

The Air Transport Network, AirTN NextGen, a CSA (Coordination and Support Action) funded under FP7, creates a platform of networking and communication between regional, national and governmental organizations supporting research and innovation in the EU Member States and Associated Countries to the EU Framework Program in the field of Aviation.

The aim is to stimulate transnational cooperation in the aviation field for: RTD and innovation, research infrastructures related activities, education related activities.

Activities aiming at supporting transnational cooperation under H2020 and better understanding of the new ERA-NET instrument have been implemented. In this context, AirTN reports on the opportunities offered by the SME instrument and by the ERA-NET Cofund instrument, both under Horizon 2020, are available on http://airtn.eu/programmes-calls/programmes-in-europe/.

The Research Infrastructures Catalog, established under AirTN FP7, has been updated with new information (http://airtn.eu/catalogues/research-facilities/).

3.3.3. GARTEUR papers and presentations at the CEAS 2015 Conference

The GARTEUR Council Chairman presented a paper at the CEAS 2015 conference in Delft, The Netherlands, in September 2015, in a specific session dedicated to international collaboration. In his presentation he provided an overview of collaboration in aeronautics between European countries as stimulated in GARTEUR and highlighted the fields of scientific and technical activities covered by the different GoRs.

Three additional GARTEUR-related papers were presented at the CEAS 2015 conference:

- AD/AG-46 (Highly Integrated Subsonic Air Intakes) by T. Berens, AIRBUS Defense & Space, Germany;
- HC/AG-16 (Rigid Body and Aeroelastic Rotorcraft-Pilot Coupling (RPC) – Prediction Tools and Means for Prevention) by O. Dieterich, Airbus Helicopter, Germany;
- SM/AG-32 (Damage growth in composites) by A. Riccio, Seconda Università degli Studi di Napoli.

3.4. GARTEUR Certificates 2015

GARTEUR Certificates were in 2015 awarded to the following persons:

France		
Mrs. Blanche Demaret	HC-GoR Member, leaving in October 2015	ONERA
Mr. Elio Zoppitelli	HC-GoR Member, leaving in 2015	Eurocopter Group
Dr. Patrick Gnemmi	Chairman of AD/AG-48	ISL
Germany		
Mr. Walter Zink	SM-GoR Member, leaving in 2015	Airbus
Italy		
Dr. Marcello Amato	Executive Committee representative, leaving in March 2015	CIRA
Mr. Lorenzo Notarnicola	HC-GoR Chair, leaving 2015	CIRA
Eng. Umberto Mercurio	SM-GoR Member, leaving 2015	CIRA
The Netherlands		
Col dr. T.W.G. (Theo) de Laat	Council member, leaving in October 2015	Ministry of Defence of The Netherlands
Mr. Bimo Premata	AD-GoR Member, leaving 2015	NLR
Mr. C.P. Groenendijk	Chairman de SM/AG-33	NLR
Spain		
Mr. José Maroto Sánchez	SM-GoR Member, leaving in 2015	INTA
Sweden		
Prof. Gunnar Hult	Council member, leaving on 1st January 2015	FHS
Mr. Björn Jonsson	Executive Committee representative, leaving on 1st January 2015	FMV
Dr. Eva Lindencrona	Council member, leaving on 1st January 2015	VINNOVA
Mr. Fredrik Karlsson	FM-GoR Member, leaving in October 2015	SAAB AB
Dr. Sören Nilsson	SM-GoR Member, leaving in 2015	Swerea SICOMP
United Kingdom		
Ms. Michelle Willows	Chairperson of SM/AG-30	Imperial College

Table 1: GARTEUR Certificates 2015

4. THE EUROPEAN AERONAUTICS RTD ENVIRONMENT

A short overview of the total European aeronautics RTD environment is presented in two sections below, Civil Aeronautics and Military Aeronautics, respectively.

4.1. Civil aeronautics

For the past two decades civil aeronautics research and technology development (RTD) in Europe has been increasingly focused around the research performed within the European Framework Programmes jointly financed via EC. This has given a strong momentum to European collaboration and excellence in civil aeronautics RTD.

The Vision 2020 document[3] from 2001 and the follow on Strategic Research Agendas[4,5] (2002 and 2004) have been the foundation stones to direct and focus European RTD and collaboration for civil aeronautics. Furthermore, in the past years national agendas and platforms aligned to the ACARE SRA have been developed in several member states, and European aeronautics has made great progress in working together to reach the common goals.

A new vision “Flightpath 2050 - Europe’s Vision for Aviation” was presented[6] at Aerodays 2011 in Madrid. The follow up Strategic Research & Innovation Agenda (SRIA) was published[7] in 2012 and the European Framework Programme “Horizon 2020” was prepared in 2013.

At the ACARE General Assembly at Aerodays in October 2015 ACARE called for an update the Strategic Research & Innovation Agenda (SRIA) in 2016. Additionally the preparation of the next European Framework Programme “FP9” will start in 2016.

4.1.1. Flightpath 2050 - Europe’s Vision for Aviation

The Flightpath 2050 vision addresses two parallel objectives: firstly to serve society’s needs for safe, more efficient and environmentally friendly air transport; and secondly, to maintain global leadership for Europe in this sector with a competitive supply chain including large companies and small and medium size enterprises.

The vision set out in this document stresses the need for an innovation friendly environment relying on strong, sustainable and coherent investment in research and innovation and enhanced governance, funding and financing structures. Research, technology and innovation are essential catalysts for a competitive and sustainable future and Europe needs to start quickly in order to reach the goals for 2050.

[3] European Commission (2001) European Aeronautics: A Vision for 2020. Meeting society’s needs and inning global leadership. Report of the Group of Personalities.
[4] ACARE (2002) Strategic Research Agenda 1. Volume 1 and Volume 2.
[5] ACARE (2004) Strategic Research Agenda 2. Volume 1 and Volume 2.
[6] European Commission (March 2011) “Flightpath 2050 - Europe’s Vision for Aviation”. Report of the High Level Group on Aviation Research.
[7] ACARE (2012) Strategic Research & Innovation Agenda (SRIA).

This document setting out a European vision for the future of aviation emphasizes where those working in aviation see the priorities for the relevant policy, research and innovation instruments. It is a high-level vision of Europe leadership with a competitive aviation industry that is clean, competitive, safe and secure.

To meet the ambitious goals set by Flightpath 2050, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) developed a new Strategic Research and Innovation Agenda (SRIA).

The SRIA document is focused around five key challenges. For each of these challenges the targets by 2050 and the key action areas are described. ACARE looks into the entire aviation sector i.e. aeronautics and air transport and includes Innovation in addition to research and the work to prepare the SRIA involved all stakeholders.

4.1.2. Strategic Research and Innovation Agenda (SRIA)

The document serves as the guideline for civil RTD in Europe for years to come. Below is copied the SRIA recommendations and the five challenges with Targets by 2050 and the Key action areas.

SRIA RECOMMENDATIONS

To achieve the Flightpath 2050 goals for European Aviation, Europe must:

- **Lead the development of an integrated resilient European air transport system** that will meet the mobility needs of European citizens as well as the market needs.
- **Maintain global leadership** for a sector that is highly advanced and anticipated to grow.
- **Establish efficient and effective policy and regulatory frameworks**, which ensure a global level playing field and allow European industry to prosper and compete fairly under market conditions in order to **stimulate research, technology and innovation**.
- Put in place incentives, which are accompanied by **long-term programmes with continuity across R&T efforts over many years**. This requires developing mechanisms that provide public sector investment both at European and national level, complemented by public/private partnerships.
- **Champion sustainable growth** so that noise and greenhouse gas emissions can be further reduced and innovative, affordable, alternative energy sources can be developed.
- **Maintain the sector's safety track record** and enable solutions to increasing security risks to be 'built-in' to future designs.
- **Provide long term thinking** to develop state of the art infrastructure, integrated platforms for full-scale demonstration and meet the critical need for a qualified and skilled workforce for today and the future.

4.1.2.1. Challenge 1: Meeting societal and market needs

Targets by 2050

- European citizens are able to make informed mobility choices.
- 90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours.
- A coherent ground infrastructure is developed.
- Flights land within 1 minute of the planned arrival time.
- An air traffic management system is in place that provides a range of services to handle at least 25 million flights a year of all types of vehicles.

Key action areas

The following enablers are needed to achieve the goals:

1. Design of a customer-centric intermodal transportation system: including, for example, knowing future customer profiles and expectations as well as market and societal opportunities and acceptance factors, identifying the benefits and implementation issues of new mobility system concepts, design of the total transport system architecture, mobility performance assessment and forecast as well as innovative infrastructure planning methodologies.
2. Travel process management: to provide the customer a single ticket for the entire journey as well as travel information capable of delivering robust, relevant, complete and unbiased travel choice before and during a journey. This will also involve enhancing crisis management to mitigate the impacts of serious disruption by providing customers with a robust management and recovery mechanism as well as protecting their rights and interests.
3. Integrated air transport: offering customers a vastly improved seamless travel experience, integrating the points of arrival and departure of all types of air vehicles with other modes of transport, mitigating their impact on their neighbours, strategic and tactical air traffic management and supporting information, communication, navigation and surveillance infrastructure, and delivering system intelligence and autonomy.

4.1.2.2. Challenge 2: Maintaining and extending industrial leadership

Targets by 2050

- The whole European aviation industry is strongly competitive, delivers the best products and services worldwide and has a share of more than 40% of its global market.
- Europe has retained leading edge design, manufacturing and system integration capability and jobs supported by high profile, strategic, flagship projects and programmes which cover the whole innovation process from basic research to full-scale demonstrators.
- Streamlined systems of engineering, design, manufacturing, certification and upgrade processes have addressed complexity and significantly decreased development costs (including a 50% reduction in the cost of certification). A leading new generation of standards is created.

Key action areas

The following enablers are needed to achieve the goals:

1. Continuous development of new technologies, new vehicles and their demonstration and flight test.
2. Efficient development and manufacturing process featuring seamless integration of design and manufacturing capabilities.
3. Continued and focused investment in Research and Innovation to be at the forefront of new technologies.
4. A fair and balanced set of global regulations and standards to create a global level playing field.
5. Innovative business models, regulations and incentives to accelerate innovation.
6. Efficient certification of aviation products.

4.1.2.3. Challenge 3: Protecting the environment and the energy supply

Targets by 2050

- CO_2 emissions per passenger kilometer have been reduced by 75%, NO_x emissions by 90% and perceived noise by 65%, all relative to the year 2000.
- Aircraft movements are emission-free when taxiing.
- Air vehicles are designed and manufactured to be recyclable.
- Europe is established as a centre of excellence on sustainable alternative fuels, including those for aviation, based on a strong European energy policy.
- Europe is at the forefront of atmospheric research and takes the lead in formulating a prioritised environmental action plan and establishes global environmental standards.

Key action areas

The following enablers are needed to achieve the goals:

1. Dynamic allocation of targets between stakeholders, permanent survey of research results and regularly updated research priorities.
2. Extraordinary technological effort to define the air vehicles of the future.
3. Improved air operations and traffic management, achieved initially through the deployment phase of SESAR, allowing for short/medium-term traffic growth in Europe.
4. Improved airport environment (including heliports) which, being at the heart of the intermodal transport system, must deliver a service that meets the needs of passengers while mitigating its environmental impact.
5. Availability of affordable, sustainable, alternative energy sources for commercial aviation which will depend on liquid hydrocarbons for at least several decades.
6. Mastering aviation's climate impact to allow low impact operations planning, deeper analysis of the formation/dissipation of contrails and induced cirrus clouds and their contribution to global warming to evaluate the actual environmental impact of a given flight and to optimise flight operations according to atmospheric conditions.
7. Incentives and regulations that create the right framework to promote environmentally friendly behavior as a part of business-as usual throughout all lifecycle phases from new aircraft design and development, over the whole operational period, up to aircraft end-of-life.

4.1.2.4. Challenge 4: Ensuring safety and security

Targets by 2050

- Overall, the European Air Transport System has less than one accident per ten million commercial aircraft flights.
- Weather and other environmental hazards are precisely evaluated and risks are properly mitigated.
- Air Transport operates seamlessly through interoperable and networked systems allowing manned and unmanned air vehicles to safely operate in the same airspace.
- Efficient boarding and security measures allow seamless security for global travel. Passengers and cargo pass through security controls without intrusion.
- Air vehicles are resilient by design to current and predicted on-board and on-the-ground security threat evolution, internally and externally to the aircraft.
- The Air Transport System has a fully secured global high bandwidth data network, hardened and resilient by design to cyber-attacks.

Key action areas

Enablers covering the following aspects are detailed to achieve the goals:

1. Expectations by society for levels of safety and security, the associated burdens and the need to provide privacy and dignity.
2. Air vehicle operations and traffic management particularly relating to cyber threats and the integration of autonomous vehicles into airspace.
3. Design, manufacturing and certification to include safety and security at all stages.
4. Human factors accounting for re-alignment of responsibility and the balance of decision making between the human and the machine.

4.1.2.5. Challenge 5: Prioritising research, testing capabilities and education

Targets by 2050

- European research and innovation strategies are jointly defined by all stakeholders, public and private, and implemented in a coordinated way with individual responsibility. This involves the complete innovation chain from blue sky research up to technology demonstration.
- A network of multi-disciplinary technology clusters has been created based on collaboration between industry, universities and research institutes.
- Strategic European aerospace test, simulation and development facilities are identified, maintained and further developed. The ground and airborne validation and certification processes are integrated where appropriate.
- Students are attracted to careers in aviation. Courses offered by European Universities closely match the needs of the Aviation Industry, its research establishments and administrations and evolve continuously as those needs develop. Lifelong and continuous education in aviation is the norm.

Key action areas

The following enablers are needed to achieve the goals:

1. Optimisation of the research and innovation lifecycle: encompassing the full European aviation sector, defining research roadmaps which cover all the successive steps of the innovation cycle.
2. Modern infrastructure: high quality R&D infrastructure as a fundamental pillar of efficient high-technology research, ranging from wind tunnels to experimental aircraft, all organized in a network for use by all stakeholders.
3. A skilled workforce: possessing the quality, skills and motivation to meet the challenges of the future; and being supported by a harmonised and balanced approach covering the entire scope: from attracting talent over primary and secondary education to apprenticeship, academia and life-long professional development.

4.1.3. Update of the Strategic Research and Innovation Agenda (SRIA) in 2016

In October 2015 ACARE called for an update of the Strategic Research & Innovation Agenda (SRIA) in 2016, following a general decision at the ACARE General Assembly at Aerodays 2015 and a follow-up meeting with the European Commission in January 2016.

In order to update both volume 1 & 2 of the SRIA, different sessions are planned in 2016.

The Target Date for the 2nd edition of the SRIA is the 30th June 2017.

4.1.4. Horizon 2020

The current EU Framework Programme for Research and Innovation is named Horizon 2020.

It runs from 2014 to 2020 with a total budget of around €80 billion. It has three major objectives for research and innovation:

- <u>Excellence in the science base</u> – The aim is to strengthen the EU’s world-class excellence in science by developing talent within Europe and attracting leading researchers to Europe.
- <u>Creating industrial leadership</u> and competitive frameworks to support and promote business research and innovation in key enabling technologies; services and emerging sectors with a strong focus on leveraging private sector investment in R&D; and, to address SME-specific problems.
- The third block “<u>Tackling societal challenges</u>” will respond directly to the challenges identified in EU's growth strategy Europe 2020. It supports activities across the entire spectrum from research to market.

As key new features of Horizon 2020 it is stated that for the first time EU funding for research and for innovation is put together into a truly integrated programme. The aim is to get more impact from every euro spent, and to radically simplify the complex landscape of funding programmes that previously existed.

Implementation is simplified and standardized, with simplification covering both funding schemes and rules. Key aspects include: a rationalized set of funding schemes, a single set of rules, earlier project start and major externalization. In Horizon 2020 Aeronautics and Aviation are found under Transport under a general heading "Smart, green and integrated transport", which aims to boost the competitiveness of the European transport industries.

4.2. Military aeronautics

The European Military Aircraft Industrial base has been and is very strong, and several Air Power Systems are being taken into service as well as being upgraded. Many of the technologies developed for these programmes have also been the basis for the successful Commercial Aircraft industry and other industrial sectors.

Through various European collaboration projects and studies European countries have been paving the way for the next generation of Future Air Systems (manned and unmanned). But the sector is fragmented and the situation can be described as that five major European aerospace companies are currently engaged in three competing combat aircraft programmes and the same will be true for drones if no European strategy is put in place.

It can be noted that there are a number of 5th generation fighter programmes underway in different parts of the world (US: F22, F35/JSF; Russia: T50 PAK-FA; China: J-20, J-31), while in Europe a joint planning for the next generation is lacking. This and new operational requirements imply new challenges for defence related aeronautical R&T in Europe.

The declining defence budgets and a change in military priorities mean that it is no longer economically viable to retain a redundant development capability in Europe. This necessitates a harmonised approach between Governments, their agencies, industry and research institutions, to enable European Governments to have access to affordable European Air Power solutions, meeting future defence and security demands.

Over the past decades a number of initiatives for enhanced collaboration have been taken on the government side like the six-nation initiative of 1998, the European Technology Acquisition Programme (ETAP) and the European Defence Agency (EDA).

4.2.1. Six-nation initiative (LOI)

A first example on the governmental side was the six-nation initiative of 1998 between France, Germany, Italy, Spain, Sweden and the United Kingdom with a Letter of Intent (LOI) aiming at "Establish a co-operative framework to facilitate the restructuring of European defence industry". This initiative involves all GARTEUR member nations except The Netherlands. It should be noted that this initiative was between nations with strong capabilities in military aeronautics, which implies a joint potential to take initiatives regarding military aeronautics.

4.2.2. European Technology Acquisition Programme (ETAP)

A resulting initiative out of the LOI-agreement was the European Technology Acquisition Programme (ETAP) established as an initiative to support the cooperative development of Future Combat

Air Systems (FCAS). Encompassing both Technology Development Programmes and Technology Demonstration Vehicles, the agreement started in November 2001 when the Ministers of Defence of the six nations signed a Memorandum of Understanding underlining the importance of preparing for future fighter systems.

ETAP includes a "Global System Study" (on-going 4-year study) with the aim to define critical technologies for FCAS from a cost and capability perspective. LOI nations except UK participate.

4.2.3. European Defence Agency (EDA)

The European Defence Agency (EDA) was established under a Joint Action of the Council of Ministers on the 12th July 2004, to support the Member States and the Council in their effort to improve European defence capabilities in the field of crisis management and to sustain the European Security and Defence Policy (ESDP). EDA is composed of 27 participating Member States (all EU Member States, except Denmark).

4.2.4. JIP-RPAS: EDA Research & Technology Joint Investment Programme

The Joint Investment Programme on Remotely Piloted Aircraft Systems (JIP-RPAS) addresses the challenges of RPAS traffic insertion in the general airspace. EDA works in close coordination with ESA and the EC to achieve initial safe integration of RPAS in the European air space by 2016.

Launched in June 2012, JIP-RPAS aims at addressing the interlinked challenges of technology and regulation needed to ensure this integration, focusing on the enhancement of military capabilities. The work is strongly coordinated with the integrated roadmaps of the EC, namely the Regulatory Roadmap led by EASA, the R&D roadmap led by the SESAR-JU and the legal and societal roadmap led by the EC.

JIP-RPAS, an umbrella program of the EDA, was signed by ten member states (DE, BE, UK, FR, IT, PL, ES, CZ, SE, AT); all GARTEUR nations except The Netherlands are involved.

Three projects are conducted under this framework: MIDCAS, DeSIRE and ERA.

- **MIDCAS** (MID-air Collision Avoidance System)
  The project on demonstrating the sense and avoid function for RPAS was launched in 2009 with 5 Member States: Sweden (lead nation), France, Germany, Italy and Spain with a total budget of €50 million.
  The aim is to contribute to RPAS integration in civilian airspace by proposing a baseline of solutions for Unmanned Aircraft System Mid-air Collision Avoidance Function acceptable by manned aviation.
  MIDCAS successfully completed after 6 years, the next step being to transform the achievements into regulations and standards for Europe.

- **ERA** (Enhanced RPAS Autonomy)
  ERA is an RPAS Enabler by developing automation functions that drive RPAS behavior when air traffic control is involved.
  The objective is to establish the technological baseline for automatic take-off and landing, autotaxi, nominal/degraded mode automation functions and emergency recovery.
  The project arrangement was signed by DE, IT, FR, PL, SE and the project launch was delayed due to contractual discussions.

- **DeSIRE** (Demonstration of Satellites enabling the Insertion of RPAS in Europe)
  DeSIRE is an EDA-ESA collaboration to demonstrate secure C2 data links for RPAS using satellites:
    - DeSIRE, launched 2012: demonstrations in Spain in Spring 2013 through several flights using RPAS Heron platform;
    - DeSIRE II, launched 2014: midterm development of RPAS independent satellite data-link service;
    - DeSIRE III, launch 2017 (flight demonstration in 2018).

5. SUMMARY OF GARTEUR TECHNICAL ACTIVITIES

The total volume of technical activities in the Action Groups was at a significantly higher order of magnitude in 2015 than in 2014.

GoR-AD monitored 5 Action Groups during 2015. The final report of AD/AG-48 was completed in March 2015. Another Action Group, AD/AG-55, started in 2015. The activities of this GoR were the same in 2015 compared to 2014.

Since its creation in March 2014, the newly created AS-GoR has worked on further analysing the field of Aviation Security and has identified important R&T domains such as Cybersecurity, CBE detection, Dazzling and Malevolent use of RPAS. In 2015 the AS-GoR activity mainly focused on the redaction of the White Paper to describe the GARTEUR position on Aviation Security. The next step will be to launch Exploratory Groups and Actions Groups as in the other GoRs.

GoR-FM didn't monitor any Action Group during 2015 but promising subjects are under discussion.

In 2015 the activities in the HC-GoR were at a high level with 6 Action Groups, one of them (HC/AG-24) starting up its activities in 2015. Two Action Groups, HC/AG-22 and HC/AG-23, started their activities at the end of 2014.

GoR-SM monitored 2 Action Groups during 2015. The activities of this GoR were at the same level than in 2014. One Action Group may start in 2016.

Some statistics for the activities are included in the Appendixes as follows:

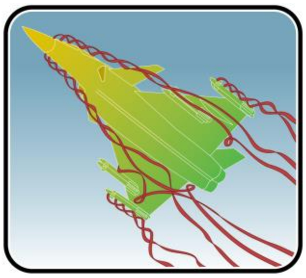
- Appendix 2 shows an overview of GARTEUR Technical activities 2012-2017;
- Appendix 3 shows the participation in the Action Groups by nations/organizations in 2015;
- Appendix 4 shows the resources deployed within Action Groups;
- Appendix 5 lists the Technical Reports that were finalised in 2015. Furthermore a number of conference presentations was made by some of the Action Groups.

The following pages present the technical highlights from the five GoRs mainly as one page posters for Action Groups active during 2015. The situation regarding Exploratory Groups and potential new topics is also described.

Detailed reports of the GoR activities 2015 are included in a separate document (X/D 52 - Annexes to the Annual report 2015). These annexes are also available on the GARTEUR website.

In chapter 6 examples of GARTEUR success stories are included as well as a section illustrating the links between GARTEUR and EU-projects.

5.1. Group of Responsables - Aerodynamics (AD)

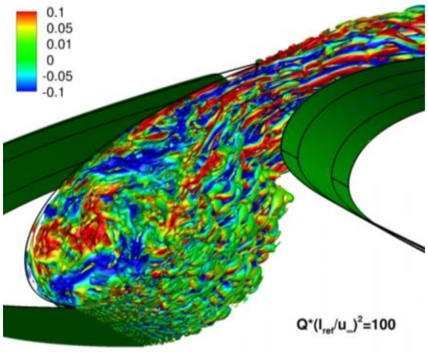


The GoR AD initiates and organises basic and applied research in aerodynamics. Whilst in general term aerodynamics makes up the majority of the research done within the GoR, some of work has a significant amount of multi-disciplinary content. This trend is driven by industrial interests, and is likely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

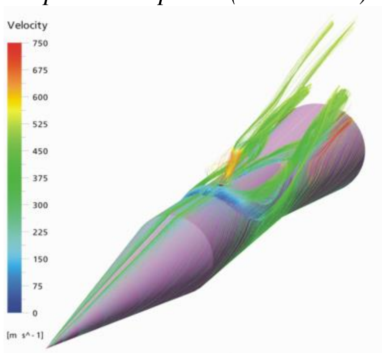
The current scope of the aerodynamic activities in the GoR covers the following:

- Aerodynamics,
- Aero-thermodynamics,
- Aero-acoustics,
- Aero-elasticity,
- Aerodynamic Shape optimum,
- Aerodynamics coupled to Flight Mechanics,
- Aerodynamic Systems Integration.

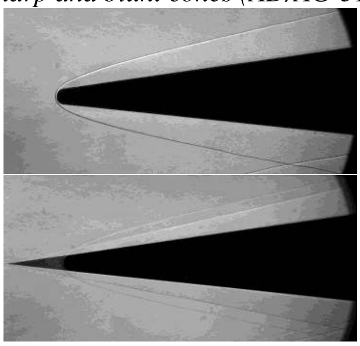
a) ZDES computation of a 3-element aerofoil (AD/AG-49)



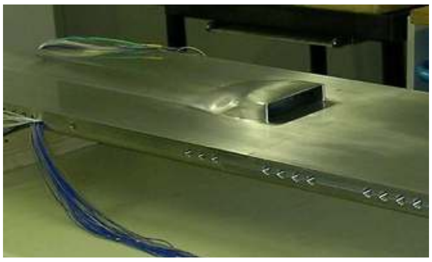
b) Lateral jets interactions at supersonic speeds (AD/AG-48)



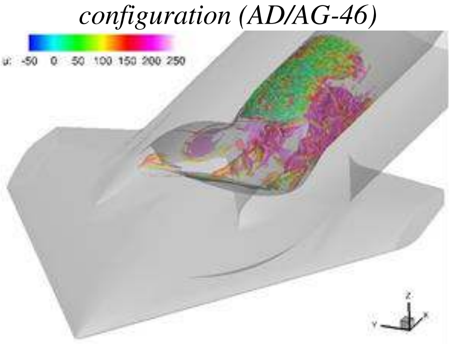
c) Transition in hypersonic flows for sharp and blunt cones (AD/AG-51)



d) Experimental parametric study of intake design (AD/AG-46)



e) CFD computations for a UAV configuration (AD/AG-46)



f) Counter-measures aerodynamics (AD/AG-55)

Figure 2: Illustrations of the Group of Responsables "Aerodynamics"

During 2015 GoR-AD monitored the following Action Groups:

- AD/AG-51 “Effect of laminar-turbulent transition in hypersonic flows”;
- AD/AG-52 “Surrogate-Based Global Optimization methods in aerodynamic design”;
- AD/AG-53 “Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations”;
- AD/AG-54 “RANS-LES Interfacing for Hybrid and Embedded LES approaches”;
- AD/AG-55 “Countermeasure Aerodynamics”.

For the Action Group 49 (for which the Final Report was delivered in 2015) and Action Groups 51 to 55 a one page summary poster is included on the following pages.

The situation regarding GoR-AD Exploratory Groups under review was as follows at the end of 2015: three Exploratory Groups have been running throughout 2015.

- AD/EG-70 “Plasma for Aerodynamics”;
- AD/EG-72 “Coupled Fluid Dynamics and Flight Mechanics of Very Flexible Aircraft Configurations”;
- AD/EG-73 “Secondary Inlets and Exhausts”.

As several AD/AGs are close to finish it is important that the new Exploratory Groups develop into Action Groups.

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

Chairman		
Frank Ogilvie	ATI	United Kingdom
Vice-Chairman		
Harmen van der Ven (from Sept. 2015 on)	NLR	The Netherlands
Members		
Norman Wood	Airbus Operations Ltd	United Kingdom
Bimo Prenata (till Sept. 2015)	NLR	The Netherlands
Eric Coustols	ONERA	France
Giuseppe Mingione	CIRA	Italy
Fernando Monge	INTA	Spain
Henning Rosemann	DLR	Germany
Geza Schrauf / Heribert Bieler	Airbus Operations GmbH	Germany
Per Weinerfelt	SAAB	Sweden
Torsten Berglind	FOI	Sweden
Industrial Points of Contact		
Thomas Berens	Airbus Defence & Space	Germany
Nicola Ceresola	Alenia	Italy
Michel Mallet	Dassault	France
Didier Pagan	MBDA	France
Luis P. Ruiz-Calavera	Airbus Defence & Space	Spain
Chris Newbold	QinetiQ	United Kingdom

Table 2: Membership GoR-AD in 2015

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

AD/AG-48: Lateral Jet Interactions at Supersonic Speeds

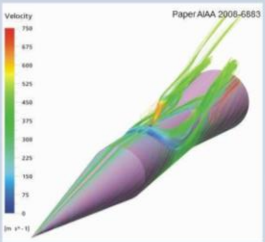
Action Group Chairman: Dr Patrick Gnemmi, ISL (patrick.gnemmi@isl.eu)

Background

Guidance of a supersonic missile: low-velocity or high-altitude missiles, fast response time of hot-gas jets, reproduction in wind tunnels of real hot-gas jet effects by the use of cold-gas jets

Application of RANS CFD methods: multi-species RANS numerical simulations, validation of different codes

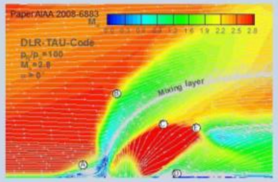
Challenge: defining the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet



Previous activity: basic experiments and wind-tunnel tests on generic missiles conducted at DLR, ISL and ONERA allowed a better understanding of the phenomenological aspects of the jet interference; effects of Reynolds number and jet pressure ratio studied, not the jet nature

State of the art: reliable steady-state CFD of cold-gas jets interacting with a supersonic flow

Critical flow region: multi-species real-gas flow interacting with the missile cross-flow



P. Gnemmi, R. Adeli, J. Longo, "Computational Comparisons of the Interaction of a Lateral Jet on a Supersonic Generic Missile", Paper AIAA 2008-6883

Programme/Objectives

Main objectives of AD/AG48: (1) to accurately predict by CFD the steady-state aerodynamics of the interaction of a hot multi-species gas jet with the cross-flow of a supersonic missile at acceptable computational costs; (2) to deeply analyze the effect of the hot-gas jet from numerical simulations; (3) to define the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet

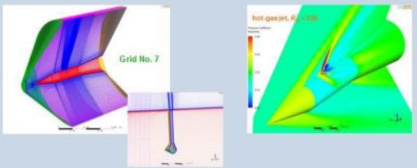
Focus: (1) numerical simulation validations of the interaction of cold-air and hot-gas jets with the cross-flow of supersonic missiles using different Reynolds-Averaged Navier-Stokes (RANS) codes and experimental data from DLR Cologne and ONERA/MBDA-France; (2) numerical simulations for the replacement of the hot-gas jet by a cold-gas jet able to reproduce the effects of the hot-gas jet

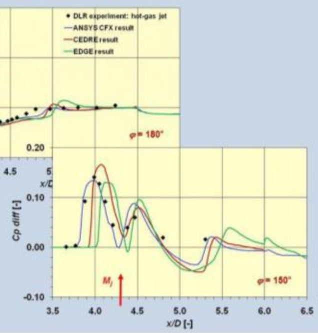
Partners: DLR Cologne, FOI, ISL, MBDA-France, MBDA-LFK, ONERA

Activity: numerical simulations with different RANS codes and validations using high-quality wind-tunnel data

DLR Cologne configurations:

- supersonic flow at Mach 3.00, $\alpha = 0°$
- cold-air and hot-gas jets
- ejection pressure ratio of 130 and 220

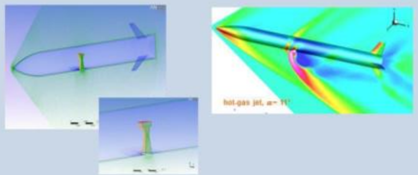


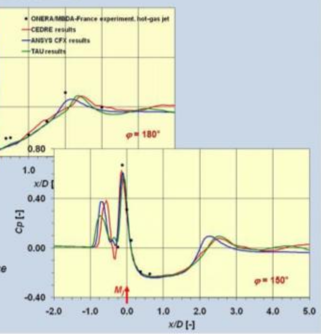


Differential pressure-coefficient distribution on the DLR missile surface, hot-gas jet, R_{0J} = 220

ONERA/MBDA-France configurations:

- supersonic flow Mach 2.01, $\alpha = 0°$ and 11°
- cold-air and hot-gas jets
- ejection pressure ratio of 81 and 137





Pressure-coefficient distribution on the ONERA/MBDA-France missile surface, hot-gas jet, $\alpha = 11°$, R_{0J} = 137

DLR FOI ISL MBDA MISSILE SYSTEMS ONERA THE FRENCH AEROSPACE LAB

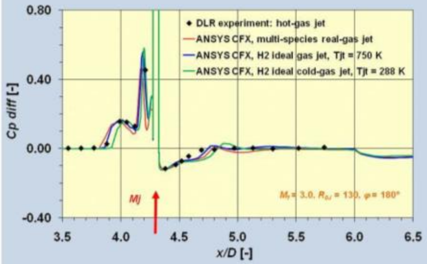
Results

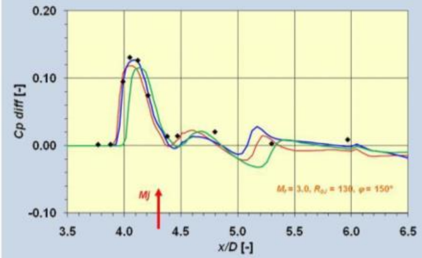
Prediction of cold-gas and hot-gas lateral jet interaction with missile cross-flow

- steady-state numerical simulations able to accurately predict the aerodynamics of cold-gas and hot-gas jets interacting with the missile cross-flow
- less accurate for hot-gas jets with some codes in case of sonic jet flow

Most appropriate similarity parameters for wind-tunnel tests using cold-gas jets

- steady-state numerical simulations used to try to reproduce the effects of a hot-gas jet by the use of a cold-gas jet
- numerous numerical simulations in progress which must be analyzed





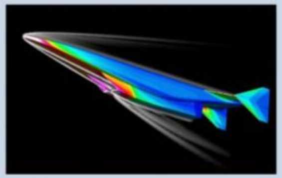
GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD-AG51 : Effect of laminar/turbulent transition in hypersonic flows

Action Group Chairman: Jean Perraud (ONERA)
Vice Chairman: Antoine Durant (MBDA-F)

The Background

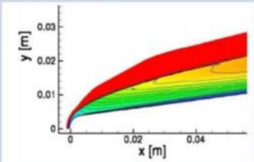
Transition laminar/turbulent:
Thrust-drag balance and air intake adaptation (air breathing hypersonic vehicles)
Heat fluxes (re-entry vehicles)



Different experimental data sources in Europe

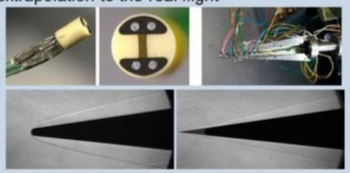
Increasing capability of CFD :
Need of tools/methods to predict laminar/turbulent transition in hypersonic using RANS code

Challenges:
Cross studies between configurations and tools (RANS, LST, wind tunnel)

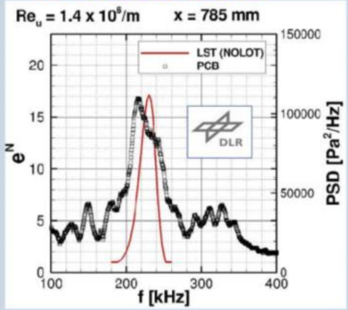


State of the art:
Linear stability theory, Wind tunnel experiments

Critical aspect:
Measurement techniques, wind tunnel noise, extrapolation to the real flight

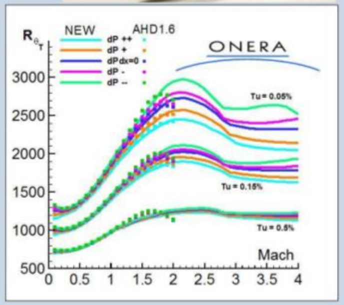


Activities 2013



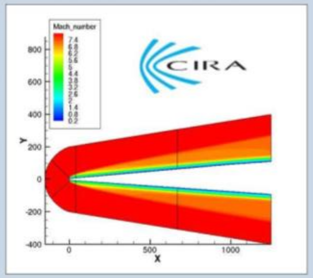
WP1 :
Experimental data described in a draft report, to be completed.
Part of the data bank available at ONERA ftp site.
Figure :
Linear stability calculation compared to experimental wall pressure spectra measured using miniature PCB pressure sensor.

Sharp and blunt cones
Natural transition
Mach=7
Re=3.7 10^6/m



WP2 :
Transition prediction model has been extended to non zero pressure gradients, for adiabatic wall.
The model has been introduced into codes 3C3D (boundary layer) and elsA (RANS) in replacement of AHD transition criteria.
Figure : validation in 3C3D (5 pressure gradients using velocity ramps, 3 turbulence levels)
Validation underway in elsA

WP3 :
First computations on the LEA forebody done at CIRA



Mach=[4-8]
Re=[1.4 – 14] 10^6/m

Hypersonic forebody
Natural and triggered transition
▪ Schlieren, Pitot pressure, Oil flow, TSP

Programme

Objectives of the Action Group AD-AG51:

- Cross studies between different wind tunnel tests (blow-down and hot shot)
- Comparisons to numerical approaches
  - Extension of transition criteria to hypersonics
  - Implementation into elsA solver validation based on above test cases
  - Impact of wind tunnel on transition extrapolation to real flight
  - Study of the design of triggering devices
- Navier-Stokes solver with extended criteria (AHD)
- Linear stability codes

Partners: industries and research establishments : CIRA, DLR, ISL, MBDA-F, ONERA, VKI, UniBwM

Current status :

- **Submission to GARTEUR council: June 2011**
- **Project approval : September 2011**
- **Kick-off meeting: 1st Feb 2012**
- **Meeting 1 at VKI: 22nd Nov 2012**
- **Meeting 2 at MBDA : February 2014**

Next Steps :

- **Validation and application of the extended AHD criterion to LEA forebody**
- **Work plan for tasks 3.3 / 3.4**
  - **Navier-stokes computations on ISL cones**
  - **Laminar BL extraction and comparison**
  - **LST codes benchmark for natural transition**
- **Next meeting : Feb 2014, MBDA**

CIRA DLR ISL INSTITUT FRANCO MBDA ONERA THE FRENCH AEROSPACE LAB Universität der Bundeswehr München VON KARMAN INSTITUTE

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

AD/AG-52: SBGO methods for aerodynamic design

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

Background

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

Current work in AG52 focuses on the assessment of different surrogate modeling techniques for fast computation of the fitness function and the evaluation of surrogate-based global optimization strategies for the shape design of the selected configurations.

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

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

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

Programme/Objectives

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

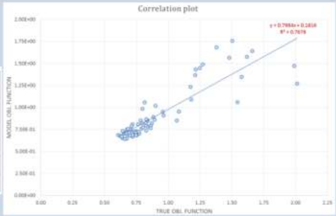
Project duration: 4 years (2013-2016)

AG52 Work Breakdown Structure

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

Final task 1 results:

Partner	MSE	R-squared	Pearson	G-metric
INTA/UAH – SVM	0.1293	0.1952	0.5153	1272.3
ONERA – Kriging	0.1580	0.7966	0.8927	1517.5
VUT - ANN	0.0261	0.9398	0.9697	543.2
CIRA - POD	0.0223	0.8047	0.8978	324.3
CIRA - Kriging	0.0247	0.7662	0.8761	679.3
UNIS - Ensemble	0.0855	0.8899	0.9440	1145.7

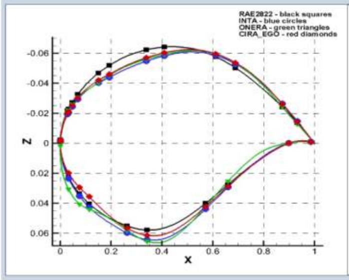


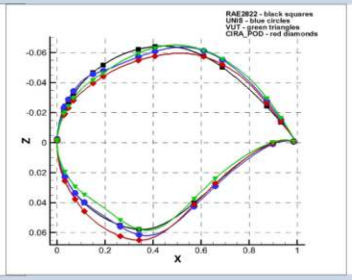
Surrogate models validation. **Error metrics comparison**

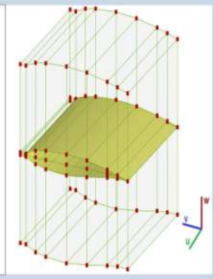
	Mean OF (TAU, MSES, ZEN 3 levels)	Mean OF (only TAU and ZEN fine)
RAE 2822 baseline	1	1
CIRA - POD + GA	0.6223	0.6266
CIRA - EGO + GA	0.6208	0.6236
INTA/UAH – SVM + EA	0.6243	0.6211
ONERA – Kriging + GA	0.6494	0.6498
UNIS – Ensemble + PSO	0.7659	0.7609
VUT – ANN + GA	0.6969	0.7063

In order to minimize the sources of discrepancies and allow a fair comparison, the **geometry parameterization**, the **computational grids** (unstructured and structured) and the **surface deformation algorithm** are **shared** in task 1 between all partners.

In addition, a **cross-analysis on the optimized geometries** was performed.







Results

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

Partial reports delivered:

- **PR01**: RAE2822 definition and common geometry parameterization (May 13)
- **PR02**: DPW-W1 definition and common geometry parameterization (March 13)
- **PR03**: Strategy for surrogate models validation in aerodynamic shape optimization (Dec.13)
- **PR04**: CFD cross-analysis (Task 1 configurations, delivered April 2014)
- **PR05**: Task 1 final report (including results from 1.1 and 1.2, already in-progress → First version prepared)

Current Status:

- Task 1 is closed.
- Partners are working on delivering results in Task 2.
- Participation and organization of a Mini-symposium on "surrogate-based optimization methods" at **EUROGEN 2015**,
- A website has been created for dissemination: www.ag52.blogspot.com

Next meetings: March 2016 (webex), October 2016 (ONERA)

AG52 dissemination history

INTA CIRA AIRBUS MILITARY BRNO UNIVERSITY OF TECHNOLOGY FOI ONERA THE FRENCH AEROSPACE LAB SAAB Universidad de Alcalá UNIVERSITY OF SURREY

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

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

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

Background

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

Programme

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

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

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

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

The Outcomes

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

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

Instability of the flow behind a bump with a freestream Mach number of M=0.87 through numerical simulations has been investigated by IC. Results indicate effects of upstream propagating acoustic wave.

The ring wing experiments (ALFET project) is under preparation by AGI. Here, effects of gap with realistic filler shape on transition will be investigated. The tests include a wide range of depths of filler surface.

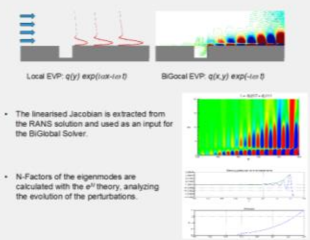
KTH & FOI have completed highly accurate simulations of the leading-edge acoustic receptivity, showing pervious results overestimating the receptivity coefficient. The new results have been verified by comparison with those obtained from compressible computations using a high-order finite-difference code. The new results also agree well with the asymptotic theory in limit of infinitely thin flat plate.

DLR has worked on improving in-house numerical tools for linear stability analysis of boundary-layer flows past forward- and backward-facing steps, i.e. cases with localized surface discontinuities. The linearized Navier-Stokes equations has been implemented in the NOLOT code.

CIRA has further developed their acoustic receptivity tools based on the adjoint methods.

Gap Analysis

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



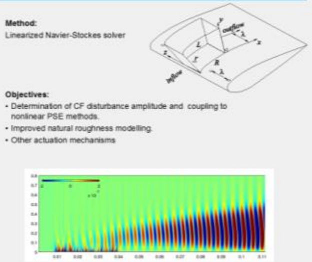
Local EVP: $q(y)\exp(i\alpha x - i\omega t)$ BiGlobal EVP: $q(x,y)\exp(-i\omega t)$

- The linearised Jacobian is extracted from the RANS solution and used as an input for the BiGlobal Solver.
- N-Factors of the eigenmodes are calculated with the e^N theory, analyzing the evolution of the perturbations.

Receptivity model development.

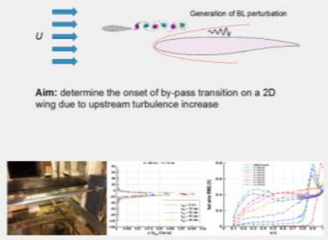
Method:
Linearized Navier-Stockes solver

Objectives:
• Determination of CF disturbance amplitude and coupling to nonlinear PSE methods.
• Improved natural roughness modelling.
• Other actuation mechanisms



Perturbations generated by randomly distributed surfaces roughness of 5 microns.

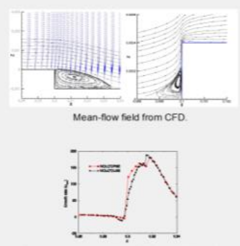
Receptivity & transition experiment



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

Middle: velocity perturbation behind small wing. Right: Effect of distance from wake on generation and growth of perturbations inside the boundary layer over the ONERA D wing. *h* is distance between the two wings.

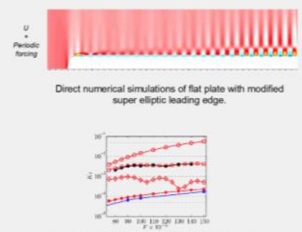
Backward/Forward-facing step



Mean-flow field from CFD.

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

Leading-edge acoustic receptivity



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

Receptivity coefficient at branch I for flat plate with modified super elliptic leading edge with different aspect ratio.

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

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
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AD/AG-54:
RANS-LES Coupling in Hybrid RANS-LES and Embedded LES

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

Background

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

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

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

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

Programme/Objectives

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

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

Task 1: Non-zonal modelling methods

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

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

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

Task 2: Zonal modelling methods

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

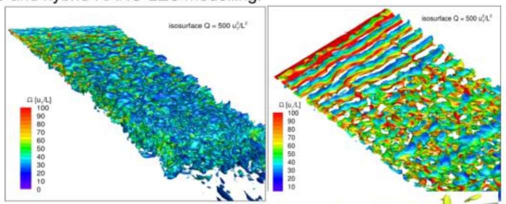
TC M2 Spatially developing boundary layer
Inflow defined with U = 70m/s and Re_θ = 3040. Focus on turbulence-resolving capabilities on the attached BL after the RANS-LES interface.

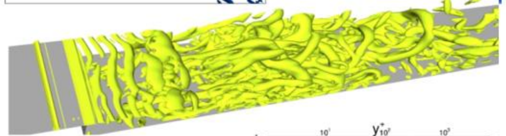
TC O2 NASA hump flow
Incoming BL has U = 34.6m/s, Re_c = 936000 (c = hump length). Focus on the turbulence-resolving capabilities on the flow separation over the hump

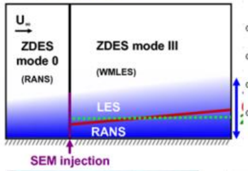
Task 3: Modelling assessment

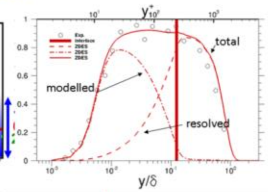
(Task Leader: **Airbus-Innovations** (EADS-IW))
Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.

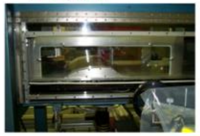
TC M3 Co-flow of BL and wake
Re = 2.4x10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.

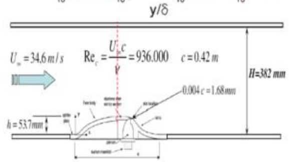


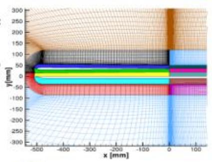


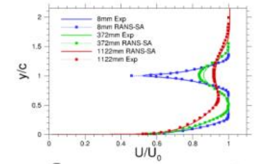












Results

- **E**valuation of existing hybrid RANS-LES methods of zonal and non-zonal modelling in computations of test cases.
- **I**mproved modelling formulation to enhance turbulence-resolving capabilities with special focus on the so-called "grey-area" problem.
- **D**efinition of all the test cases, and a number of preliminary computations conducted for different test cases.

Summary:
The project kick-off took place in April 2014. Since then, AG54 has made the following progress.

- In the evaluation, the following baseline hybrid RANS-LES models have been planned/used in test-case computations, *SST-IDDES, HYB0, HYB1, X-LES, ZDES, 2-eq. based DES, 2-velocity method, WMLES, RSM-based hybrid model, SAS and other variants.*
- For non-zonal hybrid RANS-LES modelling, improvement has been progressing on, among others, X-LES with stochastic backscatter model; HYB0 and HYB1 with energy backscatter, improved ZDES with vorticity-based length scale; SST-IDDES model with well-defined hybrid length scale.
- For zonal hybrid RANS-LES modelling, including ELES, synthetic turbulence has been further examined with ZDES formulation. Noticeably, the synthetic eddy method, DFSEM, has been further improved for ELES.
- All the test cases have been defined with formulated test-case description, including the mandatory test cases M1, M2 and M3, as well as the optional test cases O1 and O2.
- Most of AG members have actively started computations of test cases according to the plan, and some preliminary results have been presented
- AG54 had its 1st progress meeting in October 2014, hosted by UniMan.

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

AD/AG-55: Countermeasure Aerodynamics

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

The Background

In order to increase the defensive capability of aircrafts, countermeasures are used to decoy enemy tracking system. Two commonly used countermeasures are chaff and flares.
Chaff is a radar countermeasure consisting of small pieces or threads of metal or metalized glass fibre. The chaff interacts with the electromagnetic radar wave and can thereby decoy or distract enemy radar. Chaff are dispensed in very large numbers from specific dispenser devices, for an aircraft typically located on the fuselage or under the wing.
Flares are used against IR-seeking missiles. They are a few decimetres in length and can have built in propulsions systems.
The aerodynamic behaviours of these two countermeasures differ significantly. Chaff dispensed from an aircraft propagate through the wake of the aircraft with the motion induced by trailing vortices. When simulating chaff dispersion it is consequently of major importance to obtain an accurate description of the flow in the wake. Flares, on the other hand, are "solid bodies" for which the burning constantly changes their aerodynamic and mechanical properties.

Lacroix high speed track.

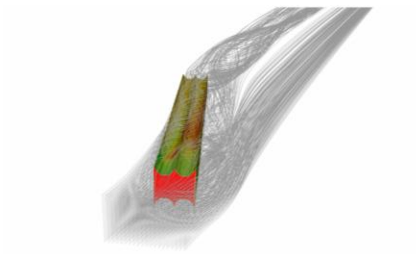
The Programme

Objectives of AD/AG-55
The main objectives of the proposed activities are improved understanding of the underlying physics and improved modelling tools for chaff dispersion and flare trajectory simulation. The project consists of two work packages: WP1 for chaff and WP2 for flares. The main focus of WP1 is to compare and investigate differences in various numerical approaches for modelling transport of chaff clouds.
For WP2, primary concern is to investigate the requirements on the model of the flare in order to be able to predict the flare trajectories sufficiently accurate.

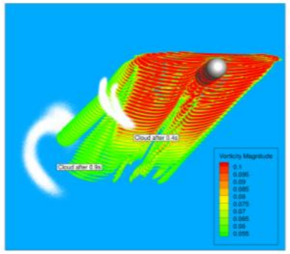
Approach
For WP1 two methods of predicting chaff dispersion, Eulerian and Lagrangian, is be considered. The principle behind the Eulerian method is that chaff is traced as a concentration instead of individual specimen. The aim is to include directional information for both approaches. In addition to this, parametric studies such as chaff dispenser position, dispenser mechanism, will be performed.
In WP2 first an aerodynamic database for the flare with shape changes is going to be generated. In the next step the procedure is going to be repeated for a model for which the real surface temperature and the exhaust gases is modelled. The latter requires that a special boundary condition is developed.

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

Project duration: January 2015 – December 2017



Visualisation of flow around the flare at 20° incidence.



Simulation of chaff dispensed from a generic helicopter.

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

The Outcomes

Expected results/benefits
The action group is expected to yield increased understanding of how simulation of chaff dispersion and flare trajectory modelling should be performed. A natural outcome is also that the concerned partners obtain improved simulation tools, as the work packages are finalized.

Main achievements
A meeting was held at MBDA le Plessis in Paris June 16th. In the WP1 for chaff it was decided that the test case should be chaff dispended from a helicopter. NLR delivered a computational grid with 14.6 million nodes around a generic helicopter in the beginning of October.
The main part of the work in WP2 is to generate aerodynamic databases for the flare with and without exhaust gases. Lacroix computed maps of the flare profile at various time stages with the program VULCAD.
Work to compute the aerodynamic database was split between Airbus, FOI and MBDA. Grids were generated around the flare geometry after 0 sec (Airbus), 1 sec (FOI), 2 and 3 secs (MBDA). The database will be used to simulate 6DoF-trajectories for the flare with varying mass and moments of inertia. This database is expected to be completed early next year. Thereafter 6DoF-simulations of flare trajectories for the ground test case will start.

5.2. Group of Responsables - Aviation Security (AS)

[8]

The Group of Responsables on Aviation Security was created during the GARTEUR Council meeting in March 2014. GoR AS pursues to do research in the Aviation Security field dealing with both military and civil R&T.

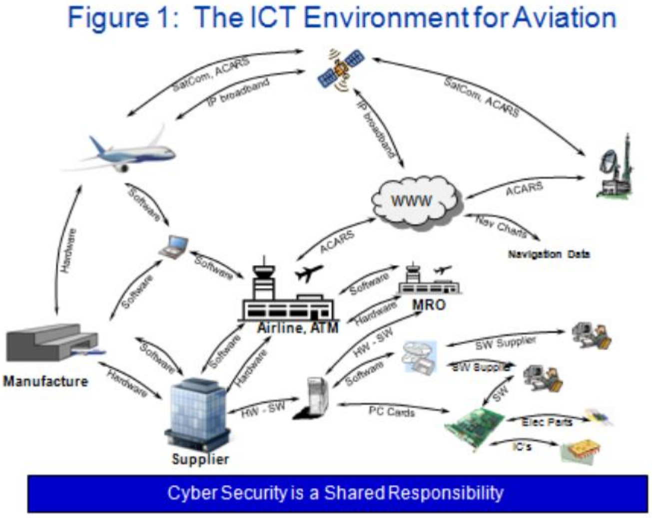
The GoR-AS is responsible for research and development on aviation security subjects concerning air vehicles, airports, airfields, air transport management. It seeks to identify potential threats to the security of all components of aviation and to propose means to protect them from these threats. Four themes, which correspond a greater or lesser extent of activities, have been more specifically identified inside GoR-AS and are listed below.

- Cybersecurity focuses on confidentiality, integrity and availability of data inside information systems. The latest aircraft rely on interconnected systems to support their missions, develop new cost efficient operations and maintenance procedures, and offer new revenue producing services. These systems extend off the aircraft to ground-based systems run by airlines, airports and Aviation Service providers of various types. These evolutions make cybersecurity an essential theme for aviation security.
- CBE detection (Chemical, Biological, Explosive): Both the criminal and the accidental releases of chemical, biological and explosive substances represent a threat to civil security, especially at public places like airports. It is thus necessary to study methods for early detection and identification of hazardous CBE substances at a distance. People and luggage shall be screened nearly instantaneously in a harmless way without any further disturbance of the passengers and by maintaining their integrity. In case of crisis management discrete and reliable detection methods shall allow for an immediate initiating of counter measures and thereby reduce the threat for people in general and first responders in particular.
- Dazzling: So called “laser pointers” with output powers of several hundreds of Milliwatt or even more are widely distributed. Often they are misused to dazzle persons. When pointing on aircraft during the landing procedure, especially during night times, pilots may be dazzled severely. Depending on the effective intensity at the eye dazzling can lead to a loss of the pilot’s vision for many seconds up to minutes and thus may lead to dangerous situations. In order to protect pilots from such attacks, laser radiation present on an aircraft has to be detected and to be reported to the pilots to make them aware of the threat and to prepare protection measures.
- Malevolent use of RPAS: Remotely Piloted Aircraft Systems and/or Unmanned Aerial Systems (RPAS/UAS) are expected to become a reality in the airspace within the coming years thanks to their (imminent) integration into non segregated airspace. This can pose a real

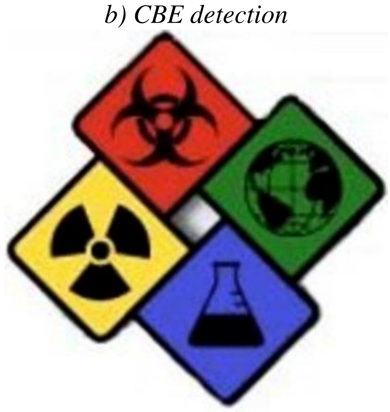
[8] It is worth mentioning that the logo for the Aviation Security GoR is made from royalty-free images. On the other hand GARTEUR has the property rights for the logos of the other GoRs (AD, FM, HC and SM).

problem if used with criminal/malevolent intentions. It can be programmed to autonomously fly against individual targets, passenger aircraft, or critical infrastructures such as Air Traffic Management Assets or Airports. More effort in prevention has to be done. The objective in GoR-AS is to precisely identify potential threats and propose adapted countermeasures.

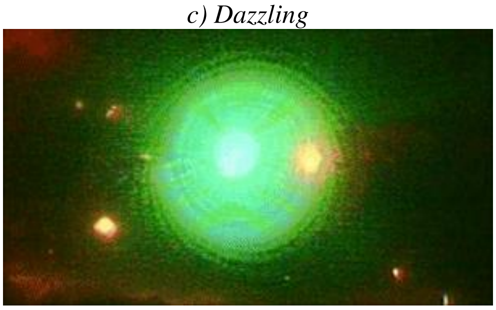
a) Cybersecurity



b) CBE detection



c) Dazzling



d)Malevolent use of RPAS

Figure 3: Illustrations of the Group of Responsables "Aviation Security".

During 2015, GoR-AS has produced a *White Paper on Aviation Security* that has been presented to the European Commission in October and has been distributed to institutions and industrial companies. It has raised a lot of interest among industrial partners. This white paper can be available upon request from the GoR-AS.

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

Chairman		
Virginie Wiels	ONERA	France
Vice-Chairman		
Ingmar Ehrenpfordt	DLR	Germany
Members		
Bernd Eberle	Fraunhofer	Germany
Anders Eriksson	FOI	Sweden
Francisco Munoz Sanz	INTA	Spain
René Wiegers	NLR	The Netherlands
Angela Vozella	CIRA	Italy

Table 3: Membership GoR-AS in 2015

It is worth reminding that the GoR on Aviation Security was created in March 2014. The current work of this newly created GoR is to define Exploratory Groups for each of the R&T domains and subsequently to come up with proposals for Action Groups, as usually done in the other GoRs.

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

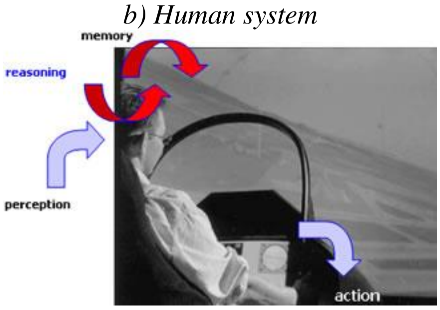
GoR-FM is active in the field of flight systems technology in general.

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:

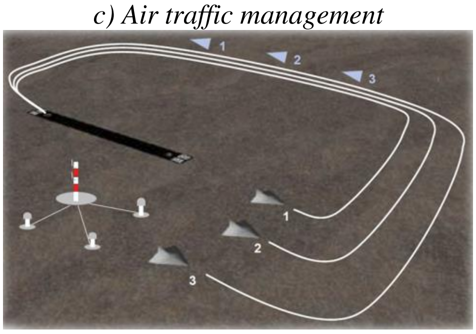
- Aircraft multidisciplinary design aspects;
- Flight performance, stability, control and guidance;
- Aircraft navigation and mission management;
- Air traffic management and control;
- Integration of remotely piloted systems in the air spaces;
- Safety critical avionics functions and embedded systems;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

a) Flight desk

b) Human system



c) Air traffic management



d) ONERA SV4 vertical wind tunnel and associated dynamic simulation test benches

e) Flexible Aircraft Modeling Methodologies (FM/AG-19)

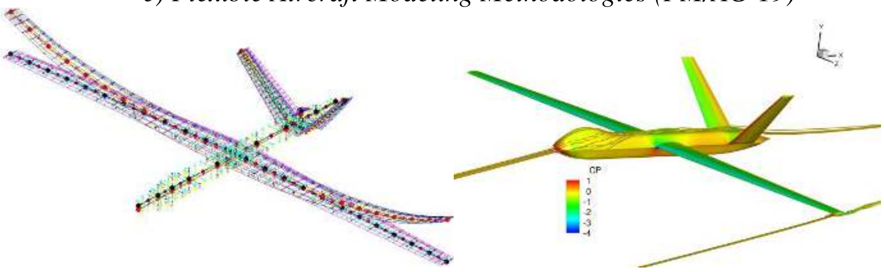


Figure 4: Illustrations of the Group of Responsables "Flight Mechanics, Systems and Integration"

Several FM-GoR members are facing significant budget reductions, preventing new ideas to grow and Exploratory Groups to transition to Action Groups. Nevertheless the FM-GoR management has been active and several discussions were held at FM GoR meetings to identify new topics which interest the industry and on which to work within the GARTEUR framework.

In 2015, there were no Action Groups active.

Two Exploratory Groups have been under discussion in 2015:

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

Within FM/EG-28, which was defined and started in 2013, there were difficulties on the technical direction, the changes in participation and limited budget at interested parties.

FM/EG-29 showed no progress in 2015. The development of a pilot paper was not successful.

Several discussions were held at FM GoR meetings to discuss new topics. FM GoR agreed to review FlightPath2050 reports and Horizon 2020 rejected proposals for topics to start in FM GoR as EGs. It was agreed to prepare a pilot paper on “Pilot Wearable Avionics”.

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

Chairman		
Rob Ruigrok	NLR	The Netherlands
Vice-Chairman		
Martin Hagström	FOI	Sweden
Members		
Leopoldo Verde	CIRA	Italy
Bernd Korn	DLR	Germany
Philippe Mouyon	ONERA	France
Emmanuel Cortet	Airbus	France
Francisco Muñoz Sanz (resigned during 2015)	INTA	Spain
Industrial Points of Contact		
Francisco Asensio	Airbus Military	Spain
Laurent Goerig	Dassault	France
Martin Hanel	CASSIDIAN	Germany
Fredrik Karlsson (resigned during 2015)	SAAB	Sweden

Table 4: Membership GoR-FM in 2015

5.4. Group of Responsables - Helicopters (HC)

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

The GoR-HC initiates, organises and monitors basic and applied, computational and experimental multidisciplinary research in the following areas and in the context of application to rotorcraft (helicopters and tilt rotor aircraft) vehicles 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 CFD and comprehensive calculation tools, validated with relevant tests campaigns;
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines, ...);
- Increase security, safety:
  - Security studies, UAVs, advanced technologies for surveillance, rescue and recovery,
  - Flight mechanics, flight procedures, human factors, new commands and control technologies,
  - Increase crashworthiness, ballistic protection, …
- Integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations);
- Tackle environmental issues:
  - Greening, pollution, …
  - Noise (external, internal), …
- Progress in pioneering: breakthrough capabilities.

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

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

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(copyright: AgustaWestland)

Figure 5: Illustrations of the Group of Responsables "Helicopters"

During 2015 GoR-HC monitored the following Action Groups:

- HC/AG-19 "Methods for Improvement of Structural Dynamic Finite Element Models using In-Flight Test Data";
- HC/AG-20 "Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction";
- HC/AG-21 "Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity";
- HC/AG-22 "Forces on Obstacles in Rotor Wake" (starting up in November 2014);
- HC/AG-23 "Wind turbine wake and helicopter operations" (starting up in November 2014),
- HC/AG-24 "Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction" (starting up in January 2015).

For the Action Groups HC/AG-19, HC/AG-20, HC/AG-21, HC/AG-22, HC/AG-23 and HC/AG-24 a one page summary poster is included on the following pages.

The situation regarding Exploratory Groups and New Topics under review was as follows at the end of 2015:

- GoR-HC Exploratory Groups:
  One Exploratory Group was running in 2015:
  - HC/EG-29 "Health & Usage Monitoring Systems - HUMS";
- New Topics
  The following topics are being considered for future Exploratory Groups:
  - Conceptual Design of Helicopters;
  - CFD based flow prediction for complete helicopters;
  - Safety (Crash, Hums, Crew Workload, all weather operations);
  - Noise external (passive, active rotors, flight procedures, atmospheric effects, shielding);
  - Noise internal (Comfort, Costs, Weight → fuel consumption);
  - Synergies between Civil and Military operations;
  - Sand/dust engine protection.

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

Chairman		
Mark White	Uni of Liverpool	United Kingdom
Vice-Chairman		
Philippe Baumier (from Oct. 2015 on)	ONERA	France
Members and Industrial Points of Contact		
Blanche Demaret (till Oct. 2015)	ONERA	France
Lorenzo Notarnicola	CIRA	Italy
Odile Parnet	Airbus Helicopters	France
Antonio Antifora	AgustaWestland	Italy
Klausdieter Pahlke	DLR	Germany
Philipp Krämer	ECD	Germany
Joost Hakkaart	NLR	The Netherlands
Observer		
Richard Markiewicz	DSTL	United Kingdom

Table 5: Membership GoR-HC in 2015

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

HC/AG-19: Improvement of Structural Dynamic FEM using In-flight Test Data

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

Background

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

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

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

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

- Study effects of configuration changes in the structure. How significant are these effects? How can uncertainties be handled in the context of an FE model. What is the influence of flight loads.

- The helicopter structure tested in HC/AG-14 was suspended in the laboratory. However, this is not the operational environment where there are very significant mass, inertia and gyroscopic effects from the rotor systems. Could in-flight measurements be made? What are the benefits?

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

Programme/Objectives

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

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

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

Traditional analysis versus OMA analysis

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

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

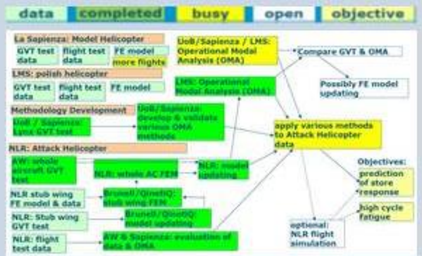
The department of mechanical and aerospace engineering of "La Sapienza" University has a model helicopter at it disposal. Flight tests have been conducted with this helicopter. A finite element model is available. Ground vibration tests have been conducted. The advantage of this helicopter is that it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

The third data set will be based on a discontinued commercial helicopter model from AW.

Results

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

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



Members of the HC/AG-19 group are:

Giuliano Cappotelli	Sapienza University Rome
Johnathan Cooper	Bristol University
David Ewins	Bristol University
Cristinel Mares	Brunell University
Simone Manzato	LMS
Hans van Tongeren	NLR
Trevor Walton	Agusta Westland Ltd

GARTEUR Responsable:
Joost Hakkaart NLR

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

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

Background

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

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

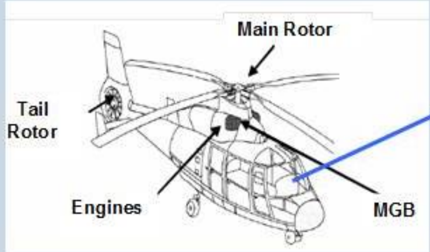
It appears that conventional passive systems (trim panels, passive anti-resonance isolation systems as well as classical vibration absorbers and pendulum absorbers) are still the main way to control the acoustic of the cabin whereas active systems (active vibration and noise control) are not completely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

Programme/Objectives

Objectives

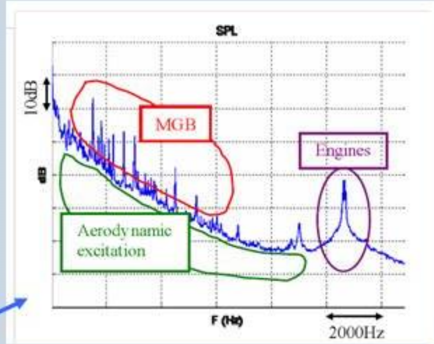
HC/EG-28, about internal noise and associated passive acoustic solutions (soundproofing, e.g. 1cm-thick trim panels designed for optimizing the absorption or the transmission loss), development of a vibro-acoustic model of the cabin (SEA coupled with FEM), human factors (subjective annoyance, speech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

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



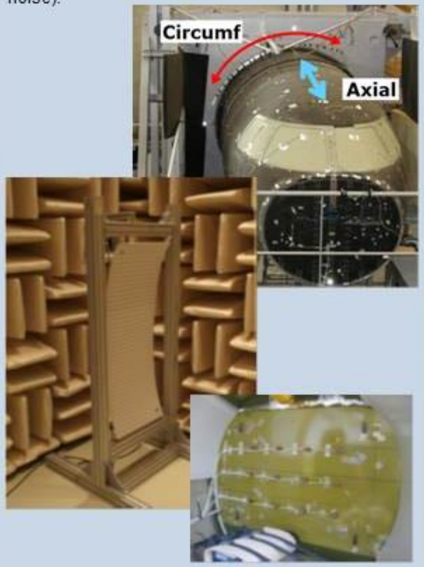
The activities in the new HC/AG-20 constitute the conclusion of HC/EG-28 and explore the points 2 to 4:

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



Results

The AG should result in a benchmark of the appropriateness of tools for complex configurations (multiple anisotropic layers with various mechanical characteristics, effect of confined medium on internal noise).



Members of the HC/AG-20 group are:

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

GARTEUR Responsable:

B. Demaret	ONERA

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

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

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

Background

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

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

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

Programme/Objectives

Objectives

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

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

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

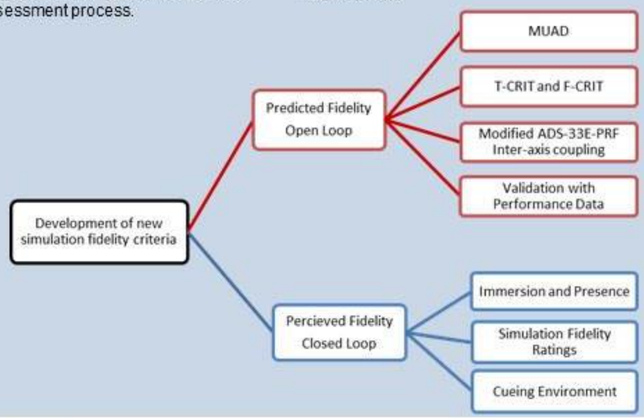
The work programme has two strands:

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

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

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

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



Results

It is anticipated that the outputs from this AG would be used to enhance the fidelity criteria that exists in current and emerging flight simulation qualification standards for rotorcraft.

An initial set of simulator test manoeuvres have been identified to be used as candidate fidelity test points. Work is underway on the development of flight loop fidelity metrics which could be used during the simulator qualification process.

Questionnaires have been developed to subjectively assess the fidelity experienced by users in virtual environments. The questionnaires will be test during simulator trials in 2015.

Members of the HC/AG-21 group are:

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

GARTEUR Responsable:
J. Haakkart NLR

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

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

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

Background

Helicopters are largely employed in missions within "confined areas", regions where the flight of the helicopter is limited in some direction by terrain or by the presence of obstructions, natural or manmade. Rescue operations, emergency medical services, ship-based rotorcraft operations are some examples of near-ground and near-obstacle operations. A helicopter sling load is another, yet particular, case of obstacle subjected to forces produced by its interaction with the rotor wake. Once airborne a sling load comes under the influence of aerodynamic forces and moments associated with its size, shape, mass, and transport speed.

The wind conditions, the distance of the helicopter from the obstacles, the space between the obstacle and the height of the helicopter from the ground are the main factors due to which the wake generated by the obstacle may result in: (a) high compensatory workload for the pilot and degradation of the handling qualities and performance of the aircraft; (b) unsteady forces on the structure of the surrounding obstacles.

These forces are of aerodynamic nature and arise from the interaction between the wake induced by the rotor and the airflow around the obstacles. The intensity of the interaction increases with the proximity of the rotor to the ground and/or the obstacles.

A bibliographic research, performed during the Exploratory Group HC/EG-32 "Forces on Obstacles in Rotor Wake", highlighted that there is a general lack of:

- experimental databases including the evaluation of the forces acting on obstacles when immersed in rotor wakes;
- both numerical and experimental investigations of the rotor downwash effect at medium-to-high separation distances from the rotor, in presence or without sling load.

Programme/Objectives

Objectives

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

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

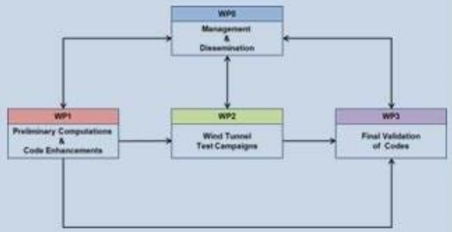
The timescale for the project is three years during which the following activities are planned:

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

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

The work programme is structured in four work packages:

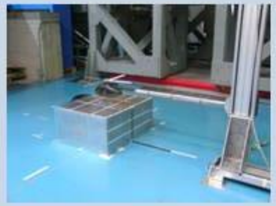
- WP0 – Management & Dissemination: is aimed at the fulfilment of all the obligations concerning the project management and the dissemination of the results;
- WP1 – Preliminary Computations & Code Enhancements: deals with a preparation phase during which partners are involved in literature review and preliminary computational activities;
- WP2 – Wind Tunnel Test Campaigns: concerns the performance of the following four wind tunnel test campaigns:
  1. HOGE/HIGE rotor with a loose/sling load (CIRA);
  2. HIGE rotor in proximity to a well-shaped obstacle (ONERA);
  3. HIGE rotor in proximity to an obstacle in windy conditions (PoliMi);
  4. HIGE rotor in proximity to an obstacle without wind (Univ. Glasgow).
- WP3 – Final Validation of Codes: is aimed at the final validation of the numerical tools proposed by partners.



Results

The action group started the activities in November 2014.

An experimental database, dealing with a helicopter rotor in HOGE/HIGE conditions in the vicinity of a cuboid obstacle, was provided by Politecnico di Milano with the aim to help partners in evaluating the initial modelling capabilities and the possible improvements applicable to the available numerical tools.



The four foreseen wind tunnel test campaigns are all in a preparation phase.

Members of the HC/AG-22 group are:

A. Visingardi	CIRA
F. De Gregorio	CIRA
T. Schwarz	DLR
R. Bakker	NLR
S. Voutsinas	NTUA
B. Rodriguez	ONERA
G. Gibertini	Politecnico di Milano
R. Green	University of Glasgow
G. Barakos	University of Liverpool

GARTEUR Responsable:
K. Pahlke DLR

CIRA Centro Italiano Ricerche Aerospaziali · DLR · NLR · ONERA THE FRENCH AEROSPACE LAB · POLITECNICO MILANO · UNIVERSITY OF LIVERPOOL · University of Glasgow

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

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

Background

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

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

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

Programme/Objectives

Objectives

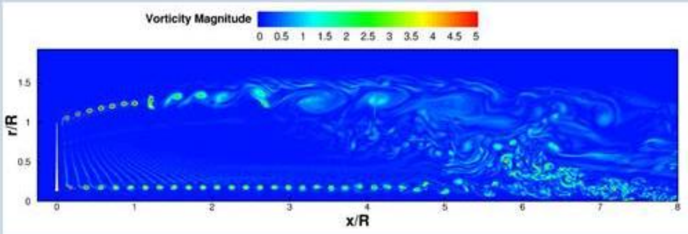
Despite the amount of literature on both wind turbine wakes and helicopter – fixed wing tip vortex encounters, not much research has been done on the interactions of wind turbine wakes and helicopter flight.
The aim of the Action Group is to set up a team of researchers from universities and research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

Programme

The programme consists of 5 work packages

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

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



Results

It is anticipated that the outputs from this AG would be used to provide recommendations for legislation and disseminate the findings to the appropriate authorities and parties concerned.

Members of the HC/AG-23 group are:

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

GARTEUR Responsable:
J. Hakkaart NLR

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

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

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

Background

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

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

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

Programme/Objectives

Objectives

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

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

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

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

The work programme is structured in three work packages:

➢ WP 1: Simulation on the acoustic scattering effect

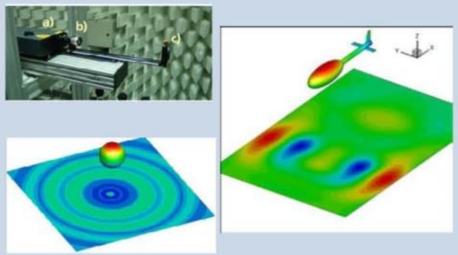
- Code adaptation & prediction
- Code validation & improvement of prediction tools
- Evaluation of noise scattering of various components using validated codes

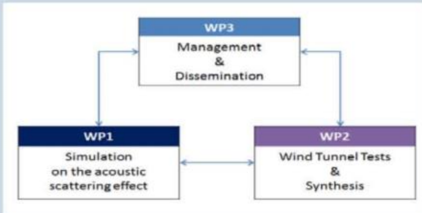
➢ WP 2: Wind Tunnel Tests & Synthesis

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

➢ WP 3: Management & Dissemination

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





Results

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

The kick-off meeting was conducted on March 21st to 22nd, 2015 in DLR Braunschweig. Following results will be achieved in first 6 month:

1. Description of available analytical, experiment test cases including database will be collected;
2. Specifications on the common simulation for the sphere scattering will be defined and the results of sphere simulation will be conducted by all partners. In addition the results will be comparied in 6 month review meeting;
3. The size of the generical helicopter composed of simple geometric form will be defined.

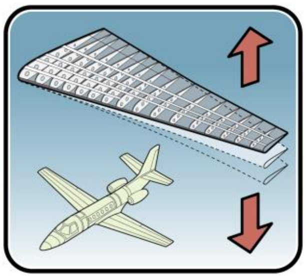
Members of the HC/AG-24 group are:
(only contact persons are listed here)

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

GARTEUR Responsable:
K. Pahlke DLR

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

5.5. Group of Responsables - Structures and Materials (SM)



The GoR SM is active in initiating and organising aeronautics oriented research on structures, structural dynamics, acoustics and materials in general. Materials oriented research is related to material systems primarily for the airframe but also for the landing gear and the engines; it includes specific aspects of polymers, metals and various composite systems. Structural research is devoted to computational mechanics, loads and design methodology. Research on structural dynamics involves vibrations, response to shock and impact loading, aeroelasticity, acoustic response and adaptive vibration suppression.

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

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

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

Computational modelling of bird strike and experimental validation, from SM/AG-24 on "Bird strikes"

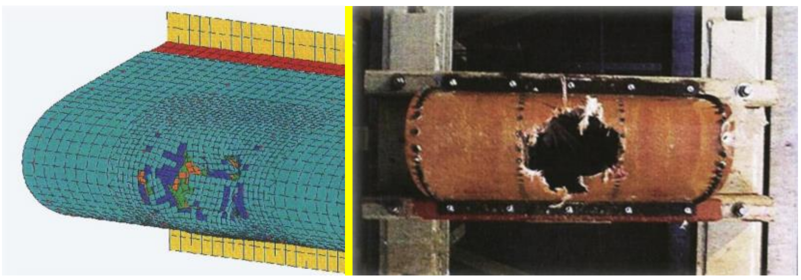


Figure 6: Illustrations of the Group of Responsables "Structures and Materials"

During 2015 GoR - SM monitored the following Action Groups:

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

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

Two reports were finalised with the following Action Groups:

- SM/AG 30: High Velocity Impact (TP-183):
  AG 30 finished in 2010;
- SM/AG-33: RTM material properties during curing (TP-184):
  AG 33 finished in 2010.

The situation regarding Exploratory Groups and New Topics under review was as follows at the end of 2015:

- GoR - SM Exploratory Groups:
  - SM/EG-39 "Design of High Velocity Impact on Realistic Structure":
    This EG could become an AG with a new coordinator.
  - SM/EG-42 "Bonded and bolted joints":
    This EG has started at the end of 2013 and no meeting has been held yet.
    This EG could continue with a new coordinator.
  - SM/EG-43: Development of additive layer manufacturing for aerospace applications. This EG was formally started at the Fall 2014 SM-GoR meeting and the first SM/EG-43 meeting was held on the 10th of April 2015.

- New Topics:
  The following topics for future Exploratory Groups are discussed:
  - Multi-functional Material;
  - Multi-scale dynamics of joints: modeling and testing;
  - New Methodologies for thermal-mechanical design of Supersonic and hypersonic vehicles;
  - Composite Fire Behaviour;
  - Structural Uncertainties;
  - Aeroelasticity and aero-servo-elasticity.

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

Chairman		
Jean-Pierre Grisval	ONERA	France
Vice-Chairman		
Peter Wierach	DLR	Germany
Members		
Umberto Mercurio (till April 2015)	CIRA	Italy
Domenico Tescione (from May 2015 on)	CIRA	Italy
Aniello Riccio[9]	Univ. II Naples	Italy
Henri de Vries	NLR	The Netherlands
Jose Maroto Sanchez (till January 2015)	INTA	Spain
Javier Sanmilan (from February 2015 on)	INTA	Spain
Tomas Ireman	SAAB	Sweden
Joakim Schön	FOI	Sweden
Industrial Points of Contact		
Caroline Petiot	Airbus AGI	France
Walter Zink (till July 1st, 2015)	Airbus	Germany
Roland Lang	Airbus DS	Germany
Massimo Riccio	Alenia	Italy
Luc Hootsmans	Fokker	The Netherlands
Angel Barrio Cárdaba	Airbus DS	Spain
Hans Ansell	SAAB	Sweden
Sören Nilsson (till January 1st, 2015)	SICOMP	Sweden
Renaud Gutkin (since January 1st, 2015)	SICOMP	Sweden
Andy Foreman	Qinetiq	United Kingdom

Table 6: Membership GoR-SM in 2015

[9] Associated member

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SM/AG-34: Damage Repair with Composites

Action Group Chairman: Aniello Riccio (aniello.riccio@unina2.it)

Background

Composites are much more prone to be damaged in service than metals, for example, by mechanical impact. Reparability of such damage is an important consideration in the selection of composites for aircraft applications.
In addition, metal structures can be repaired by using composite patches with great potential benefits such as costs reduction and time saving.
Repair techniques can be considered applicable to a wide range of structures both metallic and composites (laminates or sandwich).
The repair scheme used for structural restoration should be the simplest and least intrusive that can restore structural stiffness and strain capability to the required level and be implemented in the repair environment, without compromising other functions of the component or structure.
It is usually necessary to restore the capability of the structure to withstand the ultimate loads of the design and to maintain this capability (or some high percentage of it) for the full service life.
Important functions that must be restored include: aerodynamic shape, balance, clearance of moving parts and resistance to lightning strike. The requirement in military to restore the stealth properties of the component may also have to be considered and may influence the type of repair chosen.
The growing use of composite structures but also the need to reduce costs (both for metals and composites) have lead to an increasing interest in repair and especially in repair with composites and its potential applications.
However, uncertainties remain in the behavior of repaired structures that generally lead aircraft manufacturers to perform repairs only in secondary structures and to prefer bolted repair (mechanical fastened repair) over bonded repair (adhesively bonded repair) limiting the use of bonding only to moderate-size damage.

Programme/Objectives

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

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

This objective addresses the following issue:

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

The activities have been split in Work Packages:

WP 1 REPAIR CRITERIA (WHEN UNDERTAKING REPAIR)

task 1.1) Methodologies for the assessment of residual strength in damaged composite components to decide when repair has to be undertaken

task 1.2) Crack growth analysis (static and fatigue);

WP 2 DESIGN OF PATCHES AND REPAIR STRATEGIES

WP 3 ANALYSIS OF THE REPAIR

WP 4 MANUFACTURING AND TEST

task 4.1) Manufacturing and repair procedure issues;

task 4.2) Experimental tests

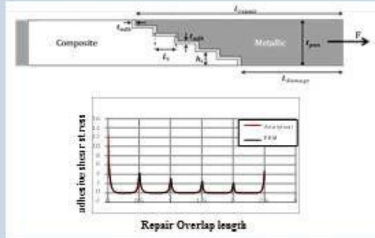
WP 5 EFFECTIVE REPAIR METHODS

task 5.1) Optimization of the patching efficiency;

task 5.2) Certification issues;

task 5.3) Technologies for repair;

task 5.4) Definition of guidelines for an effective repair of both civil and military aircraft structures.



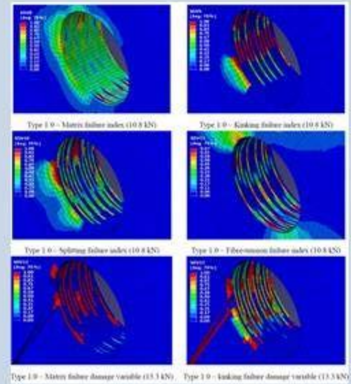
Development of an Analytical tool for Repair Design

Expected Results

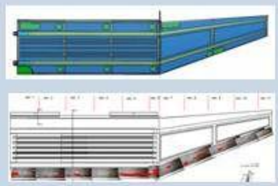
The effective outcomes can be summarized in:

1) minimize down-time of the aircraft for repair operations;
2) minimize costs for repair;
3) promote the repair of components instead of their substitution;
4) reduction of the costs and time for certification of repaired structures

A number of benchmarks have been selec ted for models validation.



Numerical Analysis - progressive Damage in composite Joint



Repair of an UAV wing

CIRA · Seconda Università degli Studi di Napoli SUN · AleniaAermacchi Una Società Finmeccanica · The Composites Centre for research, modelling, testing and training in advanced composites · QinetiQ · NLR · Institute of Composite and Biomedical Materials · INTA · FOI · NTNU – Trondheim Norwegian University of Science and Technology · SICOMP · Luleå Tekniska Universitet

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

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

Background

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

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

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

Programme/Objectives

Objectives
The main objectives are listed below:

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

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

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

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

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

Results

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

The second progress meeting was held at DLR on 19-05-2014 in Cologne and the third progress meeting was at Fokker Aerostructures at Papendrecht on 12-11-2014. SAAB hosted the fourth progress meeting on 22-09-2015 in Lynkoping.

Task 1:
A conceptual definition of a specimen geometry was proposed in order to be able to observe the behavior of the test specimen with respect to the various (conflicting) requirements associated with a hybrid (metal-CFRP) fatigue test. Further detailing of the test specimen needs to be done. A proposal for a load spectrum to which the benchmark test specimen will be subjected was made.

Task 2:
Due to the absence of DLR, the progress of DLR's work in this field of probabilistic methods could not be presented.

Task 3;

- FOI presented results of static and fatigue tests in a bi-axial test rig at elevated temperature on composite specimens.
- Saab conducted FEM studies using a new failure prediction model on the static and fatigue test specimens of the FOI tests conducted in the bi-axial test rig.
- IVW-Univ. of Kaiserslautern presented a paper on new multifunctional Hybrid Polymer composites reinforced by Carbon and Steel fibres
- FK discussed some thoughts on the determination of the test conditions since modern business jets will fly higher under colder temperature conditions.

6. GARTEUR SUCCESS STORIES AND LINKS TO OTHER EUROPEAN PROGRAMMES

In this chapter examples of GARTEUR success stories are presented as well as the links between GARTEUR projects and other European Programmes.

6.1. GARTEUR success stories

Three examples are presented in more details on the following pages: “Air Intakes Aerodynamics” from the GoR Aerodynamics, “Rigid Body and Aeroelastic Rotorcraft-Pilot-Coupling - Prediction Tools and Means of Prevention” from the GoR Helicopters and “Nonlinear Analysis and Synthesis Techniques for Aircraft Control” from the GoR Flight Mechanics, Systems and Integration.

The first example “Air Intakes Aerodynamics” (GARTEUR Award of Excellence 2013-2014) illustrates how dedicated joint European efforts coordinated by GARTEUR Aerodynamics Action Groups led to the advancement of hybrid numerical simulation methods and an improved understanding of complex instantaneous internal flow fields, thus preparing the basis for future time-accurate predictions of vital performance parameters, such as dynamic intake distortion and engine/intake compatibility, with accuracy levels meeting industrial requirements.

The second example “Rigid Body and Aeroelastic Rotorcraft-Pilot-Coupling - Prediction Tools and Means of Prevention” (GARTEUR Award of Excellence 2010-2011) clearly illustrates how joint European knowledge in mathematical modelling of helicopters, and in particular in modelling Rotorcraft-Pilot Coupling phenomena, has largely been built up over the past decades through national efforts coordinated via GARTEUR Action Groups. There is no other organisation in Europe where such a collective effort was done for the specific topics of Rotorcraft modelling for prediction of performance, flying and handling qualities.

The third example concerns the Action Group FM/AG-17 “Nonlinear Analysis and Synthesis Techniques for Aircraft Control”, which received the GARTEUR Award of Excellence 2008-2009 and resulted in a text book “Non-linear Analysis and Synthesis Techniques for Aircraft Control” published by Springer-Verlag in 2007.

Another success story regarding the GoR Structures and Materials can be found in GARTEUR Annual Report 2012. This success story on “Damage Mechanics, Damage Tolerance, Bolted Joints in Composite Materials/Structures” illustrated how the joint European knowledge in this field had largely been built up through national efforts coordinated via a series of GARTEUR Action Groups. The GARTEUR activities led to other European projects within EU Framework and WEAG (now EDA) programmes.

6.1.1. Intake Aerodynamics

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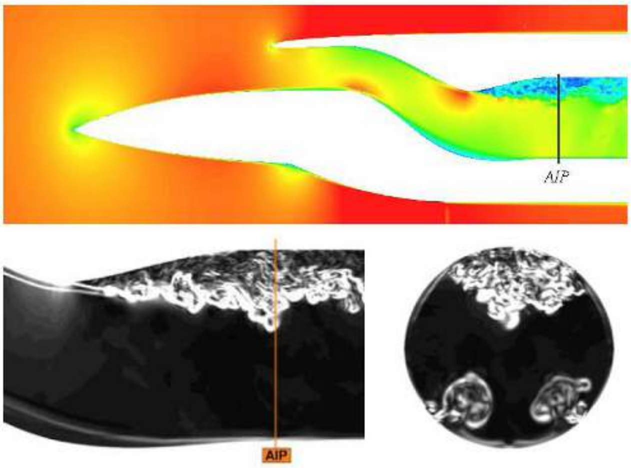
INTAKE AERODYNAMICS – A GARTEUR SUCCESS STORY

Aerodynamic integration of intakes into the airframe of unmanned aerial vehicles assuring high performance and minimized aerodynamic drag is of vital importance for innovative vehicle configurations. The accurate prediction of the instantaneous total pressure distribution in the aerodynamic interface plane as the basic parameter for the assessment of dynamic intake distortion and engine/intake compatibility is a key for successful design and for reducing system development time and cost.



Modern Computational Fluid Dynamics methods such as Detached Eddy Simulation (DES) to analyze unsteady flow phenomena are a vital means for improving performance prediction capabilities and thus possess a great potential to support efficient design for highly integrated low-observable intakes of advanced aerial vehicles.

Based on a strong commitment of the AD-GoR to the application of CFD methods, several Action Groups have been addressing research areas within the field of intake aerodynamics with enhanced emphasis on dynamic simulations of internal flow fields applying hybrid methods:

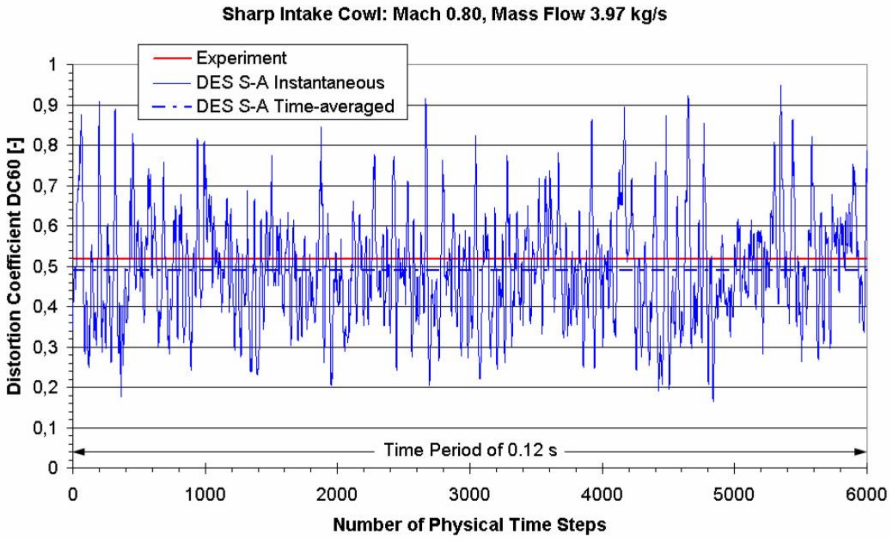
AD/AG-34 Aerodynamics of Supersonic Air Intakes

AD/AG-43 Application of CFD to High Offset Intake Diffusers

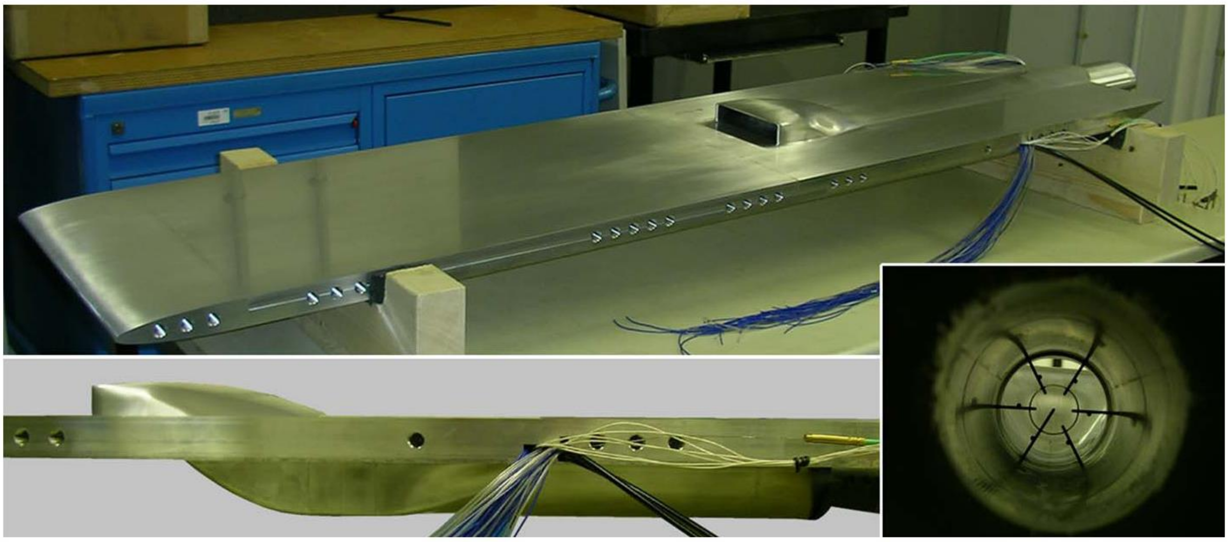
AD/AG-46 Highly Integrated Subsonic Air Intakes

AD/AG-49 Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications

These Action Groups investigated the capability of advanced CFD techniques for predicting complex internal flow phenomena and supported the improvement of numerical tools for time-accurate predictions of intake performance parameters. They essentially contributed to prepare the groundwork for engine/intake compatibility assessment with accuracy levels meeting industrial demands. Mid-term prospects for fulfilling these requirements and for successfully applying these methods for project oriented work are considered most promising.



Besides numerical simulations fundamental experimental investigations of decisive intake design parameters were performed, advancing the knowledge innovative configurations of compact air induction systems require.



In summary, dedicated joint European efforts coordinated by GARTEUR Aerodynamics Action Groups led to the advancement of hybrid numerical simulation methods and an improved understanding of complex instantaneous internal flow fields, thus preparing the basis for future time-accurate predictions of vital performance parameters, such as dynamic intake distortion and engine/intake compatibility, with accuracy levels meeting industrial requirements.

Web: www.garteur.org; Email: secretariat@garteur.org

6.1.2. Rigid Body and Aeroelastic Rotorcraft-Pilot-Coupling - Prediction Tools and Means of Prevention

RIGID BODY AND AEROELASTIC ROTORCRAFT-PILOT-COUPLING - PREDICTION TOOLS AND MEANS OF PREVENTION

A GARTEUR SUCCESS STORY

DLR BO105 Experimental Helicopter **Biodynamic test campaign featuring pilot sensors**

There is a long commitment since late 1980s of GARTEUR HC-GoR on the mathematical modelling of helicopters for the prediction of performance, flying and handling qualities as illustrated in the following action groups:

HC/AG-03 Mathematical modelling of helicopters for handling qualities and performance

HC/AG-05 Advanced rotorcraft evaluation

HC/AG-06 Mathematical modelling for the prediction of helicopter flying qualities, phase II

HC/AG-07 Helicopter performance modelling

HC/AG-09 Mathematical modelling for prediction of helicopter flying qualities, phase III

HC/AG-11 Helicopter yaw axis handling qualities modelling

HC/AG-12 Validation criteria for helicopter real-time simulation models

Unintended and unexpected oscillations or divergences of the pilot-rotorcraft system have become a critical issue for augmented helicopters with modern flight control systems. The rapid advances in the field of high response actuation and highly augmented flight control systems have increased the sensitivity to aspects that lead to complex oscillations related to unfavourable Aircraft/Rotorcraft-Pilot Coupling.

HC/AG-16 achieved an improvement in the physical understanding of both rigid body and aeroelastic Rotorcraft Pilot Coupling (RPC) by developing procedures and validating appropriate prediction methods during simulator experiments. Guidelines and criteria have been defined to prevent or suppress critical RPC incidents in the future, making use of a PIO toolbox.

Participants: Industry (Airbus Helicopters), Research Establishments (DLR, ONERA, NLR) and Universities (Delft, Liverpool, Milano and Roma Tre)

This Action Group was awarded the GARTEUR Award of Excellence 2010/2011.

Results of the HC/AG-16 work have been successfully published in 27 scientific papers and presented both in Europe and the US at prestigious aeronautical events.

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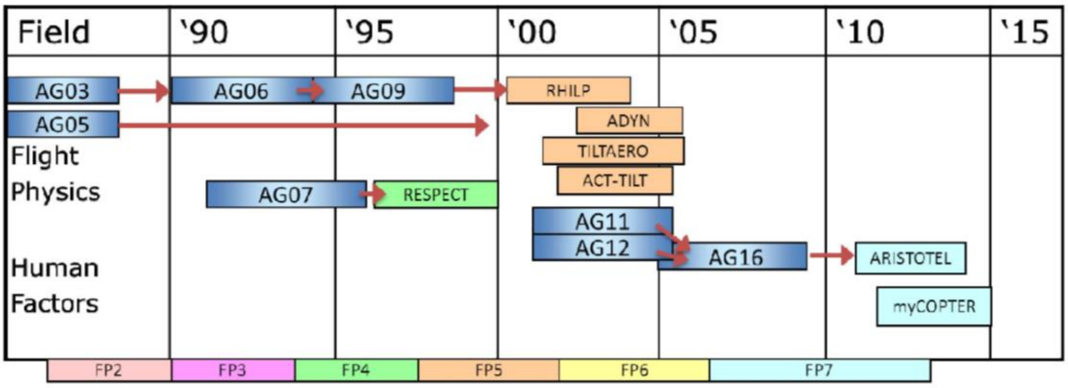
Due to the high complexity and the large variety of RPC phenomena still to be solved, follow-on activities have been defined to further refine the methods and enlarge the experimental database.

In particular, based on this GARTEUR project the EU-FP7 project ARISTOTEL (lead by TU-Delft) was established: “Aircraft and Rotorcraft Pilot Couplings / Tools and Techniques for Alleviation and Detection”. Funded with more than 3M€ by the European Commission, ARISTOTEL is a collaborative project involving a large number of research institutions and universities from the Netherlands, France, UK, Italy, Poland, Romania and Russia. End products of the project will be: Advanced vehicle-pilot-FCS simulation models for “rigid body” and aero-servoelastic A/RPC analysis; A/RPC design guidelines and criteria; Protocols and guidelines for A/RPC flight simulator training. At the 39th European Rotorcraft Forum, September 3-6, 2013, a special session was dedicated to the ARISTOTEL project and Prof. Marilena Pavel, the coordinator of the ARISTOTEL project, won the Cheeseman Award.



The figure below illustrates how HC-GoR projects are interlinked with projects performed within EU Framework Programmes.

In summary it can be stated that the joint European knowledge in mathematical modeling of helicopters, and in particular in modeling Rotorcraft-Pilot Coupling phenomena, has largely been built up over the past decades through national efforts coordinated via GARTEUR Action Groups. There is no other organisation in Europe where such a collective effort done for the specific topics of Rotorcraft modeling for prediction of performance, flying and handling qualities.

6.1.3. Non-Linear Analysis and Synthesis Techniques for Aircraft Control

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NONLINEAR ANALYSIS AND SYNTHESIS TECHNIQUES FOR AIRCRAFT CONTROL

A GARTEUR SUCCESS STORY

Background

Despite many significant advances in the theory of nonlinear control in recent years, the majority of control laws implemented in the European aerospace industry are still designed and analysed using predominantly linear techniques applied to linearised models of the aircraft' dynamics. Given the continuous increase in the complexity of aircraft control laws, and the corresponding increase in the demands on their performance and reliability, industrial control law designers are highly motivated to explore the applicability of new and more powerful methods for design and analysis.

Objectives

The overall objective of the Flight Mechanics Action Group 17 (FM/AG-17) was to explore new nonlinear design and analysis methods that have the potential to reduce the time and cost involved with control law development for new aerospace vehicles, while simultaneously increasing the performance, reliability and safety of the resulting controller. This objective was to be achieved by investigating the full potential of nonlinear design and analysis methods on demanding benchmarks developed within the project, in order to focus the research effort on the issues of most relevance to industry.

Main achievements

- **LFT[10] modelling tools**, including guidelines for LFT modelling, symbolic manipulations, model reduction and nonlinear symbolic LFT modelling.
- **On-ground benchmark modelling using LFT's**, including aircraft dynamics, actuators saturations, ground forces and time-varying dependencies such as ground velocity or nose-wheel deflection.
- **LPV-AW[11] design methods**. This parameter varying anti-windup synthesis is coupled with an on-line estimator of the ground forces. Performance in the presence of saturations is guaranteed by design using LMI[12]'s.
- **Stability and performance robustness assessment for LTI[13]-uncertain and LTV[14] nonlinear systems**. The method developed in this Action Group extends the use of μ-analysis to nonlinear systems. In addition, the method allows systems which are dependent on both uncertain and time-varying parameters to be considered. These results are based directly on the LFT modelling of nonlinearities, uncertainties and time-varying parameters, showing here again the complementarity of the works performed.
- **Object oriented modelling**. This offers the possibility for interactive modelling with reusable library and easy connection of objects, including the development of specific blocks for the benchmark. Automatic code generation then allows the integration of either a reduced or complete model into a design or simulation environment such as Matlab-Simulink, Dymola or any flight simulation environment. This is of particular interest in a design process requiring iterative loops between synthesis and evaluation.
- **Symbolic inversion-based control design tools**. These tools come with a proposed process for control laws design and evaluation based on object-oriented modelling and simulation.

[10] LFT: Linear Fractional Transformation
[11] LPV-AW: Linear Parameter Varying-Anti Windup
[12] LMI: Linear Matrix Inequalities
[13] LTI: Linear Time Invariant
[14] LTV: Linear Time Varying

The programme

In September 2004, GARTEUR Flight Mechanics Action Group 17 (FM/AG-17) was established to conduct research on "*New Analysis and Synthesis Techniques for Aircraft Control*". The group comprised representatives from the European aerospace industry (EADS Military Aircraft, Airbus and Saab), research establishments (ONERA France, FOI Sweden, DLR Germany, NLR Netherlands) and universities (Bristol, DeMontfort, Liverpool and Leicester).

To guarantee the industrial relevance of the project, two highly realistic simulation models were developed, together with demanding design/analysis challenges. These benchmarks in themselves represent significant achievements of the project, since there are still very few industrially relevant aircraft models, with realistic design and analysis specifications, available in the open literature on which control theoreticians can test and validate new techniques and algorithms. An additional benefit of the on-ground transport aircraft benchmark developed by Airbus for the project is that it represents a non-standard control application (at least in the context of aerospace control!) and thus adds another new and challenging set of problems to those traditionally addressed by flight control law designers. Nine different approaches and techniques were applied to the benchmark problems.

- Nonlinear symbolic LFT tools for modelling, analysis and design
- Nonlinear LFT modelling for on-ground transport aircraft
- On-ground aircraft control design using an LPV anti-windup approach
- Rapid prototyping using inversion-based control and object-oriented modelling
- Robustness analysis versus mixed LTI/LTV uncertainties for on-ground aircraft
- An LPV Control Law Design and Evaluation for the ADMIRE Model
- Block Backstepping For Nonlinear Flight Control Law Design
- Optimisation-based flight control law clearance
- Investigation of the ADMIRE Manoeuvring Capabilities Using Qualitative Methods

During the years several persons were involved in the project. These key persons, most of whom also participated in the final report "*Nonlinear Analysis and Synthesis Techniques for Aircraft Control*", Springer Verlag, were: Declan G. Bates, Jean-Marc Biannic, Mikhail G. Goman, Martin Hagström, Markus Högberg, Matthieu Jeanneau, Fredrik Karlsson, Stephen Kendrick, Andrew V. Khramtsovsky, Evgeny N. Kolesnikov, Udo Korte, Gertjan Looye, Mark Lowenberg, Andres Marcos, Jos Meijer, Prathyush P. Menon, Philip Perfect, Ian Postlethwaite, Christophe Prieur, Thomas Richardson, John W.C. Robinson, Clement Roos, Maria E. Sidoryuk, Sophie Tarbouriech, Daniel J. Walker.

The Outcomes

The process of undertaking this research has been beneficial for all the participants, many of whom have taken part in previous related Action Groups and have by now developed effective working relationships. As usual, the information flow has been in both directions, with industrial members providing valuable insight into the real problems and challenges faced by control law designers, and academic researchers highlighting the potential (and potential shortcomings) of the latest nonlinear design and analysis methods. The project has been particularly valuable for the doctoral students and post-doctoral researchers who participated, since it allowed them access to truly challenging problems which are also of particular interest to industry. In these respects, the Action Group has certainly demonstrated the value of GARTEUR research to the European aerospace industry - it has made a significant contribution both to narrowing the "theory-practice gap" between academics and industry, and to educating the next generation of aerospace control engineers.

Web: www.garteur.org; Email: secretariat@garteur.org

6.2. Links with other European Programmes

As illustrated in the examples on the previous page there have been strong links between GARTEUR projects and EU Framework projects since the early 1990-ies, when the Framework programmes started.

As there are no dedicated budgets available for GARTEUR projects it was logical that the GoRs look for possibilities for external funding from EU or other sources as illustrated in the figure below. The members of the GoRs are involved in setting up cooperation projects within different European fora.

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

The nature of many GARTEUR projects often concerns low TRL topics and benchmarking of methods and the possibilities to get funding for this type of projects (Level 1 projects) within the Framework Programmes vary over time.

However, as illustrated in the example on the previous pages the knowledge and methods developed within the GARTEUR projects are the basis for participation also in projects on higher TRL levels.

Additional illustrations of the links between GARTEUR Action Groups and EU projects, as provided by GoR Aerodynamics and GoR Helicopters, are included on the following pages.

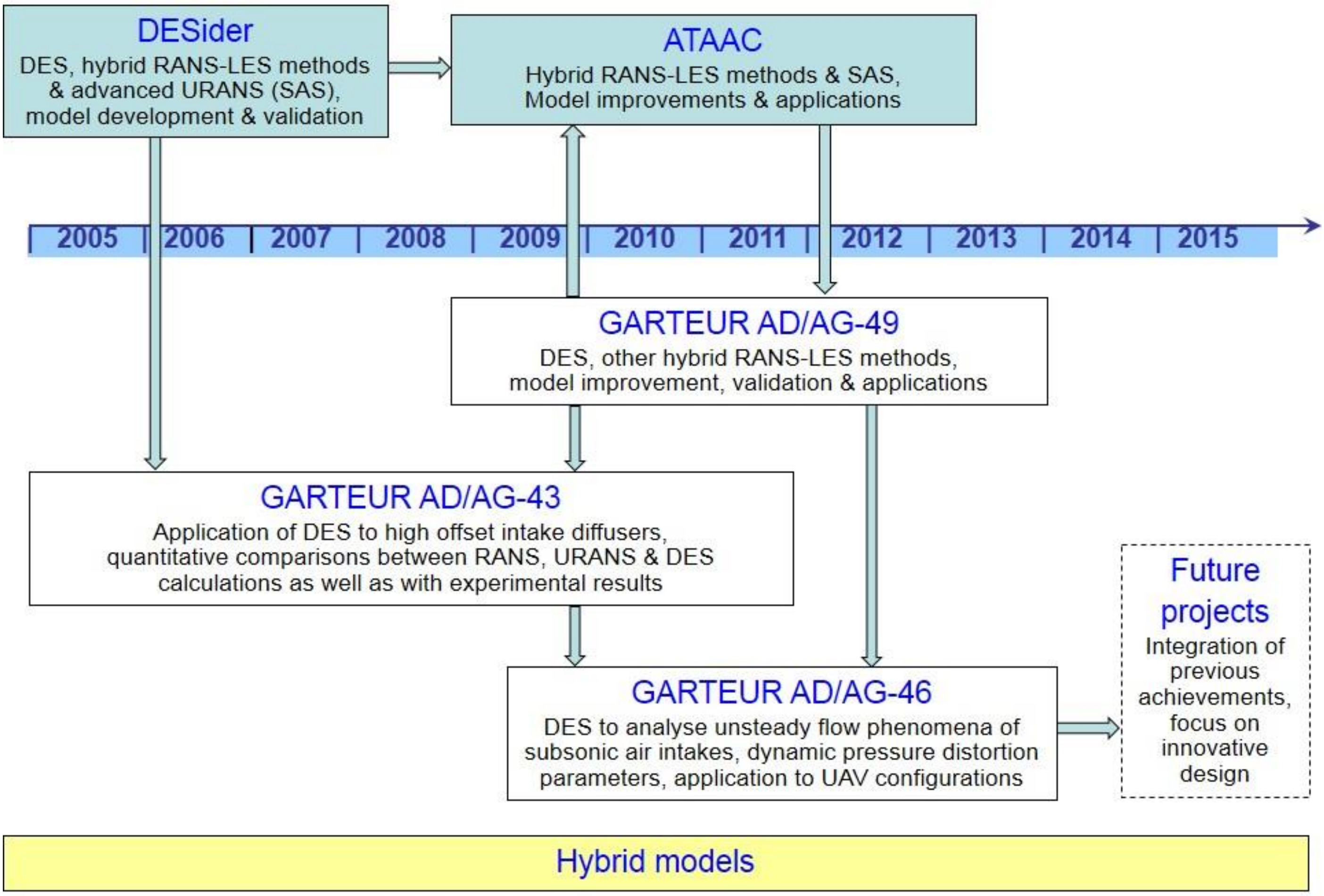
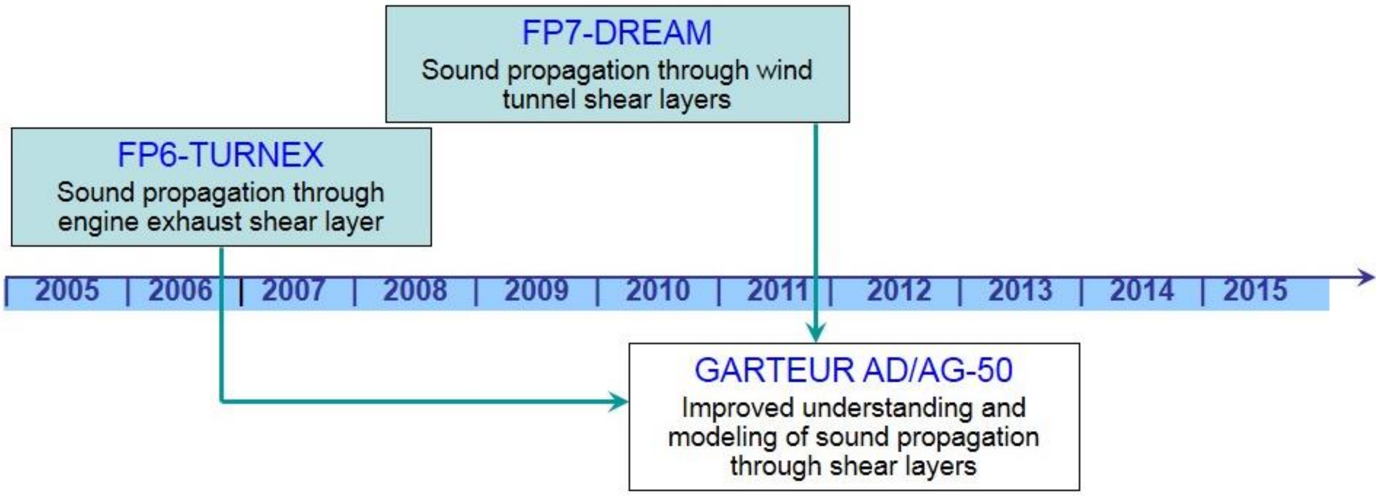


Figure 8: Links between EU-projects/proposals and GARTEUR AD/AG-43, AD/AG-46 and AD/AG-49



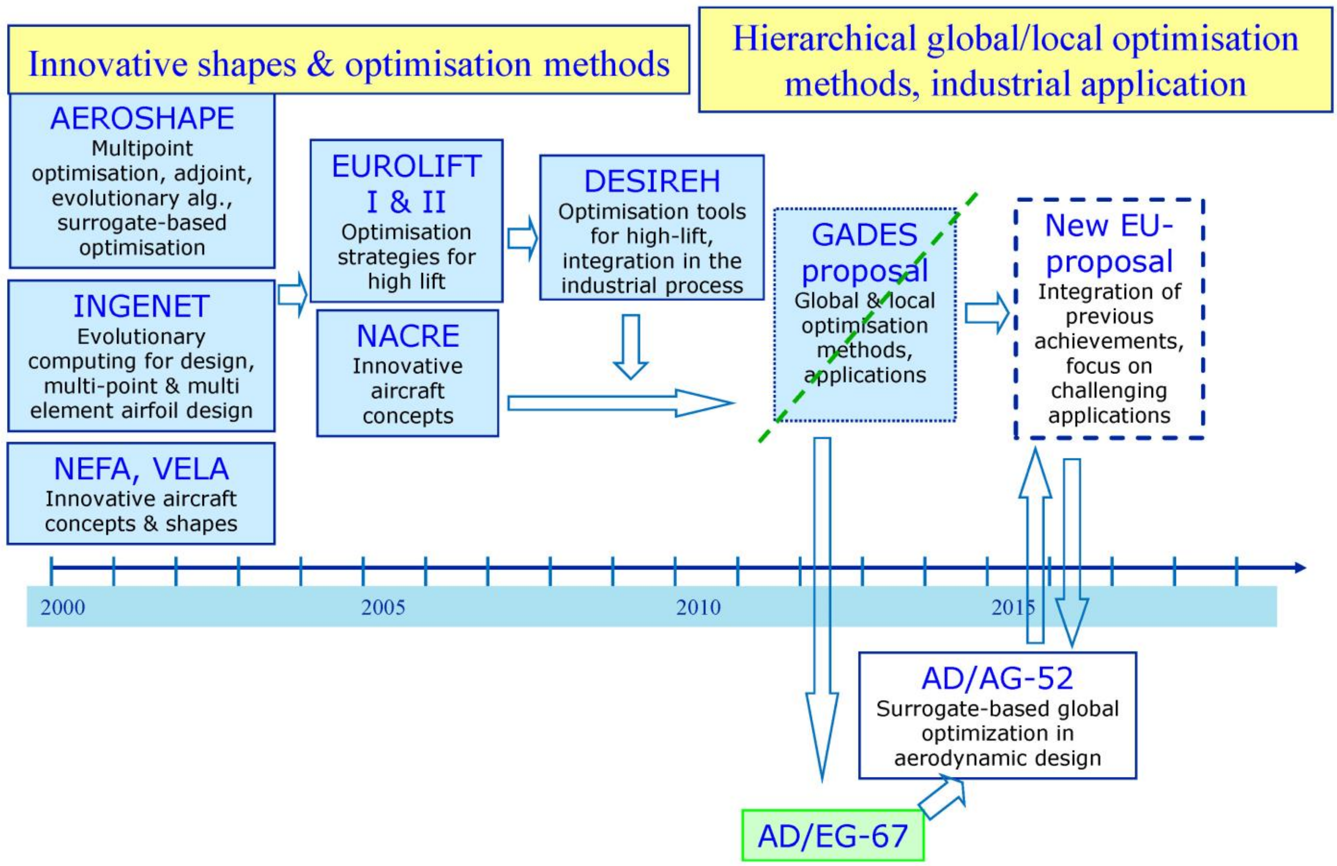
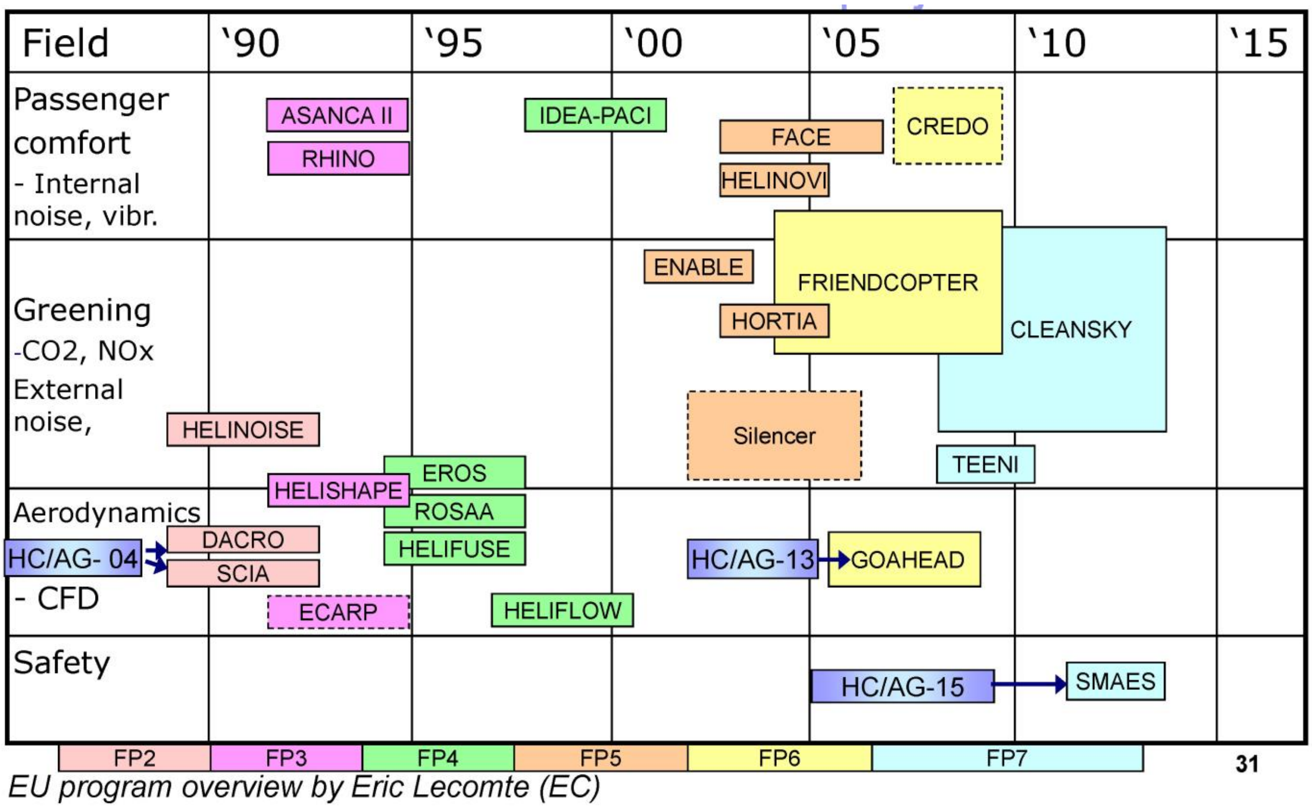


Figure 9: Links between EU-projects/proposals and GARTEUR AD/AG-50 and AD/AG-52



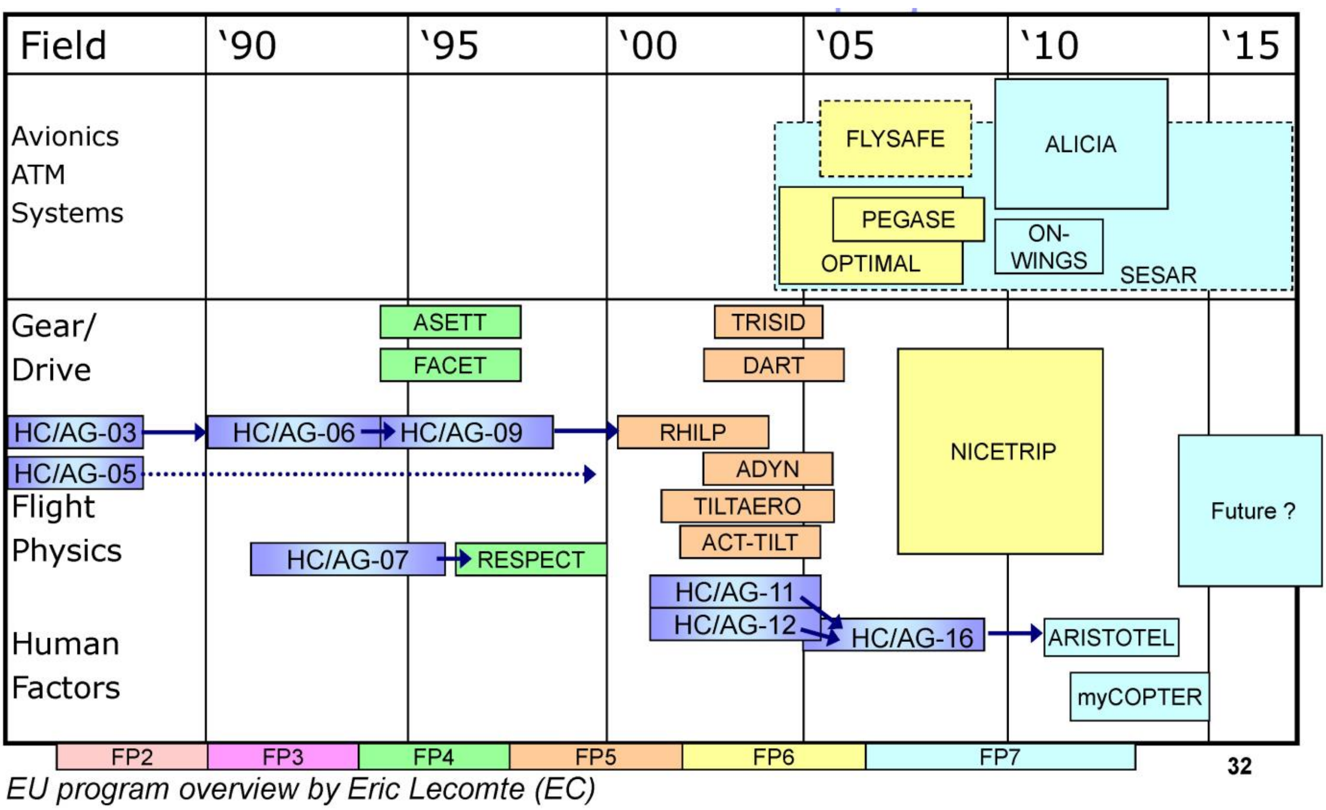


Figure 10: Links between EU-projects and a number of GARTEUR HC/AGs

7. REFERENCES

[1] GARTEUR Annexes to Annual Report 2015.
GARTEUR Document X/D 52, May 2016.

8. LIST OF TABLES AND FIGURES

9. APPENDIX 1: GARTEUR ORGANISATION

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

GARTEUR ORGANISATION

Updated 31st December 2015

GARTEUR Chair Country 2013-2015: France
Council Chair: Dr. Hervé Consigny, France
XC Chair: Dr. Olivier Vasseur, France
Secretary: Ms Anne-Laure Delot, France

GARTEUR COUNCIL

Function	France	Germany	Italy	Netherlands	Spain	Sweden	United Kingdom
Head of Delegation	H. Consigny	J. Bode	L. Vecchione	M. van Weelderen	B. Marques	A. Blom	L. Barson
XC Member	O. Vasseur	F. König	L. Paparone	B. Thuis	F. Muñoz Sanz	E. Bernhardsdotter	M. Scott
Other Members of Delegation	C. Griseri P. Desvallees	H. Konrad H. Hueners	D. Cucchi	H. van Leeuwen C. Beers	J.F. Reyes-Sánchez	J. Stjernfalk E. Lindegren	S. Weeks S. Pendry

GROUPS OF RESPONSABLES

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

Figure 11: GARTEUR organization

10. APPENDIX 2: OVERVIEW OF GARTEUR TECHNICAL ACTIVITIES

The table below presents the 6 years rolling plan 2012-2017 of GARTEUR Action Groups. Regarding new Action Groups in preparation see chapter 5.

6 years rolling Plan for AD/AGs and AD/EGs

No	Topic	2012	2013	2014	2015	2016	2017
AD/AG-48	Lateral Jet Interactions at Supersonic Speeds			Final report finalised in 2015			
AD/AG-49	Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications						
AD/AG-51	Laminar-Turbulent Transition in hypersonic flows				Reporting		
AD/AG-52	Surrogate-based global optimization methods in Preliminary Aerodynamic Design	EG67 =>					
AD/AG-53	Receptivity & Transition Prediction: Effects of surface irregularity and inflow	EG66 =>					
AD/AG-54	RANS-LES Interfacing for hybrid and embedded LES approaches		EG69 =>				
AD/AG-55	Countermeasure Aerodynamics			EG71 =>			
AD/EG-70	Plasma for Aerodynamics						
AD/EG-72	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configs						
AD/EG-73	Secondary Inlets and Exhausts						

Aviation Security

No	Topic	2012	2013	2014	2015	2016	2017
AS/EG-01	Cybersecurity						
AS/EG-02	CBE						
AS/EG-03	Dazzling						
AS/EG-04	Malevolent use of RPAS						

Flight, Mechanics, Systems and Integration

No	Topic	2012	2013	2014	2015	2016	2017
FM/AG-18	Towards Greater Autonomy in Multiple Unmanned Air Vehicles						
FM/AG-19	Flexible Aircraft Modeling Methodologies		X				

Helicopters

No	Topic	2012	2013	2014	2015	2016	2017
HC/AG-19	Methods for Improvement of Structural Dynamic FE Models using In-Flight Test Data						
HC/AG-20	Simulation methods and experimental methods for new solutions for internal noise reduction						
HC/AG-21	Rotorcraft Simulation Fidelity Assessment	EG30 =>					
HC/AG-22	Forces on Obstacles in Rotor Wake		EG32 =>				
HC/AG-23	Wind Turbine Wake and the Effect on Helicopters		EG32 =>				
HC/AG-24	Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction			EG34 =>			

Structures and Materials

No	Topic	2012	2013	2014	2015	2016	2017
SM/AG-30	High velocity impact				Report issued		
SM/AG-31	Damage Management of Composite Structures						
SM/AG-32	Damage Growth in Composites						
SM/AG-33	RTM Materials Properties during Curing				Report issued		
SM/AG-34	Damage repair with composites						
SM/AG-35	Fatigue and Damage Tolerance Assessment of Hybrid Structures						
SM/AG-36	Design for high velocity impact on realistic structure						

Active / Closed / X Stopped
Extended / Inactive
EGxx => EG number xx resulting into AG number yy

Table 7: GARTEUR Action Groups – 6 years rolling plan 2012-2017

11. APPENDIX 3: PARTICIPATION IN ACTIONS GROUPS BY NATIONS / ORGANISATIONS IN 2015

Country	Participants	GoR (Number of Action Groups)				
		AD(5)	FM(0)	HC(6)	SM(2)	TOTAL(16)
France	ONERA	4	0	5	0	9
	Industry	4	0	1	0	5
	Academia	1	0	0	1	2
Germany	DLR	3	0	5	1	9
	Industry	2	0	0	0	2
	Academia	2	0	0	0	2
Italy	CIRA	4	0	5	1	10
	Industry	0	0	2	0	2
	Academia	0	0	6	1	7
The Netherlands	NLR	2	0	6	1	9
	Industry	0	0	1	0	1
	Academia	0	0	3	0	3
Spain	INTA	2	0	0	1	3
	Industry	2	0	0	0	2
	Academia	1	0	0	0	1
Sweden	FOI	4	0	0	2	6
	Industry	2	0	0	2	4
	Academia	1	0	0	1	2
United Kingdom	DSTL	0	0	0	0	0
	Industry	1	0	1	1	3
	Academia	3	0	7	1	11

GoR	AG number	Research Establishments	Industry	Academic Institutes	TOTAL
AD	51	3	1	2	6
	52	4	2	2	8
	53	4	2	2	8
	54	6	3	2	11
	55	2	3	0	5
FM	/	0	0	0	0
HC	19	1	1	3	5
	20	4	1	1	6
	21	3	3	2	8
	22	4	0	4	8
	23	4	0	4	8
	24	5	0	2	7
SM	34	3	2	4	9
	35	3	1	0	4

Table 8: Participation in Actions Groups by nations / organisations in 2015

12. APPENDIX 4: RESOURCES DEPLOYED WITHIN ACTION GROUPS: PERSON-MONTHS AND OTHER COSTS IN K€

GoR	AG	2012		2013		2014		2015		2016		2017*	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	44			1	0								
	45	5	5	1	0								
	46	3	0	3	3	0	0						
	47	10		1	0	0	0						
	48	3	6	6	8	1	0						
	49	15	100	7	70								
	50	8	0	10	20								
	51	13	40	12	40	12	40	0	0	0	0	0	0
	52			20	45	23	63	23	63	23	63	0	0
	53			10	12	13	24	13	24	13	24	0	0
	54					18	100	22	140	22	140	5,5	50
	55							16	24	16	24	16	24
AD	**TOTAL**	**57**	**151**	**71**	**198**	**67**	**227**	**74**	**251**	**74**	**251**	**21,5**	**74**

GoR	AG	2012		2013		2014		2015		2016		2017*	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	18	30	6	12	8								
	19	0	0										
FM	**TOTAL**	**30**	**6**	**12**	**8**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

GoR	AG	2012		2013		2014		2015		2016		2017*	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	17	1	1										
	18	0	0										
	19	12	5	3	0								
	20	1	1	18	13	20	28	18	28				
	21			15,5		14,5	10	15	10				
	22							21,7	33,1	18,5	33,3	15	20
	23							14	1,6	22		18	
	24							30	66	25	48	22	34
HC	**TOTAL**	**14**	**7**	**36,5**	**13**	**34,5**	**38**	**98,7**	**138,7**	**65,5**	**81,3**	**55**	**54**

GoR	AG	2012		2013		2014		2015		2016		2017*	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	31	3											
	32	2											
SM	33												
	34	6	0	50	49								
	35	1	1	10,5	16	11	41,5	10	35	10	35	10	35
SM	**TOTAL**	**12**	**1**	**60,5**	**65**	**11**	**41,5**	**10**	**35**	**10**	**35**	**10**	**35**

GRAND TOTAL	**113**	**165**	**180**	**284**	**112,5**	**306,5**	**182,7**	**424,7**	**149,5**	**367,3**	**86,5**	**163**

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

** NOTE: Several Action Groups are planned to end during 2016, while others are in preparation to be started during 2016 and 2017. Hence it is not meaningful at this stage to estimate resources for 2017.*

13. APPENDIX 5: LIST OF GARTEUR REPORTS ISSUED IN 2015

13.1. Technical Reports

GARTEUR number	Action Group	National reference	Date of issue	Title	Authors	Distribution Classification Remarks
TP-179	AD/AG-44	/	Jan. 2015	GARTEUR AD/AG-44 “Application of transition criteria in Navier-Stokes Computations Phase II”	Compiled and Edited by T. Berglind	GARTEUR Open
TP-168	AD/AG-48	/	March 2015	GARTEUR AD/AG-48 “Lateral Jet Interactions at Supersonic Speeds”	P. Gnemmi et al	GARTEUR Limited
TP-183	SM/AG-30	/	March 2015	GARTEUR SM/AG-30 “High Velocity Impact”	L. Iannucci, M. Willows et al	GARTEUR Limited
TP-184	SM/AG-33	NLR-TR-2015-030	May 2015	GARTEUR SM/AG-33 “RTM material properties during curing”	C.P. Groenendijk	GARTEUR Open

Table 10: List of GARTEUR Technical Reports 2015

13.2. Executive Committee and Council

GARTEUR number	Date of issue	Title	Distribution Classification Remarks
X/D-49	June 2015	GARTEUR Annual Report 2014	GARTEUR Open
X/D-50	June 2015	GARTEUR Annexes to Annual Report 2014	GARTEUR Open

Table 11: List of GARTEUR reports issued by Executive Committee and Council in 2015

13.3. Conference Publications

The different Action Groups and GoRs did also make presentations at various technical conferences. This is noted in the respective GoR chapters in the Annex report (also included on the GARTEUR website).

13.4. Availability of technical reports

The GARTEUR Council decided the following regarding older GARTEUR technical reports:

- to make Open GARTEUR reports available on the website after 3 years;
- that the titles of all GARTEUR reports (also GARTEUR Limited) should be listed on the website;
- that most older reports should be declassified to GARTEUR Open and made available on the website;
- to implement these decisions available older reports have been scanned. Some reports are still missing.

By the end of 2015 the number of reports available on the website was 162.
Another 50 reports are still GARTEUR Limited and kept by the secretariat.

14. APPENDIX 6: LIST OF ABBREVIATIONS

ACARE	Advisory Council for Aviation Research and Innovation in Europe
AD	Aerodynamics
AS	Aviation Security
AG	Action Group
AirTN	Air Transport Net
ASD	Aerospace and Defence Industries Association of Europe
ASG	Aircraft Sectorial Group (within ASD)
ATM	Air Traffic Management
ATS	Air Transport System
AVT	Applied Vehicle Technology
BERR	Department for Business, Enterprise and Regulatory Reform, UK
BMWi	Federal Ministry of Economics and Technology, DE
BWB	Federal Office of Defence Technology and Procurement, DE
CDTI	Centre for the Development of Industrial Technology, ES
CFD	Computational Fluid Dynamics
CIRA	Italian Aerospace Research Center
DLR	German Aerospace Centre
DSTL	Defence Science and Technology Laboratory, UK
EADS	European Aeronautics Defence and Space company
EASA	European Aviation Safety Agency
EC	European Commission
EDA	European Defence Agency
EDTIB	European Defence Technological and Industrial Base
EFAPS	European Future Air Power Systems

EG	Exploratory Group
ERA	European Research Area
ERF	European Rotorcraft Forum
EREA	(Association of) European Research Establishments in Aeronautics
ESDP	European Security and Defence Policy
ESRP	European Security Research Programme
ETAP	European Technology Acquisition Programme
EU	European Union
FAS	Future Air Systems
FCAS	Future Combat Air Systems
FE	Finite Element
FM	Flight Mechanics, Systems and Integration
FOI	Swedish Defence Research Agency
FP	Framework Programme
GARTEUR	Group for Aeronautical Research and Technology in Europe
GMES	Global Monitoring for Environment and Security
GoR	Group of Responsables
HC	Helicopters
IMG4	Industry Management Groups
INTA	National Institute for Aerospace Technology, ES
ISMS	Information Security Management System
JAR	Joint Aviation Requirements
JTI	Joint Technology Initiative
NLR	National Aerospace Laboratory, NL
NS	Navier-Stokes
ONERA	Office National d'Etudes et de Recherches Aérospatiales (The French Aerospace Lab)
PIO	Pilot-In-the-loop Oscillations
PPP	Public-Private Partnership
R&T(&D)	Research and Technology (and Development)
RE	Research Establishment
STO	Science & Technology Organization (NATO)
SCT	Supersonic Civil Transport
SeNTRE	Security Network for Technological Research in Europe
SESAR	Single European Sky ATM Research
SM	Structures and Materials
SME	Small to Medium Enterprise
SRIA	Strategic Research and Innovation Agenda
SSA	Specific Support Action
TDP	Technology Demonstration Programmes
UAV	Unmanned Aerial Vehicle
XC	GARTEUR Executive Committee