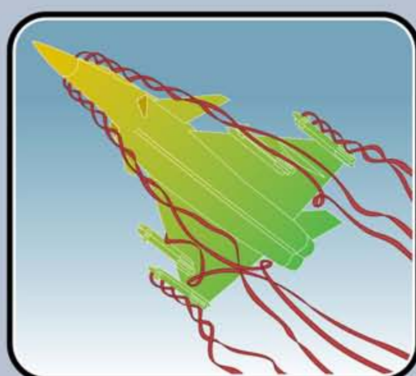
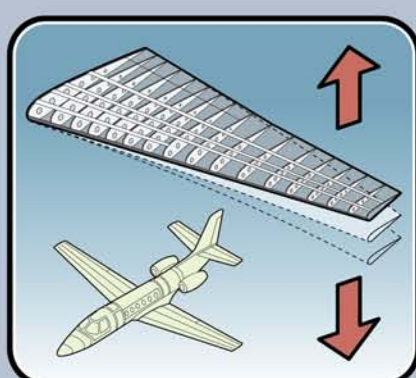
GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

Document X/D 45

GARTEUR Annual Report 2012





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ANNUAL REPORT 2012

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1. EXECUTIVE SUMMARY

Aviation is recognized as one of the top five advanced technology sectors in Europe. The European industry is currently a world leader in aviation and contributes very positively to European economic welfare. The role of Air Transport has never been more important to society than today, with changing demographics in an increasingly urbanised world, and the need for more long range transport to connect markets and people.

It is therefore vitally important that aviation is prepared to meet those challenges particularly as the long term market prospects for civil aircraft are so promising. Climate change is a major societal and political challenge, so aviation must improve its environmental performance to keep its total climate effects at sustainable levels. Research, technology and innovation are essential catalysts for a competitive and sustainable future and we need to start quickly to be effective. Industrial competition is fierce and increasing, not only from established regions but also from new, strong challengers notably China, India as well as Brazil, Canada and Russia. .

Aviation operates on long timescales for exploitation of technology and innovation both because of the complexity of the systems involved and 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.

Decision makers, stakeholders and society have recognized the strategic role of this industry and the need to maintain and extend its leadership through an appropriate and balanced regulatory framework putting European companies on a level playing field with their competitors from all over the world.

Maintaining global leadership for aviation in Europe and meeting the needs of citizens are thus the top level objectives that are addressed by the vision document ‘Flightpath 2050’ presented in 2011. It underlines the need for further emissions reductions, recommends maintaining and extending Europe’s leadership, enhancing safety and security as air transport needs grow as well as developing excellent research infrastructure and education for the sector. ACARE stakeholders have come together to develop the Strategic Research and Innovation Agenda (SRIA), presented in 2012, which provides details on the strategy the aviation sector commends to deliver to support that vision.

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.

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.

Through various European collaboration projects and studies European countries are paving the way for the next generation of Future Air Systems (manned and unmanned). It can be noted that there are a number of 5^{th} generation fighter programmes underway in different parts of the world, 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.

Towards this background GARTEUR arranged a workshop in Paris October 2012 in cooperation with EDA to discuss these challenges and the way ahead. The workshop focused around some recent studies performed by EDA and the industry, such as the FAS4EUROPE report “The Future of the European Military Aerospace Defence Technological Industrial Base (DTIB)”.

It was concluded at the workshop that there are some key questions and challenges to be resolved by the European nations involved:

- Is there a common will to retain aeronautic capabilities (industry and R&T) for joint defence purposes?
- How will Europe retain what is needed with increasingly constrained R&T and procurement budgets
- Long term R&T collaboration and technology demonstration up to TRL 6 is needed before work share in a joint fighter programme can be defined

The EU Heads of States meeting in December 2013, will have defence issues on the agenda and the future for European military aeronautics ought to be a key question at that meeting.

The present European environment for aeronautics RTD (Research and Technology Development) is briefly summarized in chapter 4. GARTEUR, as the only European network for civil and military collaboration in aeronautical R&T, has been working within this complex environment for a long time and has continuously adapted to meet new challenges. A key asset of GARTEUR is its unique mechanism for cooperation, which has been used successfully for numerous collaboration projects over the past decades. Beyond that, GARTEUR can stimulate R&T activities in the aeronautical framework programmes at national and European levels.

Growing budgetary pressures will increase the focus on dual use projects. The GARTEUR collaboration mechanism, which can be used for civil and military as well as for dual-use projects, provides a straightforward mechanism to increase collaboration on dual use projects without introducing new procedures. Partners with civil as well as military funding can easily work together.

Practice shows that GARTEUR projects are often continued in more application-orientated EU-funded projects, complementing national R&T efforts. Chapter 6 illustrates these links and highlights some GARTEUR success stories.

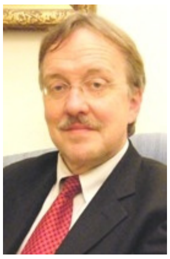
This Annual report includes a summary overview of GARTEUR projects (Action Groups) as well as new topics under consideration. The activities and projects of the Groups of Responsables are described in more detail in a separate report (GARTEUR X/D 46 - Annexes to the Annual Report 2012). These annexes can also be downloaded from the GARTEUR website.

The GARTEUR Council is a unique forum of 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.

The reports on the national situations in aeronautics, on the civil and military side, 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 year some of the GARTEUR countries, have formulated new national strategy plans and R&T programmes. These are made available at the GARTEUR website.

Sweden has been the GARTEUR chair country for 2010-2012
and is handing over to France for 2013-2014.

Gunnar Hult
Chairman
GARTEUR Council
(2010-2012)



2. INTRODUCTION

The GARTEUR Annual Report 2012 has been prepared by the Executive Committee for the 54th Council meeting to be held in Bonn March 14-15, 2013.

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 December 2011. Matters directly connected to Council activities or decisions are addressed in the next section on GARTEUR Council.

Chapter 4 presents an overview of the present 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 46 - Annexes to the Annual Report 2012). 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

Sweden has continued as the GARTEUR chair country also for 2012 (a third year) with
Prof. Gunnar Hult as the Council Chair and
Mr Björn Jonsson as the Chairman of the Executive Committee (XC) and
Mr Anders Gustafsson as the GARTEUR Secretary

In 2012 the following changes to the national delegations to GARTEUR Council took place:

France:
Mr Olivier Dugast, DGA replaced Ronan Cornen, DGA as Head of the French Delegation
Dr Olivier Vasseur, ONERA replaced Pierre Gicquel, ONERA (also as member of XC)

Italy:
Col. Daniele Cucchi replaced Col. Armando Bonavoglia

The Netherlands:
Mr Bert Thuis, NLR replaced Mr Christophe Hermans,NLR (also as member of XC)

Spain:
Mr Juan Francisco Reyes-Sánchez replaced Mr Miguel Ortiz Pajares

France will take over as the GARTEUR chair country for 2013-2014 and ONERA will manage the French chair period as follows:
Herve Consigny will be the Council chair
Olivier Vasseur will be the Executive Committee chair
Anne-Laure Delot will be the GARTEUR Secretary

The composition of the GARTEUR Council as of January 2013 is presented in Appendix 1.

Meetings

The GARTEUR Council met twice in 2012:

- C52 in Madrid, Spain on 15th -16th March 2012
- C53 in Paris, France on 26th October 2012

The Council meetings followed the usual meeting agenda with the main focus on recurring agenda topics i.e. the GoR chairmen report about the activities in the Action/Exploratory Groups on their 3-5 years rolling plans and the XC Chairman's report about the status of ongoing and planned GARTEUR actions w.r.t. the GARTEUR Action Plan.

An important point on the Council meeting agendas is the reports on the national situations in aeronautics, on the civil and military side. Members of the GARTEUR Council are also involved with several other European organisations and hence the GARTEUR Council meetings also act as an effective forum for information exchange. Several member countries have published strategy documents on aeronautics. The public versions of these are to be included on the GARTEUR website.

The Executive Committee (XC) met twice in 2012:

- XC149 in Bonn, Germany on 3rd February 2012
- XC150 in Malmö, Sweden on 4th September 2012

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

The GARTEUR Basic documents have been updated at the end of 2012 to comply with the changes agreed over the past 3 years.

Specific issues beyond the standard agenda items which were dealt with at the 2012 Council meetings are briefly summarised below:

Workshop on "Requirements for long term aeronautical R&T for military and dual-use applications"
A workshop on military R&T was held in connection with the Council 53 meeting in Paris in October 2012 with invited speakers from EDA and industry. More about this follows in chapter 4.

Contacts with industry
In order to strengthen the ties 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. During 2012 this was arranged in a slightly different way, related to the focus on long term planning for R&T in civil and military aeronautics:

At the Council 52 meeting in Madrid in March 2012, Mr Anders Rubensson, Saab, EUROMART chair within IMG4, gave an overview presentation of RTD projects and programmes performed and planned by the industry groupings within IMG4. The presentation contained:

- Prioritising Research & Testing Capabilities
- R&T Roadmap
- Strategic Technology Streams for Next FP

The technology overview and roadmaps developed within IMG4 could serve as guidelines for the GoRs when identifying suitable new topics for GARTEUR research.

The above mentioned workshop on military R&T had several participants (including speakers) from industry.

European Commission

As part of the preparations for the next EU framework program Horizon 2020 two letters were sent in 2011 to the Commissioners Máire Geoghegan-Quinn and Siim Kallas expressing a joint view from the GARTEUR Council on the role for Aeronautics/Aviation in Horizon 2020.

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).

Towards the end of 2012 it became clear that Aeronautics/Aviation will not get a separate budget line for Aeronautics/Aviation within Horizon 2020. Aviation will be contained under “Smart, green and integrated transport”.

Strategy discussions

At the Council meetings the status for ongoing and planned GARTEUR actions w.r.t. the GARTEUR Action Plan are discussed. At the 2011 Council meetings extra time was devoted to strategic discussions with the aim to strengthen the role of GARTEUR projects within the European R&T environment. This has been followed up during 2012 with some special actions.

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 and the enthusiasm and competence of the GoR members and GoR chairs is most important 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 2012 activities.

- Presentation by IMG4/EUROMART chair on industry plans and scope for EU-programmes

- Workshop on military R&T as follow up on the EDA study regarding Future Air Systems and also on EDA/ETAP CapTech studies. The aim is to couple basic R&T needs to long term military requirements for Future Air Systems.

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:

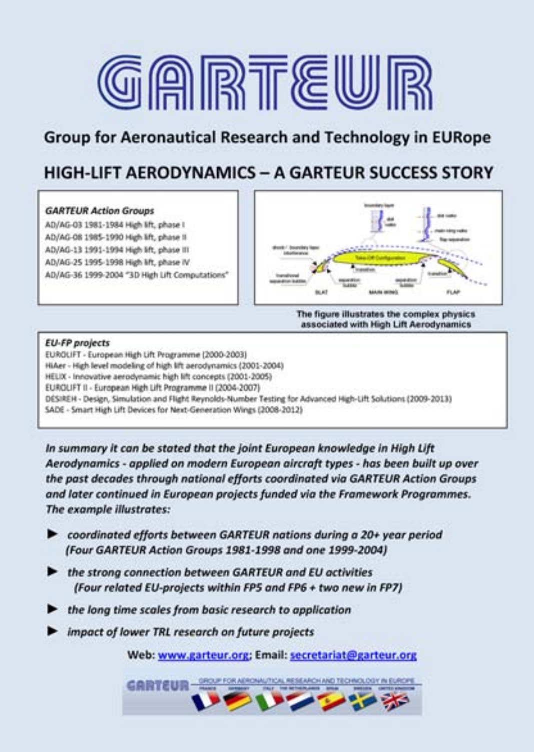
- benchmarking of codes and methods
- experimental data for validation of codes and criteria
- initial studies of new technologies with potential for future applications in aeronautics

The third type listed, implies a potential special role for GARTEUR. Lower TRL projects have difficulties to fit within EU-FP projects as well as within applied military projects. It could be a good role for GARTEUR to make sure that these needed projects are performed.

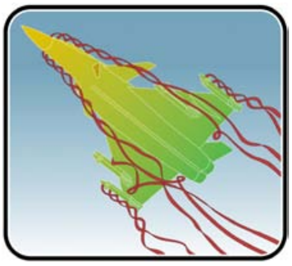
External Communication

The contacts and relations to other European fora are followed up at all GARTEUR Council meetings:
- In the field of civil aeronautics: with EU, ACARE, EREA, JTI and AirTN
- In the field of defense related organizations: with EDA, ETAP and NATO/RTO

During 2012 GARTEUR was present with posters and brochures to inform about GARTEUR as follows:
- July: Farnborough Air Show – Innovation Zone
- September: ILA Berlin as part of German Ministry exhibition
- September: ICAS 2012 in Brisbane – own “ministand”

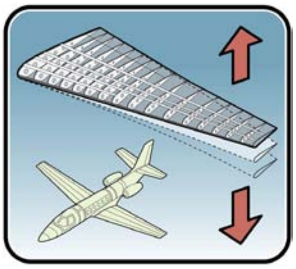


To streamline the information packages new symbolic pictures for each GoR have been developed.


AD-GoR


FM-GoR


HC-GoR


SM-GoR

GARTEUR Website and archive

The new GARTEUR website was launched in 2011. Dedicated pages to the four Groups of Responsables give information on 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.

Open Technical Reports are since 2011 made available on the website and a few more missing old reports have been found and have been included on the website. At the end of 2012 the number of available reports on the website is 166.

During 2012 some national strategy documents on aeronautics have been included or linked from the GARTEUR website.

Finally old documents, meeting minutes and annual reports from the paper archive have been scanned with the aim to have the entire archive in electronic form, when the secretariat is transferred from Sweden to France.

AirTN

The AirTN second phase will formally finish at the end of 2012. AirTN has been supporting ACARE in setting up the Strategic Research & Innovation Agenda (SRIA) and implementing Flightpath 2050. This is done by arranging workshops and other support activities.

AirTN arranged a workshop on “Aeronautical Research Infrastructures” in Brussels on 25th January 2012, which was well attended. AirTN has prepared a list of facilities and this database was presented at the workshop. A second workshop will be arranged in February 2013 in Brussels.

In the fall of 2012 the ACARE Member States Group initiated an Independent Expert Group (IEG) on Aviation Research & Testing Infrastructures in cooperation with AirTN. The IEG task and approach is twofold:

- Firstly defining immediate support need for research infrastructures that are at risk today
- Secondly to propose a scheme for a wider, long term support mechanism for the “strategic” European aviation research & testing infrastructure.

During 2012 AirTN launched a coordinated call with Spanish CDTI as responsible. Participant countries are: Spain, Austria, Ireland and Sweden. Four proposals were received.

GARTEUR Certificates

GARTEUR Certificates were in 2012 awarded to the following persons:

Germany:		
Michael Sinapius	GoR-SM member – left 2011	DLR
Thomas Berens	Chair AD/AG-43	Cassidian
France:		
Ronan Cornen	Head of Delegation - leaving 2012	DGA
Pierre Gicquel	Council and XC member - leaving 2012	ONERA
Jean-Luc Hantrais-Gervois	Chair AD/AG-45	ONERA
Italy:		
Arturo Minuto	GoR-SM IPoC	Alenia
Aniello Riccio	Chair SM/AG-31	Uni Naples
Netherlands:		
Christophe Hermans	Council and XC member - leaving 2012	NLR
Bimo Prananta	Chair AD/AG-47	NLR
Spain:		
Miguel Ortiz Pajares	Council and XC member - leaving 2012	CDTI

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.

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[1] from 2001 and the follow on Strategic Research Agendas[2] (2002 and 2004) have been cornerstones 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[4] at Aerodays 2011 in Madrid. During 2012 the follow up new Strategic Research and Innovation Agenda (SRIA) was published[5] and the next European Framework Programme "Horizon 2020" was being prepared.

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. 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 European leadership with an 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) has 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. The renewed ACARE does look 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.

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

Strategic Research and Innovation Agenda (SRIA)

The document will serve 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.

Challenge 1: Meeting societal and market needs

Targets by 2050
• European citizens are able to make **informed mobility choices**.
• 90% of travelers 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 neighbors, strategic and tactical air traffic management and supporting information, communication, navigation and surveillance infrastructure, and delivering system intelligence and autonomy.

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.

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.

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.

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.

Horizon 2020

The next EU Framework Programme for Research and Innovation has been named Horizon 2020. It will be running from 2014 to 2020 with a total budget initially set around €80 billion. It has three major objectives for research and innovation:

- **Excellence in the science base** – The aim here will be to strengthen the EU's world-class excellence in science by developing talent within Europe and attracting leading researchers to Europe.
- **Creating industrial leadership** 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 **'Tackling societal challenges'** will respond directly to the challenges identified in EU's growth strategy Europe 2020. It will support 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 currently exist. Implementation will be simplified and standardized, with simplification covering both funding schemes and rules. Key aspects will include: a rationalized set of funding schemes, a single set of rules, earlier project start and major externalization. In Horizon 2020 Aeronautics and Aviation will be found under Transport under a general heading "Smart, green and integrated transport".

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 infinitives for enhanced collaboration have been taken on the government side like:

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.

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.

European Defence Agency (EDA)
The European Defence Agency (EDA) was established under a Joint Action of the Council of Ministers on 12 July, 2004, to support the Member States and the Council in their effort to improve European defense capabilities in the field of crisis management and to sustain the European Security and Defence Policy (ESDP). EDA is composed of 26 participating Member States (all EU Member States, except Denmark).

The industry has through its organisation **AeroSpace and Defence Industries Association of Europe (ASD)** initiated related activities by its Aircraft Sectoral Group (ASG). This group presented in 2009 'A Food for Thought Paper' called **"**European Future Air Power Systems (EFAPS) in the 2035 perspective".

ASD/ASG recommended a national coordinated approach by a small number of EU nations which are strongly committed to developing FAS. This will give the nations a sovereign FAS solution (studies, demonstrators, programmes) with freedom of choice to meet their individual needs related to requirements, affordability, security of supply, sustainment of national key capabilities, and leverage with both other EU-nations as well as non-EU nations**.**

GARTEUR workshop October 2012
Towards the background described above GARTEUR arranged a workshop in Paris October 2012, in cooperation with EDA, to discuss these challenges and the way ahead. The theme of the workshop was *"Requirements for long term aeronautical R&T for military and dual-use applications".*

In the introduction from EDA the following statements were made:

- *A robust European Defence Technological and Industrial base (EDTIB) is a prerequisite for the European Defence Agency achieving its mission - of improving the EU's defence capabilities - and military aeronautics is a crucial part of that.*
- *While market forces will, in the end, determine the health of our industrial base it will be our investments particularly in R&T which will determine its strength and competitiveness.*
- *Europe's ability to produce sophisticated future aerospace systems is being eroded. Critical defence technologies and defence industrial capabilities are at risk across Europe. They depend on investment: particularly RT&D funding and programmes.*
- *Co-operative European aerospace development programmes, including collaborative research and development, are one way to avoid fragmentation and inefficiencies, but such programmes are few and far between.*

- *A more coherent European approach exploiting, where possible, the potential for common civil/military activities, would provide opportunities to better access emerging markets such as in the field of UAS.*
- *If a future world class European combat aircraft is the strategic objective the immediate tactical battle we face is getting Europe's policy right on Unmanned Aircraft Systems (UAS).*

Some recent studies performed by EDA and the industry were presented at the workshop as follows:

- ETAP Global Systems Study phase 2
- EDA Captech Studies
- EDA FAS4Europe

The ETAP Global Systems Study phase 2, performed by Alenia, EADS-Cassidian, Dassault and Saab provides an outline for the future air systems requirements based on the input from the governmental Capability Requirement Working Group (CRWG) with representatives from the national Air Forces. The goal of the GSS study was to define the Technology Needs of the future generation of FCAS applicable to the participating European nations and to derive the technology prioritisation and specification of the subsequent technology requirements. The report *"ETAP GSS PHASE 2 Final report, GSS-2.ES.SEW.W.0008 Issue 1"* was issued November 2011.

The aim of the EDA CapTechs (Technologies for Capabilities) is to propose R&T activities in response to agreed defence capability needs and to generate projects accordingly. The management and the planning of the research activity in each technology domain contributes to establish Strategic Research Agendas (SRA) for the respective technology area. EDA CapTech efforts within *ESM02 "Air Systems & their Environment"* have focused on technologies for the improvement of the performance, affordability, and capabilities of aircraft systems. A report *"Strategic Research Agenda for the CapTech ESM02 Air Systems & their Environment"* was issued in 2012.

The EDA study "Future Air Systems for Europe" (FAS4Europe) was launched in 2010. It has the objectives to prepare an initial roadmap for the European Future Air Systems and to propose an implementation roadmap for the next 10 years. The study was performed by the European aeronautical industries and they presented their report *"Meeting future European defence and security challenges requires a strategic approach to the Aeronautics EDTIB"* in December 2011.

The FAS4Europe study has identified the required key industrial capabilities necessary to enable Europe continued access to cost effective sovereign military Future Air Systems (FAS) in strategic areas in the 2035 timeframe. The study includes an analysis, an initial roadmap and proposed appropriate actions for starting the implementation, in an overall European context. The future development plans for already established European air system programmes are not described in the report.

FAS4Europe study conclusions:

- Europe's ability to access sovereign FAS is now at a turning point.
- The aeronautics EDTIB is eroding and if appropriate measures are not taken it is at risk.
- Lost capabilities will be very difficult and costly to recover.
- A window of opportunity exists if action is taken now.

FAS4Europe study recommendation is to launch a three phase roadmap and implementation plan:

- <u>Roadmap Phase 1 (2012 – 2017): Keeping options open</u>
  A set of projects that will:
  - Sustain industrial capabilities.
  - Start maturing technologies.
  - Prepare cooperation and business models.
  Preparation of Roadmap Phase 2.

- Roadmap Phase 2 (2017 – 2022): Preparing for the future
  A set of substantial project proposals:
  - To develop required industrial capabilities.
  - To reduce risks in future development programmes.
  FAS demonstrator programmes will be important.
  Preparation of Roadmap Phase 3.

- Roadmap Phase 3 (2022 >): Securing a competitive EDTIB
  Preliminary proposals focusing on developing the identified FAS EDTIB longer term needs.
  Substantial FAS development programmes are necessary.
  Preparation of further EDTIB development.

In a final comment from EDA it was underlined that Europe's future independence of action is at stake and that it is vital that Europe retains the skills and know-how to design, produce, maintain and support defence air systems. Already the Star 21 report in 2002 pointed out that *"Unless Europe maintains these capabilities and develops them further, there is a real risk that Europe's ability to act will be determined by the US through its dominance over the supply of certain types of equipment, or support to systems already delivered".*

After the above presentations a general discussion was held on how these challenges will be met and each national delegation was asked to make statements regarding:
- Interest for participation in the suggested FAS4Europe 3-phase approach ?
- Specific interests for the examples noted:
  Phase 2 (ISR UAV or UCAV);
  Phase 3 (Manned Combat Air Vehicles – 5th generation)
- Is national funding available or can it be anticipated ?
- Plans for upgrading of legacy systems and possible timing clashes
- Critical R&T needs and needed demonstrator programmes
- Requirements for long term R&T for military applications

The general conclusion from the GARTEUR workshop was that there is a clear need to retain European aeronautic capabilities (industry and R&T) for defence purposes but that present efforts are not enough to secure this. However there are some key questions and challenges of political nature to be resolved by the European nations involved:
- Is there a common will to retain aeronautic capabilities (industry and R&T) for joint defence purposes?
- How will Europe retain what is needed with increasingly constrained R&T and procurement budgets?
- Long term R&T collaboration and technology demonstration up to TRL 6 is needed before work share in a joint fighter programme can be defined

The EU Heads of States meeting in December 2013, will have defence issues on the agenda and the future for European military aeronautics ought to be a key question at that meeting. It was agreed that each GARTEUR delegation should, via their national channels, push for supporting EDA in bringing European military aeronautics issues on the agenda for EU Heads of States meeting.

5. SUMMARY OF TECHNICAL ACTIVITIES

The total volume of technical activities in the Action Groups was at a somewhat lower level in 2012 compared with 2011. One reason is that a number of Action Groups are finalizing while new Action Groups in preparation are in a starting up phase.

GoR - AD monitored 9 Action Groups during 2012 - one of them was completed and one starting up its activities in 2012. The activities of this GoR were roughly at the same level as in 2011. One more Action Group is expected to start early 2013.

GoR - FM monitored 2 Action Groups during 2012- one of them has a severe delay.
The activities of this GoR were at a lower level compared with 2011.

GoR - HC monitored 4 Action Groups during 2012 - one of them starting up and one with problems that resulted in a decision to close it. The activities of this GoR were at a lower level compared with 2011. One more Action Group is expected to start early 2013.

GoR - SM monitored 4 Action Groups during 2012. Two of these were finalizing their reports and two new Action Groups were started. The activities of this GoR were at a higher level compared with 2011 and are increasing. One more Action Group is expected to start early 2013.

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

Appendix 2 shows an overview of GARTEUR Technical activities 2009-2014

Appendix 3 shows the participation in the Action Groups by nations/organizations in 2012.

Appendix 4 shows the resources deployed within Action Groups

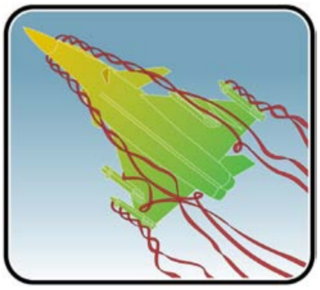
Appendix 5 lists the Technical Reports that were finalised in 2012. Furthermore a number of conference presentations were made by some of the Action Groups.

The following pages presents the technical highlights from the four GoRs mainly as one page posters for Action Groups active during 2012. The situation regarding Exploratory Groups and potential new topics is also described.

Detailed reports of the GoR activities 2012 are included in a separate document (X/D 46 - Annexes to the Annual report 2012). 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.

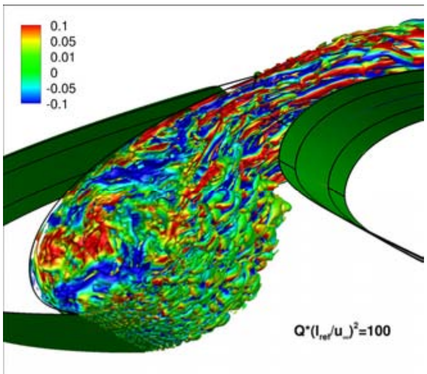
Group of Responsables - Aerodynamics (AD)

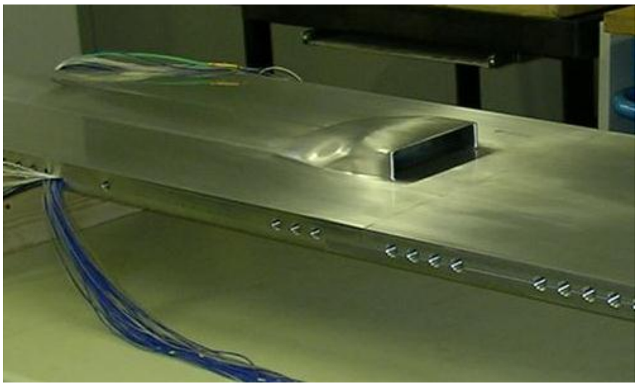


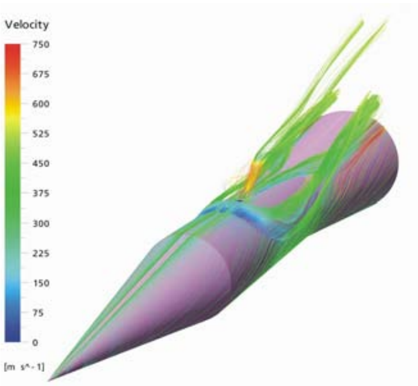
GoR AD initiates and organises basic and applied research in aerodynamics, often coupled to other disciplines. Recent and on-going research activities have been and are devoted to:

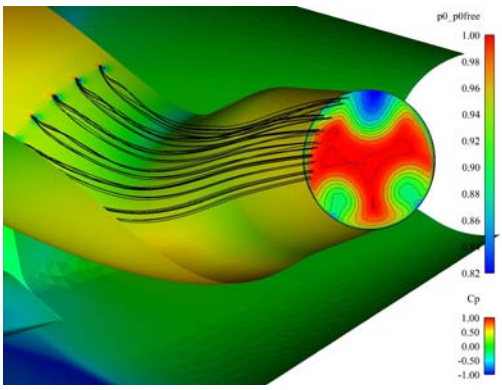
- Aerodynamics
- Aerothermodynamics
- Aeroacoustics
- Aeroelasticity
- Aerodynamic shape optimisation
- Aerodynamics coupled to Flight Mechanics
- Aerodynamic Systems Integration

The trend towards more multi-disciplinary analysis, emerging from industrial requirements, will increase in the future.









During 2012 GoR - AD monitored the following Action Groups:

AD/AG-43 Applications of CFD to High Offset Intake Diffusers (only report work)
AD/AG-45 Application of CFD to predict high "G" loads
AD/AG-46 Highly Integrated Subsonic Air Intakes
AD/AG-47 Coupling of CFD with Flight Mechanics Model
AD/AG-48 Lateral Jet Interactions at Supersonic Speeds
AD/AG-49 Hybrid RANS-LES Methods for Aerodynamic Applications
AD/AG-50 Effect of open jet shear layers on aeroacoustic wind tunnel measurements
AD/AG-51 Laminar/turbulent transition in hypersonic flows (starting up)

For the Action Groups 45-51 a one page summary poster is included on the following pages.

The situation regarding Exploratory Groups and New Topics under review was as follows end 2012:

GoR - AD Exploratory Groups

Three Exploratory Groups have been running throughout 2012. As several AD/AGs are close to finish it is important that the new Exploratory Groups develop into Action Groups.

AD/EG-66: "Receptivity and Transition Prediction"
(had its kick-off meeting March 2012 – expected to become an AG in 2013)
AD/EG-67: "Surrogate-based Global Optimization Methods in Preliminary Aerodynamic Design"
(will be launched as AD/AG-52 early 2013)
AD/EG-68: "Fluidic and Synthetic Jets" (workshop planned for March 2013)

New Topics

The following topics are considered for Exploratory Groups in 2013:

- Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations
- Thrust vectorization

Membership GoR - AD 2012

Chairman		
Torsten Berglind	FOI	Sweden
Vice-Chairman		
Norman Wood	Airbus Oper. Ltd	United Kingdom
Members		
Geza Schrauf	Airbus Oper. GmbH	Germany
Giuseppe Mingione	CIRA	Italy
Henning Rosemann	DLR	Germany
Fernando Monge	INTA	Spain
Koen de Cock	NLR	The Netherlands
Ernst Totland	SAAB	Sweden
Eric Coustols	ONERA	France
Industrial Points of Contact		
Didier Pagan	MBDA	France
Michel Mallet	Dassault	France
Thomas Berens	CASSIDIAN Air Systems	Germany
Nicola Ceresola	Alenia	Italy
Luis P. Ruiz-Calavera	Airbus Military	Spain
Chris Newbold	Qinetiq	United Kingdom

AD/AG-45:
Application of CFD to predict high “G” loads

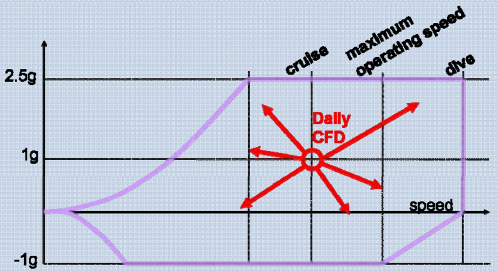
Action Group Chairman: Dr Jean-Luc Hantrais-Gervois, ONERA
(Jean-Luc.Hantrais-Gervois@onera.fr)

Background

CFD methods to tackle the load envelopes of a civil aircraft
civil aircraft, fit-for-purpose CFD for the industrial loads process

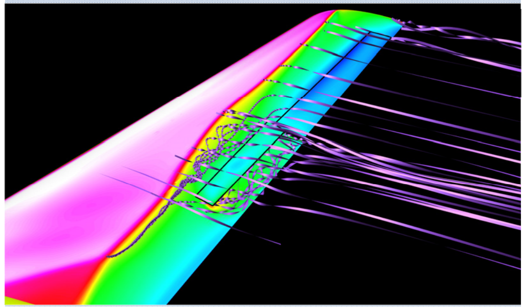
High g conditions
control surfaces (spoiler, aileron), high lift coefficient (flow separation), high transonic Mach number

Multi-disciplinary aerodynamics
steady RANS, aeroelastic coupling, turbulence modeling



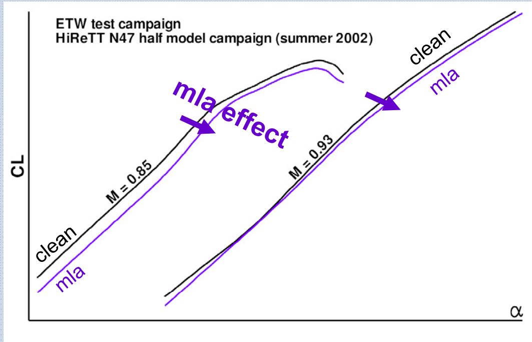
Previous activity
built upon the HiReTT EC program (ETW tests and control surface simulations)

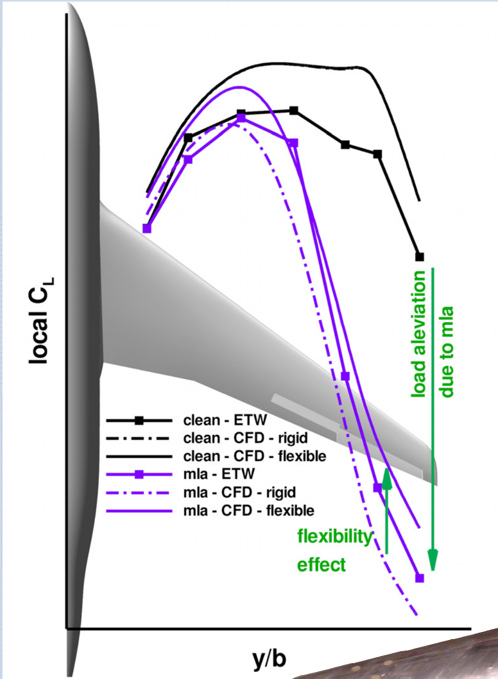
Preparation to the ALEF EC program (Aerodynamics Loads Estimation at Extremes of the Flight Envelope)



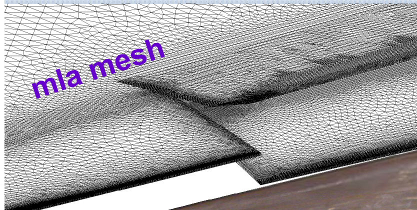
Programme / Objectives

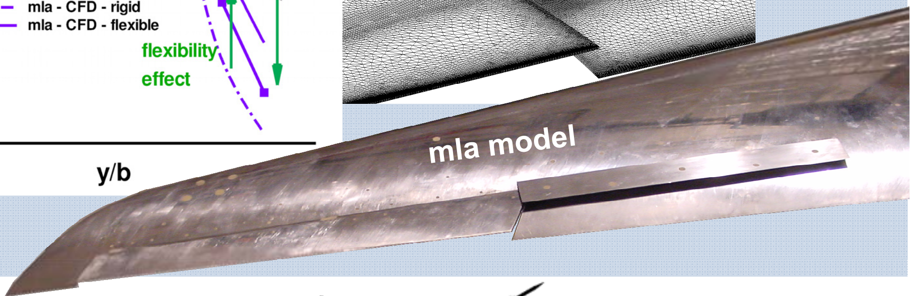
Objectives of AD/AG-45
investigate structured and unstructured numerical approaches to feed an industrial loads process
Focus
turbulence modeling
control surface modelling (meshing)
Numerical methods
steady Reynolds-Averaged Navier-Stokes (RANS)
aeroelastic coupling
Partners
3 industrial partners and 4 research establishments
several major European flow softwares
(EDGE, elsA, NSOLVE, TAU, UNS3D)





Experimental test cases
HiReTT data
ETW wind tunnel test at high Reynolds number
Clean wing and manoeuvre load alleviation configuration
Configuration clean wing
clean wing body configuration
representative of a modern large civil aircraft
Configuration MLA (manoeuvre load alleviation)
same as configuration + outer wing control surfaces
aileron deflected 10º up
spoiler deflected 10º up





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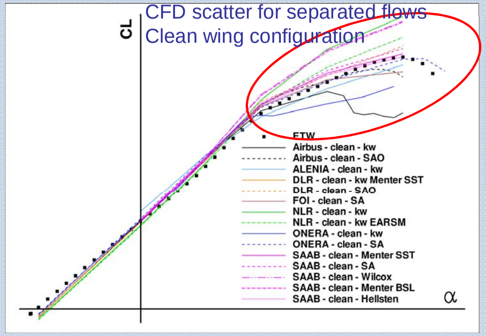
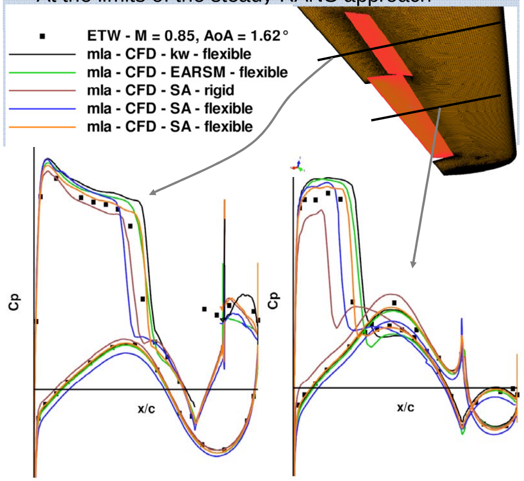
Results



Separated flows
- Fair flow separation predictions when separation is triggered by geometry (control surfaces)
- Still some progress required in RANS methods for physically triggered flow separation
- Need for specific turbulence model formulations
- At the limits of the steady RANS approach



Numerical methods for the industrial loads process
- Unstructured methods handle control surfaces more rapidly than structured ones
- Good global predictions
- Aeroelasticity affordable and necessary

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

AD/AG-46: Highly Integrated Subsonic Air Intakes

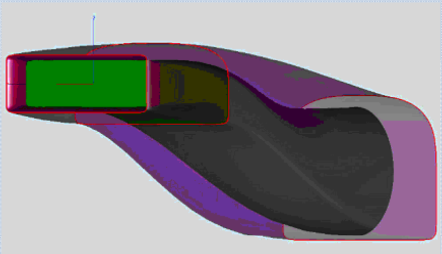
Action Group Chairman: Dr Thomas Berens, CASSIDIAN (Thomas.Berens@cassidian.com)

Background

Unsteady internal aerodynamics for UAVs: Dynamic performance of highly integrated subsonic air intakes, low-observable diffuser design

Application of modern hybrid CFD methods: Detached Eddy Simulation (DES) of internal flow field with separation, code validation

Challenge: Time-accurate prediction of dynamic intake performance parameters for enhanced assessment of engine/intake compatibility



Previous activity: Investigations in AD/AG-43 on the application of CFD to high offset intake diffusers

State of the art: CFD methods for steady and unsteady simulation of subsonic internal flow

Critical flow region: Separation at intake cowls and in high offset intake diffuser due to low-observable UAV design features

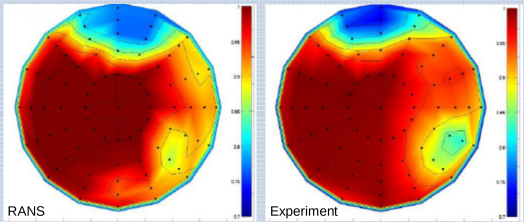
Programme/Objectives

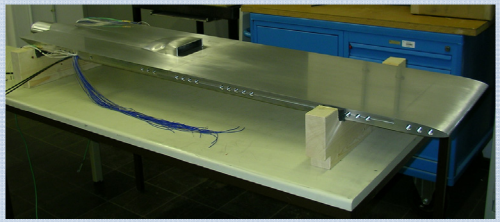
Main objectives of AD/AG-46: (1) to investigate the capability of modern CFD methods (Detached Eddy Simulation DES) to analyze unsteady flow phenomena of highly integrated subsonic air intakes, (2) to support innovative design for advanced subsonic aerial vehicles, and (3) to assess the flow behavior at the intake cowls due to complex multi-disciplinary lip shaping addressing installed intake performance

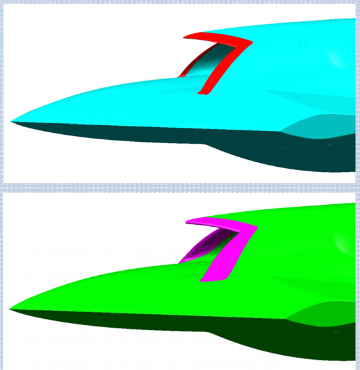
Focus: Numerical simulations of unsteady internal flow in a subsonic air intake highly integrated into the airframe of a UAV applying different standard CFD methods and DES.
Parametric studies of innovative intake design features accompanied by basic experimental investigations addressing low-observable intake design issues for UAVs and contributing to a better understanding and correlation of installed performance predictions of highly integrated intake configurations.

Partners: CASSIDIAN, ONERA, FOI, AIRBUS Military, DLR, SAAB, MBDA, Alenia, Dassault-Aviation

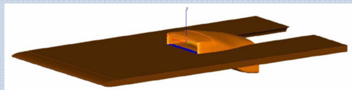
Activity: Numerical simulations for the EIKON UAV intake wind tunnel model with a variety of CFD methods and validation with T1500 wind tunnel test data; experimental investigations with a generic intake wind tunnel model in the cryogenic WT DNW-KRG at DLR Göttingen for parametric studies.

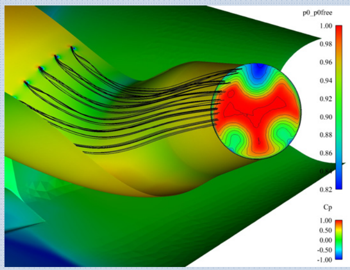






- Assessment of dynamic distortion coefficients at engine face and comparison with test data
- Simulations for internal active flow control by employing numerical models for micro-jets
- Computational study on multi-disciplinary intake lip shaping as a major design parameter impacting the intake total pressure recovery





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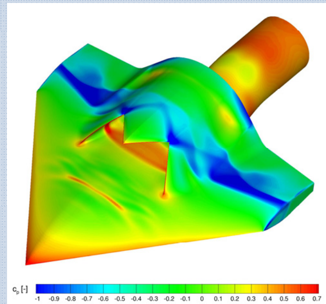
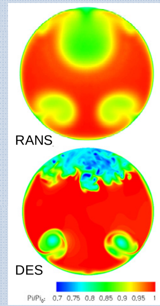
Results

Investigation of the capability of modern CFD methods (DES) to analyze unsteady internal flow phenomena

- The basis for time-accurate predictions of intake performance parameters and especially of dynamic intake distortion will be enhanced in order to prepare the groundwork for engine/intake compatibility assessment with accuracy levels meeting industrial demands.
- To accompany the design process of highly integrated subsonic air intakes, efficient hybrid CFD methods are a vital means in order to reduce development time and cost. Improved prediction capabilities for unsteady flows will enhance the ability to design such intake configurations efficiently, and expenses for wind tunnel experiments could be reduced by increasing numerical support.





Assessment of the flow behavior of diverterless intake designs due to multi-disciplinary shaping

- Fundamental experimental studies of decisive intake design parameters will advance the knowledge innovative design of compact air induction systems requires and will verify theoretical approaches through correlation.
- Numerical investigations on intake cowl shaping will provide interesting insight into the impact of this major design parameter on internal flow and intake performance.

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AD/AG-47: Coupling of CFD with Flight Mechanics Model

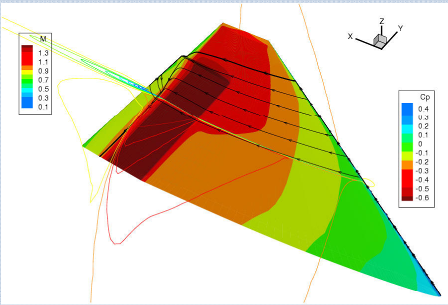
Action Group Chairman: Dr Bimo Prananta, NLR (Bimo.Prananta@nlr.nl)

Background

Flight mechanics cases influenced by non-linear aerodynamics:
unusual flight attitude, loads at extreme of flight envelope, departure recovery

Increasing readiness of unsteady CFD:
adequate accuracy, quick turn around, safe to deploy compared to flight test

Challenge:
reliable coupling method between CFD and flight mechanics model, best practices



Previous activity: successfully completed AG/AD-38 on unsteady CFD methods

State of the art: unsteady aerodynamics for prescribed rigid motion

Conclusions: CFD can simulate complex unsteady flows due to rigid body motions

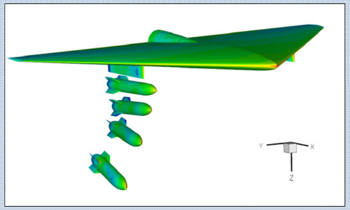
Programme/Objectives

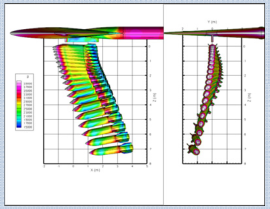
Main objectives of AD/AG-47: (1) to provide a platform to communicate and validate the development and applications of CFD coupling to flight mechanics models; (2) to gain knowledge on non-commanded flight mechanics motion caused by non-linear aerodynamic phenomena; (3) to define a suitable test set up, by means of numerical studies, for validating the algorithms and gaining further knowledge on non-commanded flight mechanics motion.

Partners: industries, research establishments and university
AIRBUS-MILITARY, ALENIA, CASSIDIAN, DLR, FOI, NLR, ONERA, University of Liverpool

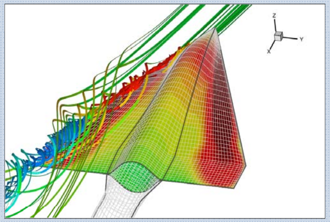
Activities: Numerical simulations of aerodynamics coupled to flight mechanics and validations using wind-tunnel data

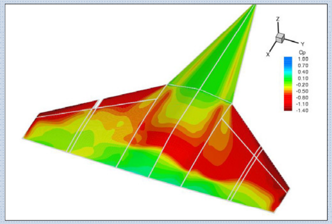
Case 1 AGARD store release
- availability of test data
- needs complex grid handling



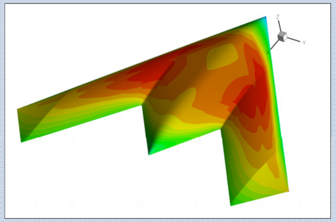


Case 2 rolling motion of wings
- non-linear aerodynamics
- vortex breakdown
- transonic abrupt stall



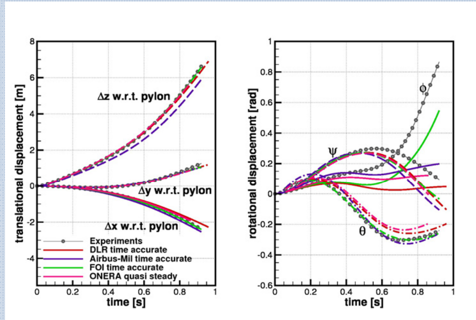


Case 3 longitudinal motion of UCAV
- realistic configuration



AIRBUS MILITARY, CASSIDIAN, FOI, ONERA, AleniaAeronautica A Finmeccanica Company, DLR, NLR, UNIVERSITY OF LIVERPOOL

Results



- various strategies of solving six-DOF EOM implemented and verified
- various implicit CFD-FM coupling methods developed, quasi-steady and time-accurate
- grid strategies successfully applied:
  grid deformation+regridding, chimera overset
- store release test case
  - wing-interference effects are important
  - comparable accuracy of quasi-steady with assumed aerodynamic damping and time accurate
  - experimental data reproduced
- results of rolling motion of wings
  - nonlinear response due to vortex breakdown is fully captured
  - exploratory study to obtain abrupt wing stall using SiS wing results in a too-weak roll moment, more studies underway
- results of longitudinal motion of UCAV
  - results in linear region obtained, typical short period+phuigoid mode observed

Conclusion:
- improved readiness of coupled CFD-FM method for simulation of nonlinear flight mechanics problems

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

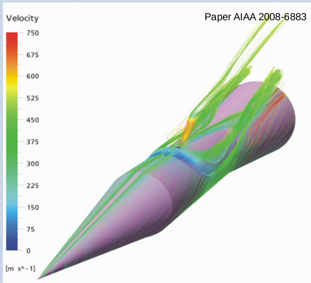
Action Group Chairman: Dr Patrick Gnemmi, ISL (patrick.gnemmi@isl.eu)

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

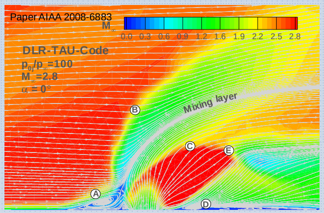
Challenge: defining the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet



Previous activity: basic experiments and wind-tunnel tests on generic missiles conducted at DLR, ISL and ONERA allowed a better under-standing 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 hot multi-species gas jets with the cross-flow of a supersonic missile at acceptable computational costs; (2) to deeply analyse the effect of hot-gas jets from numerical simulations; (3) to define the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet

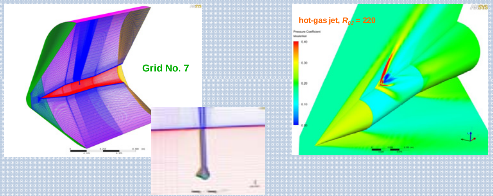
Focus: (1) numerical simulation validations of the interaction of cold-air and hot-gas jets with the cross-flow of supersonic missiles using different Reynolds-Averaged Navier-Stokes (RANS) codes and experimental data from DLR Cologne and ONERA/MBDA-France; (2) numerical simulations for the replacement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

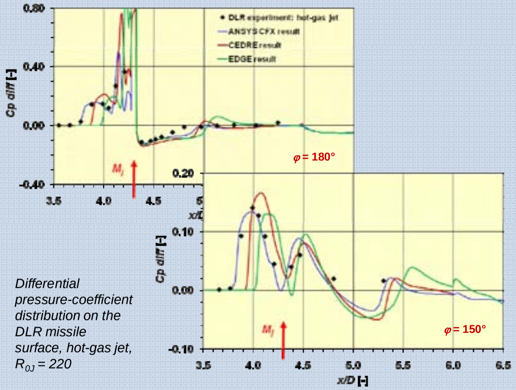
Partners: DLR Cologne, FOI, ISL, MBDA-France, MBDA-LFK, ONERA

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

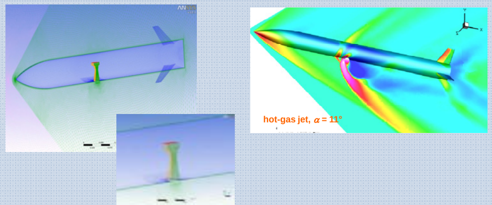


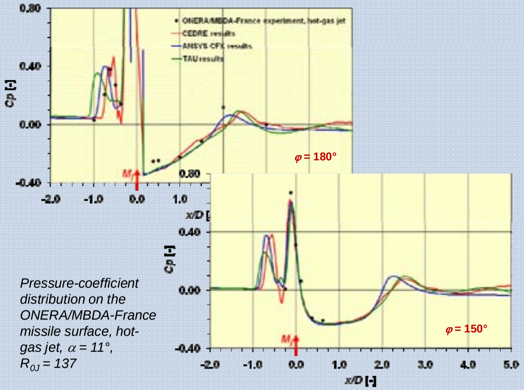


Differential pressure-coefficient distribution on the DLR missile surface, hot-gas jet, $R_{0J} = 220$

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 ONERA THE FRENCH AEROSPACE LAB

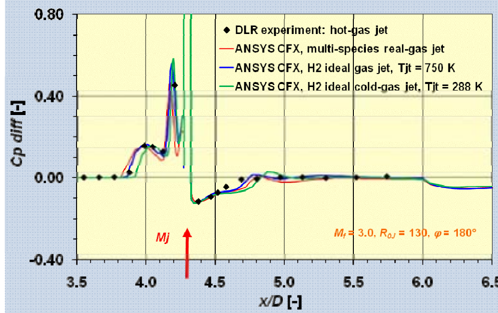
Results

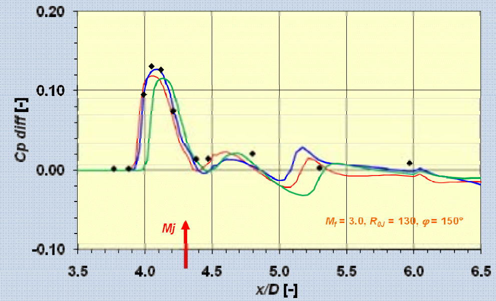
Prediction of cold-gas and hot-gas lateral jet interaction with missile cross-flow

- 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/AG-49:
Hybrid RANS-LES Methods for Aerodynamic Applications

Action Group Chairman: Dr Shia-Hui Peng, FOI (peng@foi.se)

Background

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

A number of hybrid RANS-LES modelling approaches have been developed in previous projects, validated and applied to a wide variety of turbulent flows.

Current work in AD/AG-49 focus on an exploration of modelling capabilities in resolving some underlying flow physics in typical aerodynamic applications, e.g., free shear layer, confluence of BLs and wakes, flow separation, recirculation and reattachment. Several selected hybrid RANS-LES methods (including wall-modelled LES, WMLES) are scrutinized and evaluated. Some further modelling improvements are also undertaken.

Fundamental aspects: hybridization of RANS and LES modes, modelling evaluation and improvement, modelling-related numerical issues.

Aerodynamic applications: high-lift flows with boundary-layer separation, vortex bursting and shedding, and unsteady flow phenomena associated potentially to flow control and aero-acoustic noise generation.

Partners: Research and academic organizations : CIRA, DLR, **FOI**, INTA, NLR,ONERA and TUM.

Programme/Objectives

Main objectives of AD/AG-49: To evaluate and to further improve selected hybrid RANS-LES methods with a focus on the simulation and modelling capabilities of handling B.L. separation, shear-layer instabilities and vortex motions and, further, to bridge the gap between "academic" modelling and industrial application.

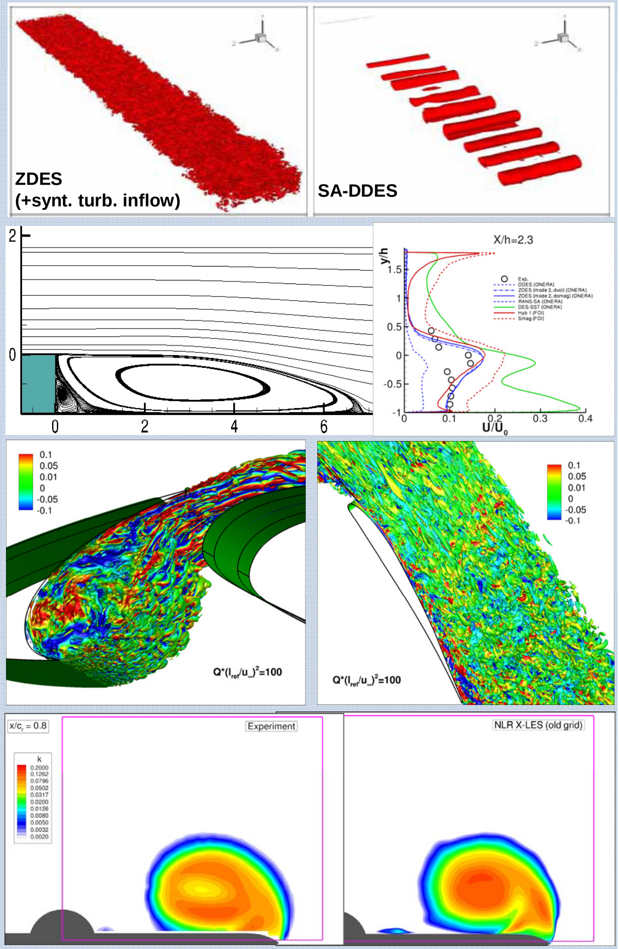
Work plan: The work in AD/AG-49 is divided into three tasks. Task 1 and Task 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3

TC 1.1 Spatially developing mixing layer
Participants: **NLR**, FOI, INTA, ONERA & TUM
Flow conditions: U_1 = 41.54 m/s, U_2 = 22.40 m/s, with BL. θ =1.00/0.73 mm, Re_θ = 2900/1200
Focus: shear-layer instabilities (in association to grey-area problem), effect of upstream inflow condition, LES mode accounting for downstream vortex motions.

TC 1.2 ONERA backward-facing step flow
Participants: **ONERA**, FOI, NLR, CIRA & TUM
Flow Conditions: U = 50m/s, Re_h = 40000
Focus: shear-layer instabilities (in association to "grey-area" problem), effect of inflow condition, flow recirculation and reattachment, downstream flow recovery.

TC 2.1 F5 high-lift configuration
Participants: **DLR**, FOI, ONERA & TUM
Flow conditions: M = 0.15, Re = 2.094 M
AoA = 7.05 deg. (WT), 6.0 deg. (CFD-corrected)
Local transition specified
Focus: BL and wakes confluence, shear-layer interaction, BL separation and subsequent vortex motions, effect of local transition.

TC 2.2 VFE-2 delta wing
Participants: **TUM**, CIRA, FOI & NLR
Flow Conditions: M = 0.07/0.14
Re =1.0 M, AoA = 23 deg, round leading edge
Focus: formation of primary and secondary vortices, vortex breakdown and shedding.



Results

- **E**xploration and further improvment of modelling and turbulence-resolving capabilities based on a number of test-case computations using different hybrid RANS-LES models
- **A**ssessment of hybrid RANS –LES methods investigated by AG members in terms of their respective advantages and disadvantages, by means of cross comparisons of partners' computations.

Current Status:
- **F**uther improvement on modelling approaches: XLES with stochastic forcing and/or based on EARSM; HYB0 with energy backscatter in the LES mode, improved ZDES with vorticity-scaled length scale in the LES mode.
- **A**ll AG members have computed the test cases planned. Further refined computations have been being conducted.
- **P**artners have used the following hybrid models: *SA-DES / DDES, SST-DES / DDES, zonal SA-DDES, IDDES, zonal RANS-LES/DNS, HYB0, X-LES, ZDES and their variants, WMLES*.
- **C**ross plots have been conducted for TCs 1.1, 1.2 and 2.1. For TC 2.2, cross-plotting will be reported in the final meeting.
- **E**xperimental data for all TCs are available for modelling validation and calibration.
- **C**omparative studies are being conducted for modelling evaluation.
- **A**long with inherent modelling mechanisms, impacts of other significant factors have been explored, typically, incoming BL, turbulent inflow condition, numericla dissipation, grid resolution and domain size etc..
- **O**ngoing summary of computations, as well as of "best-practice" guidelines based on experience gaines and lessone learned from the work conducted

CIRA DLR FOI INTA NLR ONERA THE FRENCH AEROSPACE LAB TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

AD/AG-50: Effect of open jet shear layers on aeroacoustic wind tunnel measurements

Action Group Chairman: Dr Stefan Oerlemans, NLR (Stefan. Oerlemans@nlr.nl)

Background

Aeroacoustic wind tunnel tests are typically conducted in open jets
Sound propagates through shear layer

Shear layer causes refraction, spectral broadening and coherence loss
These effects complicate interpretation of test results (e.g. identification of open rotor tones)

Shear layer effects depend on frequency, wind speed, and source position

Currently most groups only correct for shear layer refraction, using ray-acoustics approximation

Challenge
Understand shear layer effects and develop correction methods or reduction concepts

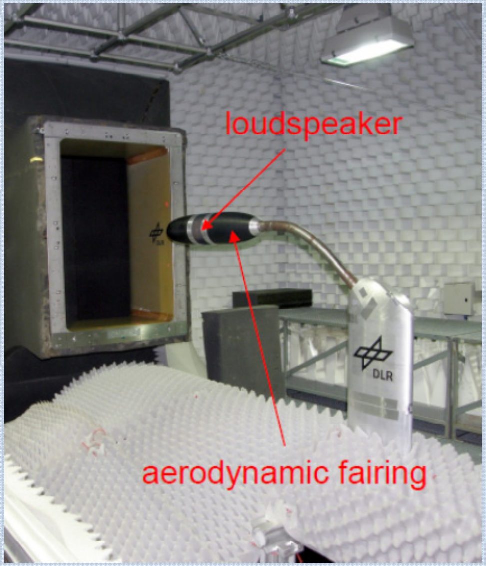
Programme/Objectives

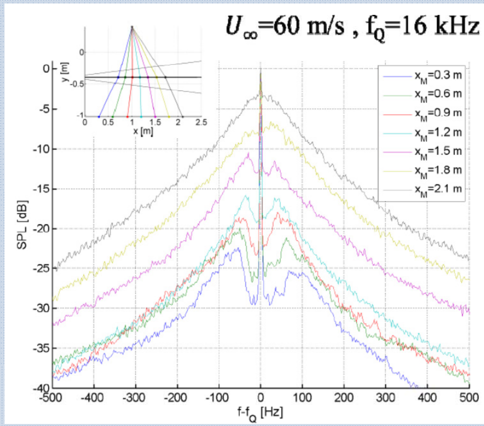
Objectives of AD/AG-50
- To improve the understanding of shear layer effects;
- To quantify the magnitude of shear layer effects, including the dependence on different parameters;
- To develop procedures to correct for shear layer effects;
- To investigate the possibilities to reduce shear layer effects.

Approach
- Experiments with calibration sources in different wind tunnels
- Benchmark computations using existing correction methods
- Advanced computations to improve understanding

Partners
Airbus, CIRA, DLR, NLR, ONERA, University of Southampton

Project duration: 3 years (2010-2012)
- Extended by 3 months to finalize reporting



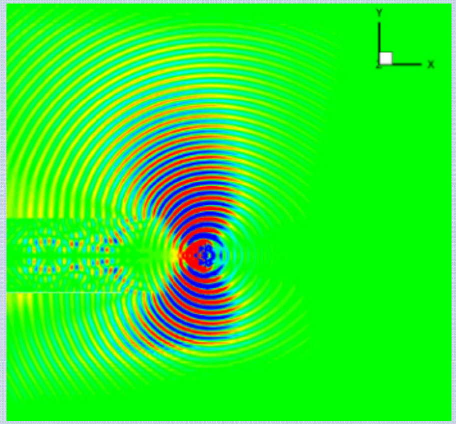


Results

Wind tunnel experiments
- Quantification of spectral broadening as a function of wind speed, frequency and source position
- Better understanding of mechanisms through turbulence measurements
- Methods to retrieve correct acoustic energy of tones measured outside shear layer

Computations
- Existing analytical correction methods were benchmarked
- Advanced numerical methods were developed and compared to benchmark cases
- CAA calculations including spectral broadening
- Comparison to experiments

AD/AG-50 improved the quality of aeroacoustic wind tunnel testing



AIRBUS CIRA DLR NLR ONERA UNIVERSITY OF Southampton Institute of Sound and Vibration Research

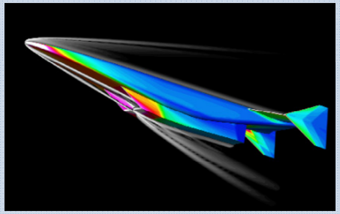
AD/AG-51: Effect of laminar/turbulent transition in hypersonic flows

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

Action Group Chairman: Dr Jean Perraud, ONERA (Jean.Perraud@onera.fr)

Background

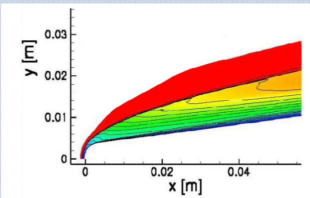
Transition laminar/turbulent:
Thrust-drag balance and air intake adaptation (air breathing hypersonic vehicles)
Heat fluxes (re-entry vehicles)



Different experimental data sources in Europe

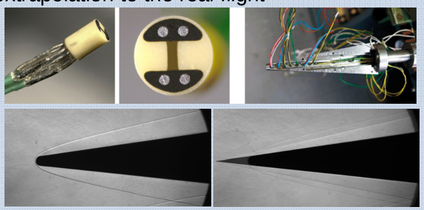
Increasing capability of CFD :
Need of tools/methods to predict laminar/turbulent transition in hypersonic using RANS code

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



Programme/Objectives

Objectives of the Action Group AD/AG-51: From a well documented database :

- Cross studies between the different wind tunnel tests (4 different facilities blow-down and hot shot one)
- Comparisons to numerical approaches
  - Extension of transition criteria (longitudinal transition) to hypersonics
  - Implementation into the elsA solver and validation based on above test cases
  - Impact of wind tunnel on transition and extrapolation to real flight
  - Study of the design of triggering devices

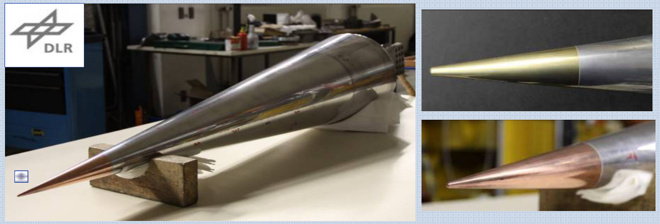
Focus: Mach number between 4 and 10. Altitude < 30 km

Numerical methods:
- Navier-Stokes solver with extended transition criteria (AHD)
- γ-Re_θ like transition prediction approach
- Linear stability codes

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

case 1 – Sharp and blunt cones
Natural transition
Mach=7
Re=3.7 10^6/m

- Heat-flux measurements
- Temperature
- PCB pressure sensor
- Frequency spectra (for the BL)



case 2 –Sharp and blunt cones
Natural transition
Mach=6
Re=23.5 10^6/m and 9.6 10^6/m

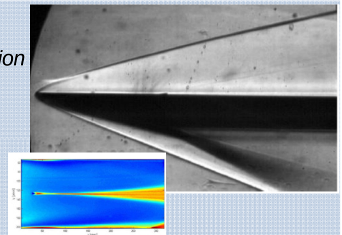
- Schlieren
- Heat flux measurement
- Interferometry

case 3 – Hypersonic forebody
Natural and triggered transition
Mach=[4-8]
Re=[1.4 – 14] 10^6/m

- Schlieren
- Pitot pressure
- Oil flow
- TSP

case 4 –Flat plate and cones
Natural and triggered transition
Mach=6
Re=[3-30] 10^6/m

- Schlieren
- Infrared measurement
- PCB pressure sensor



Results

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

<u>*WP1 – Experimental database*</u>
Wind-tunnel results collected

<u>*WP2 – Development and implementation of criteria*</u>
AHD extension to Mach 4 in validation, to be applied

<u>*WP3 – Numerical/experimental cross studies*</u>
CAD database of all geometries + growing mesh package
Work plan for studies launched on case2

Next Steps :

- **Implement and apply extended AHD criterion**
- **Work plan for tasks 3.3 / 3.4**
  - **Navier-stokes computations on ISL cones**
  - **Laminar boundary layer extraction and comparison**
  - **LST codes benchmark and validation for natural transition**
- **Next meeting : May 2013, CIRA**

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

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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

During 2012 GoR - FM monitored the following Action Groups:

FM/AG-18 Towards Greater Autonomy in Multiple Unmanned Air Vehicles
This group has demanded and obtained a 6 month extension in order to prepare a series of publication in the international Bristol UAV Conference, to be held in May 2013.

FM/AG-19 Flexible Aircraft Modeling Methodologies
This group has been stalled since 2011 and until end of 2012. Neither the group, nor the GoR have been able to recover from the defection of expert and specific resources in the critical work package that was to provide the common working benchmark to the rest of the group. An emergency plan is to be presented to the GoR in its next meeting in first semester of 2013, or an end will be put to this group.

For the Action Groups FM/AG-18 and FM/AG-19 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 2012.

<u>GoR/FM Exploratory Groups</u>
Two Exploratory Groups were decided in 2012 to be launched by first semester of 2013:
FM/EG-28 Non-linear flexible civil aircraft control benchmark for flight control methods assessment
FM/EG-29 Safety assessment of flight collision avoidance systems with formal V&V, simulation and proofs

<u>New Topics under Review</u>
Any other new topics under discussion have been put on hold until at least one of the two new EGs is launched.

Membership GoR – FM 2012

Chairman		
Patrick Fabiani	ONERA	France
Vice-Chairman		
Francisco Muñoz Sanz	INTA	Spain
Members		
Antonio Vitale	CIRA	Italy
Daniel Cazy	Airbus	France
Rob Ruigrok	NLR	The Netherlands
Martin Hagström	FOI	Sweden
Bernd Korn	DLR	Germany
Industrial Points of Contact		
Francisco Asensio	Airbus Military	Spain
Laurent Goerig	Dassault	France
Fredrik Karlsson	SAAB	Sweden
Martin Hanel	Cassidian	Germany

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

FM/AG-18: Towards greater Autonomy in Multiple Unmanned Air Vehicles

Action Group Chairman: Dr Jon Platts (jtplatts@QinetiQ.com)

Background

The wider use of UAVs for Military, Civil and Commercial applications is dependent on obtaining the optimum partnership between the human supervisor and the system. Communications between the supervisor and the system should be reduced as far as possible and be at high levels of abstraction with the majority of activity carried out with a minimum of human intervention. Given adequate autonomy, communications between the human supervisor and the vehicle can be minimised being necessary only where critical decisions are required. Moreover, it is clear that the more challenging applications with only a small number of human supervisors available to operate more than one UAV will create a distributed control problem.

Work carried out by the GARTEUR nations has led to the conclusion that unprecedented autonomy levels will be required and world-wide research in the area is very active examining a range of methods for achieving autonomy. It is very difficult to judge the effectiveness of innovative methods for achieving UAV autonomy due to:

- Scarcity of adequate models and simulation environments.
- Dispersion of techniques (not well-known or unknown)
- Lack of common benchmark for comparison
- Lack of awareness about autonomy gap and its implications.

Consequently, it is difficult to identify where investment is needed to rapidly mature the most promising contenders. This action group is designed to aid this process and the aim of the work is the:

Collection, implementation and systematic categorisation of machine based reasoning and artificial cognition approaches applicable to facilitate co-operation between UAVs and other assets with reduced human intervention. Those other assets will include other UAVs, manned assets and human operators performing supervisory control. The environment is highly uncertain, the goals may change and the problem may have no unique solution.

Programme/Objectives

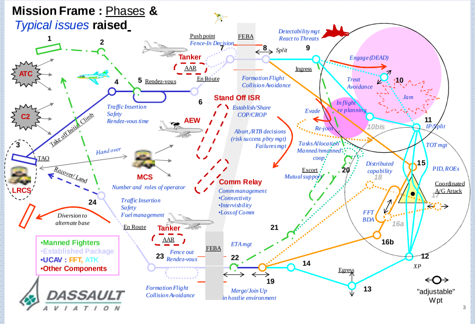
Within the aviation industry human supervisory control of complex systems has long been a requirement driven by the need to reduce air vehicle crew levels and workload, compensate for human frailty and latterly, the demands of UAVs deployed in many diverse tasks. The development of autonomous planning and decision making techniques will increase vehicle autonomy potentially enabling a reduction in the number of operators required, a reduction in operator workload, as well as compensating for human frailty and thus preserving system effectiveness in a more cost-effective manner.

The objectives of the FM/AG-18 are:

- The definition and selection of a suitable overarching framework comprising relevant aspects of anticipated future autonomous UAV missions.
- The application of various methods within the framework.
- A better understanding of autonomous systems and levels of autonomy.
- An indication of spin-off applications and critical technology research areas for the future.
- To inform the generation of a toolset and metrics to support the work.
- Better understanding of human operator requirements for different levels of autonomy.
- To acquaint the wider UAV community of the current state of the art and to inform the development of a technology roadmap to greater autonomous capability.

It is expected that the machine reasoning and artificial cognition methods to be developed in this AG will have broader application in a wider range of domains than FM/AG-14 given the greater coverage of the work framework.

A three-year project is in progress (having commenced in Sep 2009) and composed of a number of Work Packages (WP). Problem areas are derived (WP2) from an overarching framework (WP1) and then appropriate methods (WP3) are mapped to these areas. Applicable methods are applied to the problem areas in WP4 and the experimental approach and gathering of results is contained within WP5. WP6 looks after exploitation of the knowledge gained within the study.



Typical mission framework showing mission phases

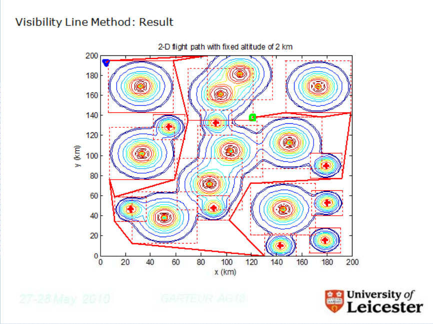
WP1 has concluded, producing an operational framework into which all of the methods addressed will be contextualised. An example framework is shown above. WP2 has developed a matrix methodology that allocates the framework functions to six broad categories of technology. These are: Automated Flight; Vehicle Health Management; Data Management; Reasoning/Planning/Decision-making; Communication and Collaboration. These categories, in the broadest terms, reflect the nature of the technology being addressed in WP4 of the AG. Within each of these broad categories are further sub-categories of problem which are cross referred to the original framework function. Using this matrix it has been possible to map the chosen technological approaches investigated within the AG to be assessed as to their fitness to solve a range of problems within the context of the over-arching framework. WP3 is carrying out an ongoing assessment via questionnaire of each of the candidate technologies being investigated across the AG. The questionnaire will elicit a general description of all methods, their maturity, applicability as well as implementation considerations.

Results

Organisations taking part in the FM/AG-18 are: Cassidian, CIRA, Dassault Aviation, DLR, INTA, NLR, ONERA, QinetiQ, Selex-Galileo, Thales NL, and the Universities of Complutense, German Armed Forces, Leicester and Loughborough. This impressive team aspires to gather evidence as to where particular technologies can be applied across the entire UAS design space, the relative strengths and weaknesses of each approach in solving these problems, and finally, where particular approaches have not been addressed within FM/AG-18 but which might offer some value. Such evidence will help to identify where investment is needed to rapidly mature the most promising technological approaches. The AG is confident that the exploitation of the results can improve the understanding of research and industrial bodies of the key domain issues, helping to further develop strategies and methodologies for increasing Autonomy in UAVs.

The candidate methods are being further applied to the problem to produce the results, on the basis of which indications will be given of spin-off applications and critical technology research areas for the future. How the candidate approaches can be applied to both military and civil systems with few or minor modifications will be articulated.

The AG hopes to exploit its results by a dedicated session in the Bristol UAV conference in May 2013. Therefore, the AG has been extended to the end of June 2013



Screenshot of Path Planning work

GARTEUR — GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

FM/AG-19: Flexible Aircraft Modeling Methodologies

Action Group Chairman: Francisco Asensio (Francisco.Asensio@military.airbus.com)

Background

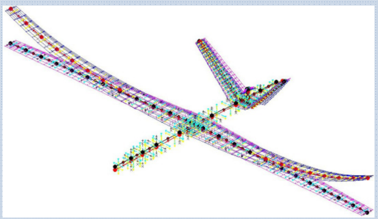
The next generation of air vehicles will have to face very challenging requirements in terms of performance, weight saving and overall performance efficiency. One way to achieve these targets is via an advanced flight control system performing multiple functions related with stabilization, envelope protection, handling qualities, loads control and configuration control. In order to successfully design the control laws algorithms in an affordable time and cost frame it is essential to get high quality mathematical models of the vehicle to be controlled.

As the structures become lighter they are more flexible, with natural flexible frequencies closer to the rigid motion frequencies. The proximity of both frequencies makes the control algorithms design more challenging, since traditional techniques based on the assumption of sufficient frequency separation become less applicable.

In the future, to get the maximum capability of the Flight Control System (FCS), the design must be done using an integrated rigid and flexible model. The level of modelling has direct influence on the final capability provided by the FCS.

The challenge is to pick up the problems associated with this modelling in order to provide the FCS designers with an accurate and suitable model to be used within a proper design and evaluation environment.

The problems associated with the model generation will deal with a real multidisciplinary task joining different disciplines such as flight mechanics, control laws, aerodynamics, load and structural dynamics.



Programme/Objectives

The aim of FM/AG-19 is to define a way of working for the integrated modelling activities, with the objective to generate an integrated aerodynamic and aeroelastic model to be used in the flight control laws design of advanced FCS. It is essential also to establish a procedure for model validation in the different stages of the air vehicle development process, from initial ground testing to final flight test validation.
With this objective a number of work packages with a balance commitment in terms of disciplines and partners to ensure that all the required work can be addressed have been defined. Main work packages activities will include:

- Definition of the requirements that should be met for the FCS design point of view by an interdisciplinary flexible aircraft model to achieve two major objectives; FCS design and validation cycles reduction and to provide an early and accurate knowledge of the adverse effects due to structural flexibility.
- Define the mathematical formulation and develop a flexible aircraft model with the constrains requirements in the sense of being suitable for control laws design and analysis and keeping the matching between this low order model and highly complex physical models. Low order , high fidelity flexible aircraft models which contain relevant high order non-linear effects and couplings of the aircraft will allow a coupled FCL optimization within an affordable computational effort.
- Define a problem where the design should be challenging enough from a structural coupling point of view.
- Built a software code including required data handling and analysis functions with a model applicable to a specific case under study that will be used for the model validation and functional application activities.
- Develop identification methods suitable for flexible aircraft allowing the definition of a process for model validation in ground and flight test. Developed methods will be assessed using data generated by the high fidelity simulation model
- Perform an integrated design exercise and compare the result with the design performed following traditional methods with three major objectives; develop and apply a FCL design work flow that fully exploits the availability of an integrated multi-disciplinary aircraft mode, compare this work flow with current practices to demonstrate the benefits in terms of design cycles reduction and to demonstrate that design quality can be improved
- Perform a continuous industrial review activity in order to steer it an gathered the maximum benefit from the industrial perspective

Organisations taking part in the FM/AG-19 are:

CIRA

DLR

ONERA

NLR

DSTL

Airbus Military

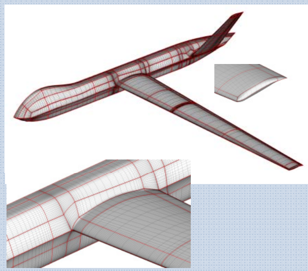
CASSIDIAN

BAE Systems

Imperial College

Univ. of Liverpool

TU Berlin



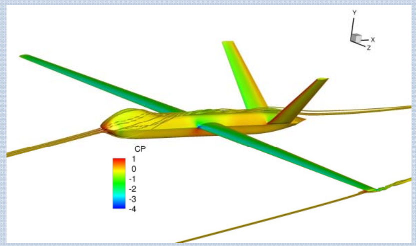
Results

FM/AG-19 was kicked-off in November 2009. However, it had a slow start and most of the running work packages have been delayed now by about 12 months. Mitigation and recovery actions have been put in place. However, situation have not improved significantly . Main achievements comprise:

- Definition of the requirements of the flexible aircraft model for FCS design and software coding requirements agreed
- Flexible aircraft mathematical formulation (review of existing approaches and models) state of the art finished
- Benchmark specification frozen. Catia CAD and FEM benchmark model release to the partners
- Rigid aerodynamic tables generated
- Model validation (basis philosophy established)

Next actions will be:

- Building the flexible aircraft aerodynamic tables based aeroelastic calculations.
- Model development for flexible aircraft flight dynamics.
- Establish hierarchy of models from low-fidelity to high-fidelity and their application.
- Test cases definition for flexible model high fidelity simulations.



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.....
  - Increase crashworthiness, ballistic protection,....
- 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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During 2012 GoR - HC monitored the following Action Groups:

HC/AG-17 Wake Modelling in Presence of Ground Obstacles
HC/AG-18 Data and Methods for Error Localisation and Model Refinement of Structural Dynamic Finite Element Models (this AG had problems and was closed down)
HC/AG-19 Methods for Improvement of Structural Dynamic Finite Element Models using In-Flight Test Data
HC/AG-20 Simulation/Testing for Design of Passive Noise Absorption Panels (stating up)

For the Action Groups HC/AG-17, HC/AG-19 and HC/AG-20 a one page summary poster is included on the following pages.

The situation regarding Exploratory Groups and New Topics under review was as follows end 2012:

<u>GoR - HC Exploratory Groups</u>

New Exploratory Groups were in preparation during 2012.

HC/EG-29: "Intelligent Lifeing & HUMS" is expected to start early 2013
HC/EG-30: "Helicopter Simulator Fidelity" is expected to result in an Action Group early 2013.

Fortunately, the GoR was able to initiate several new ideas and pilot papers of which at least three are expected to become an EG in 2013.

<u>New Topics</u>

The following topics are being considered for future Exploratory Groups:

- Conceptual Design of Helicopters
- Performance, fuel efficiency
- 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)
- Forces on obstacles in Rotor Wakes
- Vibrations having impact on: Comfort, Costs (maintenance)
- Predictive method & Tools
- Synergies between Civil and Military operations
- Sand/dust engine protection
- Wind Turbine wake influence on h/c operations
- Aerodynamics & CFD simulation

Membership GoR - HC 2012

Chairman		
Joost Hakkaart	NLR	The Netherlands
Vice-Chairman		
Lorenzo Notarnicola	CIRA	Italy
Members		
Blanche Demaret	ONERA	France
Klausdieter Pahlke	DLR	Germany
Antonio Antifora	AgustaWestland	Italy
Philipp Krämer	ECD	Germany
Elio Zoppitelli	Eurocopter	France
Mark White	Univ. Liverpool	United Kingdom
Observer		
Richard Markiewicz	DSTL	United Kingdom

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

HC/AG-17: Helicopter Rotor Wakes in Presence of Ground Obstacles

Action Group Chairman: Antonio Filippone (a.filippone@manchester.ac.uk)

Background

The wake trailed from the blades of a helicopter rotor has a significant influence on many aspects of the performance and dynamics. At low forward speeds, the wake runs very close to the rotor blades. This can lead to high levels of vibration and an uncomfortable flight.

The wake dynamics is complicated by interaction with the ground or other obstacles that are close enough to the helicopter to affect the flow induced by the rotors. The highly unsteady and re-circulatory nature of the flows that arise when the wake interacts with the ground and other obstacles plays an important part in defining the envelope within which the rotorcraft is allowed to operate safely.

For both military and civil operations, recirculation of sand and snow particles, causing brown-out and white-out, makes hovering close to the ground and landing very difficult. The available flight envelope for operation off the back of ships can be severely constrained by the interaction of the wake from the ship superstructure with the helicopter's own wake under certain wind conditions. During airport/airfield operations, the downwash (and also the 'side-wash', as the wake moves outwards) that is induced when hover-taxiing must be considered when manoeuvring near to other aircraft and buildings

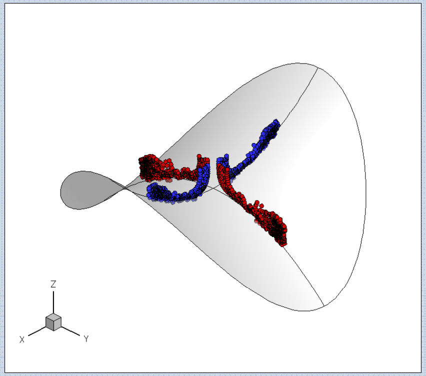
Agusta-Westland Merlin in brown-out landing.

Programme/Objectives

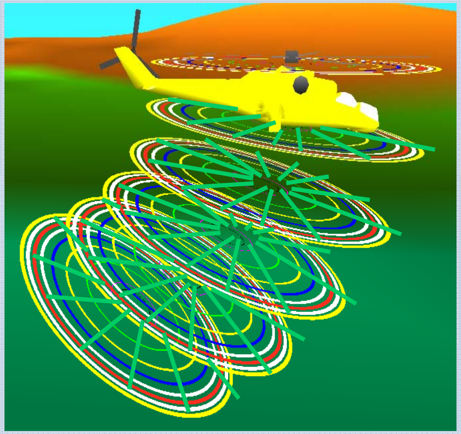
Research activities were launched in 2008 under the umbrella of the GARTEUR organisation in order to improve the physical understanding of helicopter wakes in confined spaces and to define criteria for quantifying the helicopters susceptibility. The GARTEUR Helicopter Action Group 17 (HC/AG-17) comprises representatives from the research establishments (CIRA-Italy, ONERA-France, NLR-The Netherlands, Qinetiq-UK) and universities (Manchester, Glasgow, Stuttgart).

The core objectives of the Action Group are:

1) To review the current status of methods of modelling wake interaction with ground obstacles.
2) If such methods are not available or are deficient, then the group is to identify the feasibility of modifying existing methods to allow wake/ground obstacles to be modelled.
3) To examine and identify existing databases for the purposes of validation and convert the data to a form suitable for validation.
4) To perform a series of experimental investigations for data gathering allowing each partner organisation to correlate and improve the respective analytical models.

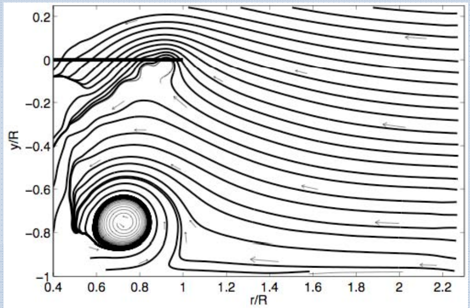


Helicopter Wakes in Saddle-Shaped Ground plane.



Multi-vortex rings rotor model.

The Action Group is working along different lines, including critical literature review, advanced numerical simulation methods, wind tunnel testing, and data comparison.



Rotor in ground effect, forward flight (moving to the left)

Results

Critical assessment of numerical methods, from low-order (lifting lines, lifting surfaces), to boundary element methods (panel methods), and field methods (unsteady Reynolds-averaged Navier-Stokes, vorticity transport methods). The numerical methods include multi-disciplinary analysis, such a trim conditions, flight dynamics and structural dynamics.

Validation of numerical methods with reference test cases, including Light's experiments of a rotor in ground effect over an inclined plane. Analysis includes cases of a variety of ground obstacles (vertical walls, inclined walls, saddle planes, etc.)

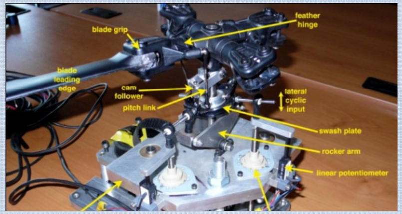
Advancement of some numerical methods for the prediction of ground effects.

Wind tunnel scale measurements of ground effects in hover and forward fligth, as well as analysis of brown-out (isolated rotor and full rotorcraft configurations, including tandem rotors). Results were published during two ERF conferences;

C. Philipps et al., "The Effect of Rotor Design on the Fluid Dynamics of Helicopter Brownout", 35th ERF, Sept. 2009, Hamburg, Germany.

A. Filippone et al., "Rotor Wake Modeling in Ground Effect Conditions", 37th ERF, Sept. 2011, Gallarate (VA), Italy.

Final report is drafted (issued early 2013)



Rotor assembly for wind tunnel tests (Glasgow Univ.)

Members of the HC/AG-17 group are:

Antonio Filippone chair	Manchester University
Antonio Visingardi	CIRA
Ian Roberts	QinetiQ
Richard Bakker	NLR
Pierre-Marie Basset	ONERA
Okko Boelens	NLR
Benjamin Kutz	Stuttgart University
Richard Green	Glasgow University

GARTEUR Responsable:

Klausdieter Phalke DLR

NLR CIRA QinetiQ University of Glasgow MANCHESTER 1824 The University of Manchester University of Stuttgart Germany ONERA THE FRENCH AEROSPACE LAB

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?

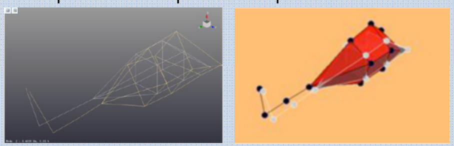
Other recommendations with respect to ground vibration testing are considered in the closely related GARTEUR Action Group HC/AG-18.

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.

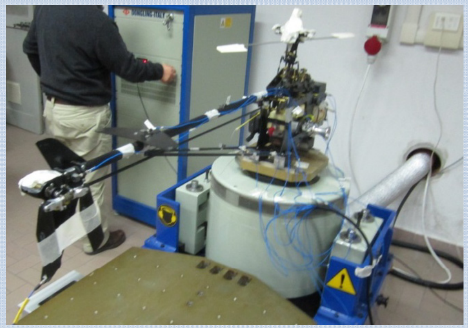


Traditional analysis versus OMA analysis

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.

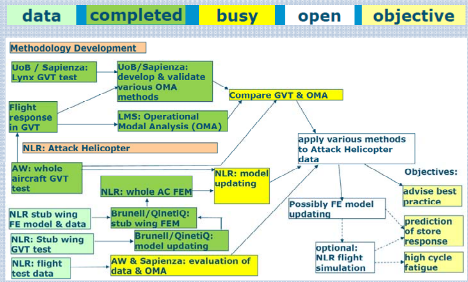


The third data set will be based on a discontinued commercial helicopter model from AW .

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:

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

GARTEUR Responsable:
Joost Hakkaart NLR

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

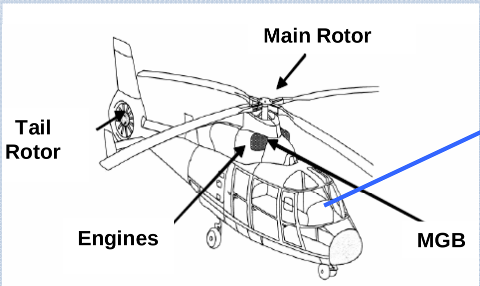
2) to design composite trim panels with industrial requirements and simulate acoustic performances of treatments after integration in cabin

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)

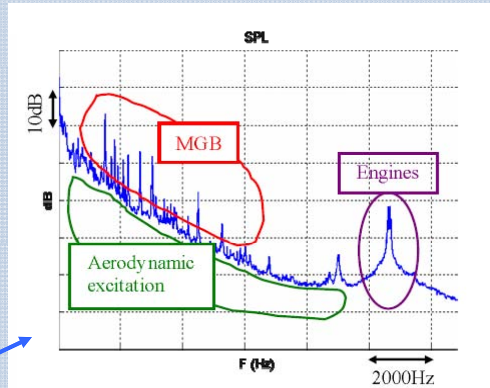


The activities in the new HC/AG-20 constitute the conclusion of HC/EG-28 and explore the points 2 to 4:

• 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

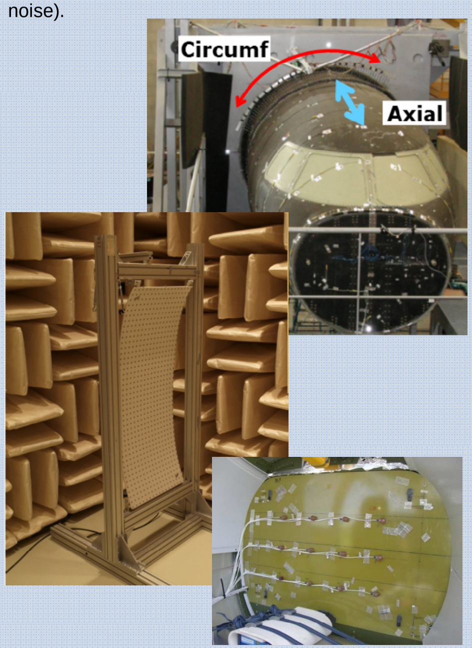
• applying different types of experimental techniques to characterize composite trim panel acoustic radiating in both a standardized test set –up and a generic helicopter cabin.

• 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

GARTEUR Responsable:

B. Demaret ONERA

Microflown Technologies Charting sound fields — NLR — ONERA THE FRENCH AEROSPACE LAB — CIRA — DLR

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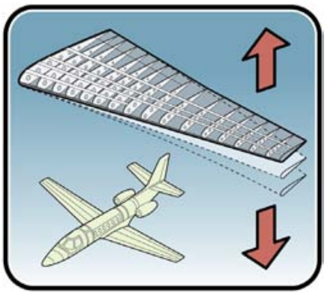
Group of Responsables - Structures and Materials (SM)



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 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
- Damage Management of Composite Structures for Cost Effective Life Extensive Service
- Damage growth in composites
- Fatigue and damage tolerance assessment of hybrid structures
- Damage repair in composite and metal structures
- Sizing of aircraft structures subjected to dynamic loading

During 2012 GoR - SM monitored the following Action Groups:

SM/AG-31: Damage management of composites Structures for Cost Effective Life Extension Service.
The work within this AG has been completed with a final report TP-175.

SM/AG-32: Damage growth in composites.
The work within this AG has been completed with a final report TP-176.

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

The situation regarding Exploratory Groups and New Topics under review was as follows end 2012:

GoR - SM Exploratory Groups

SM/EG-39 Design of High Velocity Impact on Realistic Structure
This EG will become an AG in 2013

SM/EG-41: Sizing of aircraft structures subjected to dynamic loading.
This EG was started end of 2012

New Topics
A number of new topics have been identified to be considered for future Exploratory Groups:

- Virtual testing
- Effect of defects in composite structures
- Bonded and bolted joints
- Compression testing
- Impact loading on transparent materials

Membership GoR - SM 2012

Chairman		
Tomas Ireman	Saab	Sweden
Vice-Chairman		
Vacant		
Members		
Jean-Pierre Grisval	ONERA	France
Peter Wierach	DLR	Germany
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Joakim Schön	FOI	Sweden
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Umberto Mercurio	CIRA	Italy
Aniello Riccio	Univ. II Naples	Italy
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Hans Ansell	SAAB	Sweden
Walter Zink	Airbus	Germany
Sören Nilsson	SICOMP	Sweden
Andy Foreman	Qinetiq	United Kingdom
Caroline Petiot	EADS-IW	France

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

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

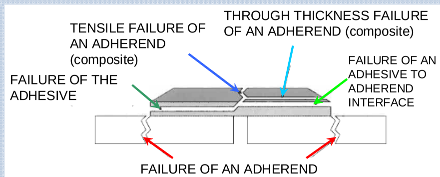
WP 5 EFFECTIVE REPAIR METHODS

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.



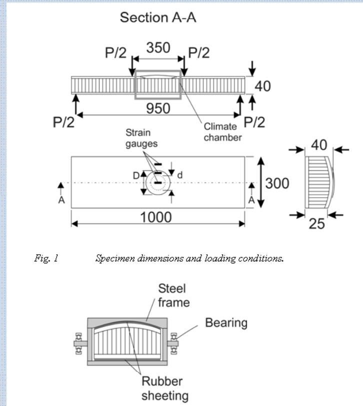
Failure modes in adhesively bonded repair will be analysed

Expected Results

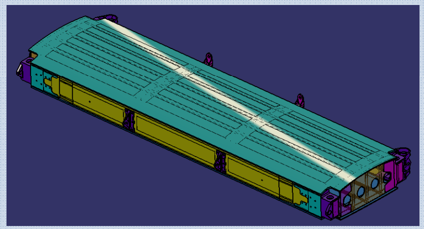
The effective outcomes can be summarized in:

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.



Coupon Benchmark



Structural Benchmark

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, FOI, NTNU – Trondheim Norwegian University of Science and Technology, SICOMP, LULEÅ TEKNISKA UNIVERSITET, INTA, SAAB TECHNOLOGIES

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

Action Group Chairman: Rudy Veul (Rudy.Veul@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

DLR FOI FOKKER AEROSTRUCTURES NLR SAAB

Results

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

6. GARTEUR SUCCESS STORIES AND LINKS WITH 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.

GARTEUR success stories

Three examples are presented in more detail on the following pages; “High-Lift Aerodynamics” and “Missile Aerodynamics” from GoR Aerodynamics and “Damage Mechanics, Damage Tolerance, Bolted Joints in Composite Materials/Structures” from GoR Structures and Materials.

The first example **- High-Lift Aerodynamics -** clearly illustrates how the joint European knowledge in High Lift Aerodynamics has been built up over several decades through national efforts coordinated via GARTEUR activities and later continued in European projects funded via the Framework Programmes. It also illustrates the long time scales from basic research to application as well as the strong connection between GARTEUR and EU activities.

The second example – **Missile Aerodynamics -** illustrates how the joint European knowledge in Missile Aerodynamics, and especially in numerical simulation, has largely been built up over the past decades through national efforts coordinated via GARTEUR Action Groups.

The third example - **Damage Mechanics, Damage Tolerance, Bolted Joints in Composite Materials/ Structures** – illustrates how the joint European knowledge in this field has largely been built up through national efforts coordinated via a series of GARTEUR Action Groups. The GARTEUR activities have led to other European projects within EU Framework and WEAG (now EDA) programmes.

There are other examples of success stories also within GoR FM and GoR HC; two of these have received the GARTEUR Award as follows:

FM/AG-17: Nonlinear Analysis and Synthesis Techniques for Aircraft Control
This AG received the GARTEUR Award 2008 and resulted in a text book “Non-linear Analysis and Synthesis Techniques for Aircraft Control” which was published by Springer-Verlag in 2007.

HC/AG-16: Rigid Body and Aeroelastic Rotorcraft-Pilot Coupling
This AG received the GARTEUR Award 2010/2011 and the activities of this AG were continued in the EU-FP7 project ARISTOTEL (Aircraft and Rotorcraft Pilot Couplings – Tools and Techniques for Alleviation and Detection).

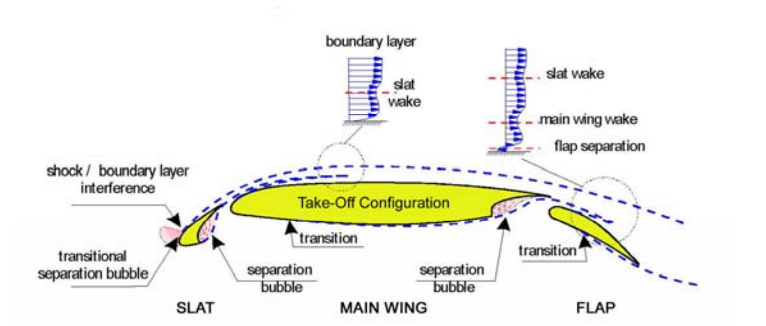
HIGH-LIFT AERODYNAMICS

In “sales pictures” for the effects of EU-FP projects a number of EU-projects are quoted as important contributors to the wing design on modern European aircraft types like Airbus A380 and Dassault Falcon 7X.

Contribution of FP projects to High Reynolds Number, Low Drag Wing Design on Airbus A380: ECARP BE*3, EUROLIFT FP5, AWIATOR FP5, C-WAKE FP5 (maiden flight April 2005)

Contribution of FP projects to the efficiency of the aerodynamic design on Dassault Falcon 7X: ECARP BE*3, AVTAC FP4, EUROLIFT FP5 (maiden flight May 2005)

One example noted is the **EUROLIFT** project in FP5, which can serve as the basis to illustrate the connections between national efforts coordinated via GARTEUR activities and later continued in European projects.



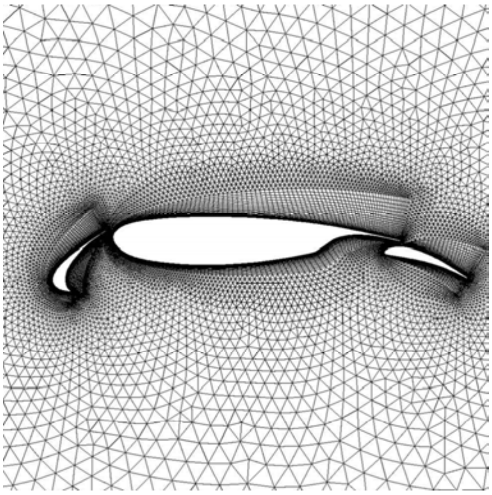
The figure illustrates the complex physics associated with High Lift Aerodynamics

GARTEUR early activities on High Lift Aerodynamics were four Action Groups during 1981-1998:
AD/AG-03 1981-1984 High lift, phase I
AD/AG-08 1985-1990 High lift, phase II
AD/AG-13 1991-1994 High lift, phase III
AD/AG-25 1995-1998 High lift, phase IV (maximum lift prediction)

In these action groups with participation of Research Establishments and industries from the GARTEUR member countries knowledge was built up step by step through development of CFD methods and careful experimental investigations in various wind tunnels. These projects were all based on national funding and coordinated efforts through GARTEUR activities. This work is reported in 15 GARTEUR technical reports.

These GARTEUR Activities paved the way for European High Lift Activities within EU-FP5 and FP6:
EUROLIFT - European High Lift Programme (2000-2003)
HiAer - High level modeling of high lift aerodynamics (2001-2004)
HELIX - Innovative aerodynamic high lift concepts (2001-2005)
EUROLIFT II - European High Lift Programme II (2004-2007)
The core group of participants were the same as in the original GARTEUR projects.

Another GARTEUR Action Group “3D High Lift Computations” (AD/AG-36) was performed 1999-2004 as a complement to the EUROLIFT programme. In AD/AG-36 additional computations were performed on an infinite
swept wing as well as in 3-dimensions.



Computational grid for a High-Lift test case

High Lift activities have then continued also in EU-FP7 with projects like:
DESIREH - Design, Simulation and Flight Reynolds-Number Testing for Advanced High-Lift Solutions(2009-2013)
SADE - Smart High Lift Devices for Next-Generation Wings (2008-2012)

In summary it can be stated that the joint European knowledge in High Lift Aerodynamics - applied on modern European aircraft types - has been built up over the past decades through national efforts coordinated via GARTEUR Action Groups and later continued in European projects funded via the Framework Programmes.

The example illustrates:
- coordinated efforts between GARTEUR nations during a 20+ year period
(Four GARTEUR Action Groups 1981-1998 and one 1999-2004)
- the strong connection between GARTEUR and EU activities
(Four related EU-projects within FP5 and FP6 + two new in FP7)
- the long time scales from basic research to application
- impact of lower TRL research on future projects

MISSILE AERODYNAMICS

Meteor is the new generation Beyond Visual Range Air-to-Air Missile system that will revolutionize air-to-air combat in the 21st Century. The weapon brings together six nations (DE, ES, FR, IT, SE, UK) with common requirements.

For such a missile development to be successful, it is largely depending on numerical simulation for external aerodynamics at supersonic conditions and high angle of attack, supersonic air intake and ramjet design and aircraft integration (Typhoon, Gripen and Rafale).

There is a long commitment since the 1990-ies of GARTEUR AD-GoR on the application of CFD to missile aerodynamics as it can be seen through the list of the following action groups:

AD/AG-15 Validation of Euler Codes for Supersonic Flows

AD/AG-24 Navier-Stokes Calculations of the Supersonic Flow About Slender Configurations

AD/AG-34 Aerodynamics of Supersonic Air Intakes

AD/AG-42 Numerical simulations of turbulent subsonic and transonic flows about missile configurations

All these actions groups allowed to develop and improve the numerical tools for the specificities of missile aerodynamics: high angle of attacks, vortical flows, high supersonic regimes (Mach > 3) and increased confidence in the European portfolio of CFD codes for these applications. Recent use of advanced CFD applications gave also a deep insight on flow physics.

Presently (2012-2013), three on-going GARTEUR groups are of great interest for future applications:

AD/AG-46 Highly Integrated Subsonic Air Intakes

In which advanced CFD is used for calculating the air intakes which will equip the future cruise missiles.

AD/AG-48 Lateral Jet Interactions at Supersonic Speeds

Dedicated to a crucial aerodynamic aspect of a potential future European Ballistic Missile Defence terminal vehicle

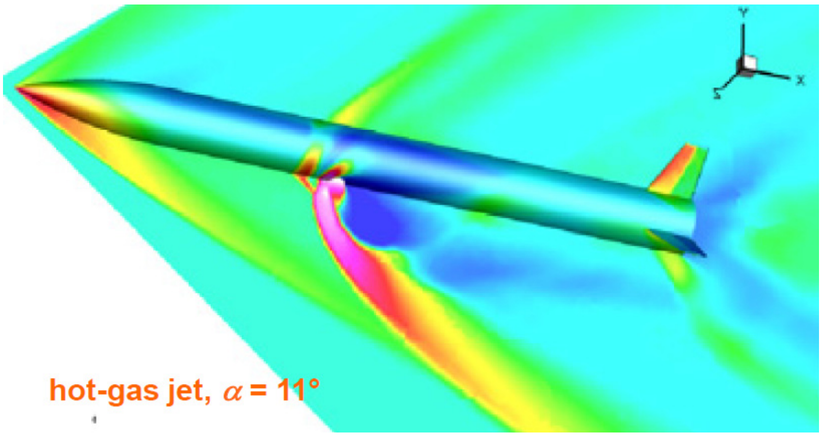
and

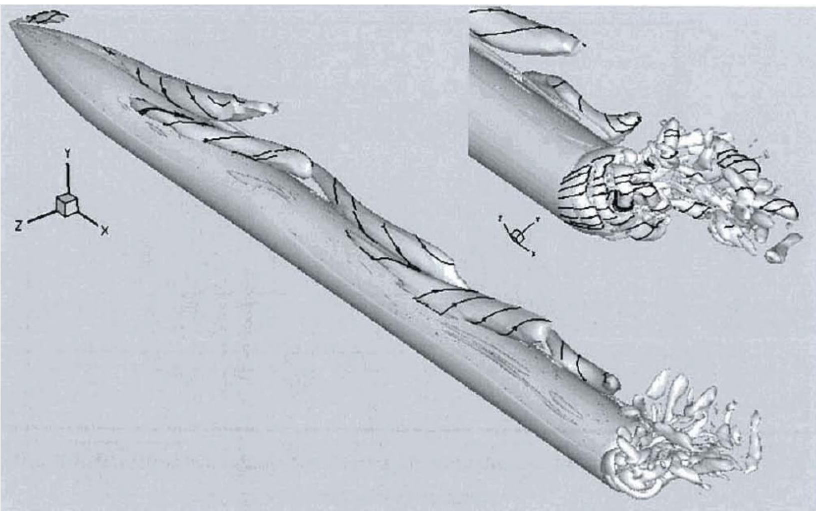
AD/AG-51 Laminar-Turbulent Transition Prediction in Hypersonic flows

Deals with the important difficulty of transition prediction and triggering on future hypersonic air-breathing vehicles.

It is worth noting that the last two action groups go further than CFD and include a deep understanding of flow physics via experimental, theoretical and simulations approaches.

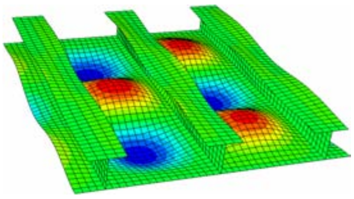
In summary it can be stated that the joint European knowledge in Missile Aerodynamics, and especially in numerical simulation, has largely been built up over the past decades through national efforts coordinated via GARTEUR Action Groups. There is no other organisation in Europe where such a collective effort is done for the specific topics of Missile Aerodynamics.



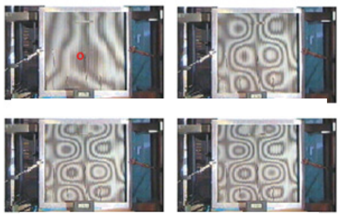


DAMAGE MECHANICS, DAMAGE TOLERANCE, BOLTED JOINTS IN COMPOSITE MATERIALS/STRUCTUES

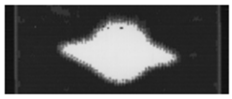
Composite materials, if properly used, offer many advantages over metals. Examples of such advantages are: high strength and high stiffness-to-weight ratio, good fatigue strength, corrosion resistance and low thermal expansion. Nevertheless, conventional composites made of pre-impregnated tape or fabric also have some disadvantages, such as poor transverse properties, inability to yield and sensitivity to moisture and high temperatures, which must be accounted for in the design. Due to the poor transverse properties composite structures are very sensitive to out-of-plane loading such as impact loading, local bending and in bonded and bolted joints. The understanding of and ability to predict damage initiation and damage growth is therefore very important. Improper design of composite structural elements and joints may lead to structural problems or conservative design leading indirectly to overweight structures and high life-cycle cost of the aircraft.



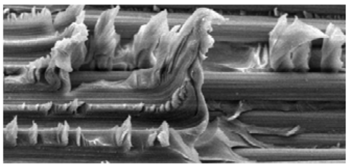
Analysis



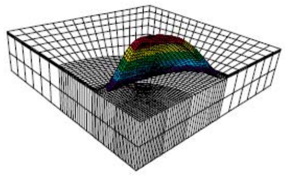
Testing



NDI



Fractography



Damage growth prediction

The pioneering research activities on damage mechanics, damage tolerance and bolted joints in composites started within GARTEUR and were later followed by more application oriented projects within EU FP4 and FP5 as well as within WEAG (Western European Armament Group). The following GARTEUR Action Groups are related to the above subject:

SM/AG-09 Damage mechanics of composites (1986-1994)
SM/AG-14 Fractography of composites (1991-1995)
SM/AG-16 Damage propagation in composite structural elements (1993-1998)
SM/AG-20 Fractographic aspects of fatigue failure in composites (1994-2001)
SM/AG-22 Design methodology for damage tolerant composite wing panels (1997-2001)
SM/AG-28 Impact damage and repair of composite structures (2002-2007)
SM/AG-31 DAMOCLES III (2006-2011)
SM/AG-32 Damage growth in composites (2006-2011)

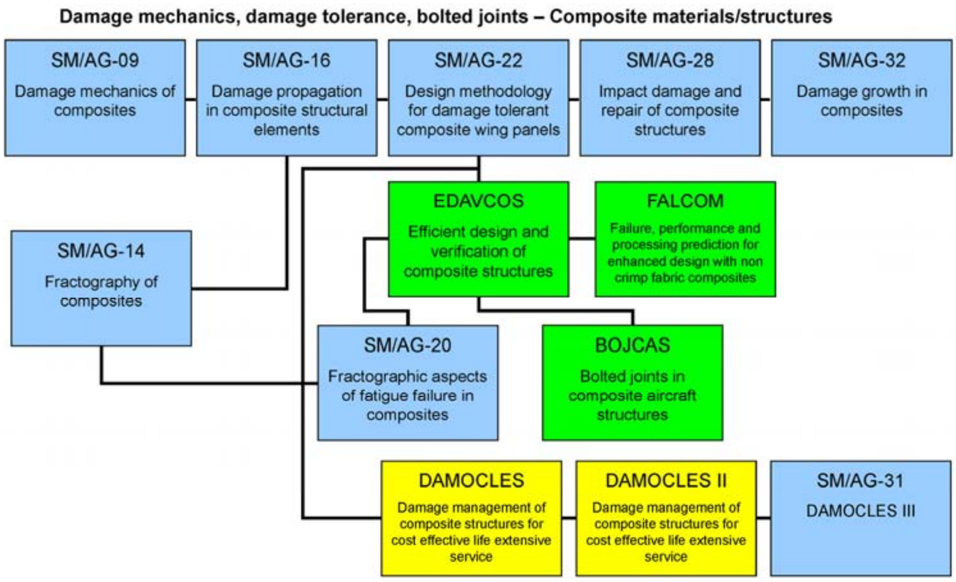
In combination with the GARTEUR Action Groups noted above three related EU FP4 and FP5 projects were performed as follows:

EDAVCOS - Efficient Design And Verification of COmposite Structures (1998-2001)
BOJCAS - BOlted Joints in Composite Aircraft Structures (2000-2003)
FALCOM - Failure, performance and processing prediction for enhanced design with non crimp fabric composites (2001-2005)

Furthermore two related projects were initiated within the WEAG military framework (EDA predecessor):

DAMOCLES - Damage management of composite structures for cost effective life extensive service
These projects, performed as DAMOCLES I and DAMOCLES II (1999-2005), were followed up by the GARTEUR SM/AG-31 DAMOCLES III (2006-2011)

The figure below illustrates how all these projects are interlinked.



The above activities are documented in numerous technical reports and conference publications. Most of them can be found as references in the open GARTEUR reports available at the "Structures and Materials" part of the GARTEUR website.

In summary it can be stated that the joint European knowledge in Damage Mechanics, Damage Tolerance and Bolted Joints in composites, has largely been built up over the past decades through national efforts coordinated via GARTEUR Action Groups. **The GARTEUR activities have led to other European projects within EU Framework and WEAG (now EDA) programmes.** ***There is no other organisation in Europe where such a collective effort in done for this topic.***

Links with other European programmes

As illustrated in the three examples on the previous pages there has 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 looked 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.

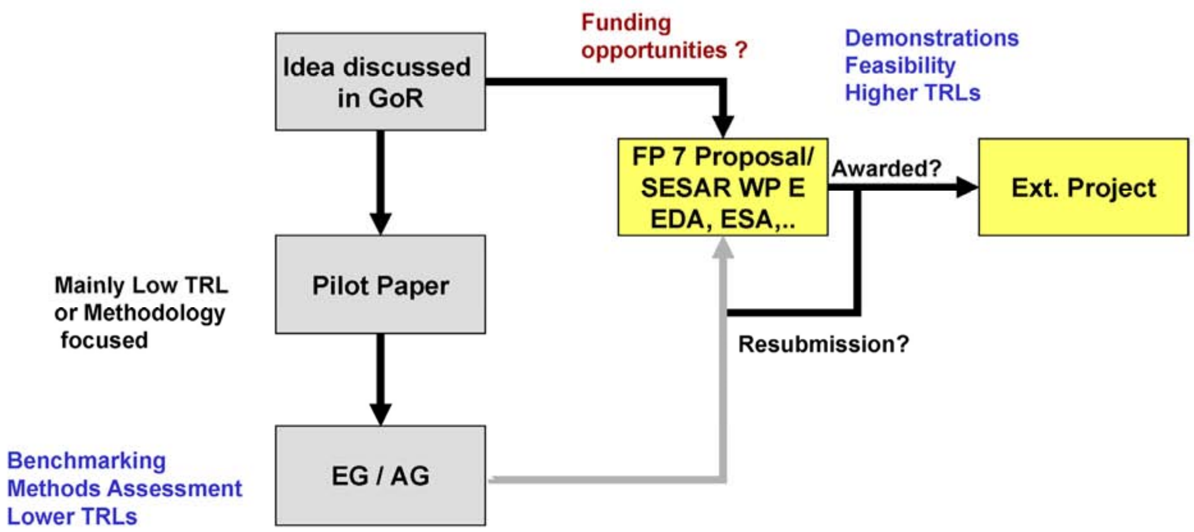
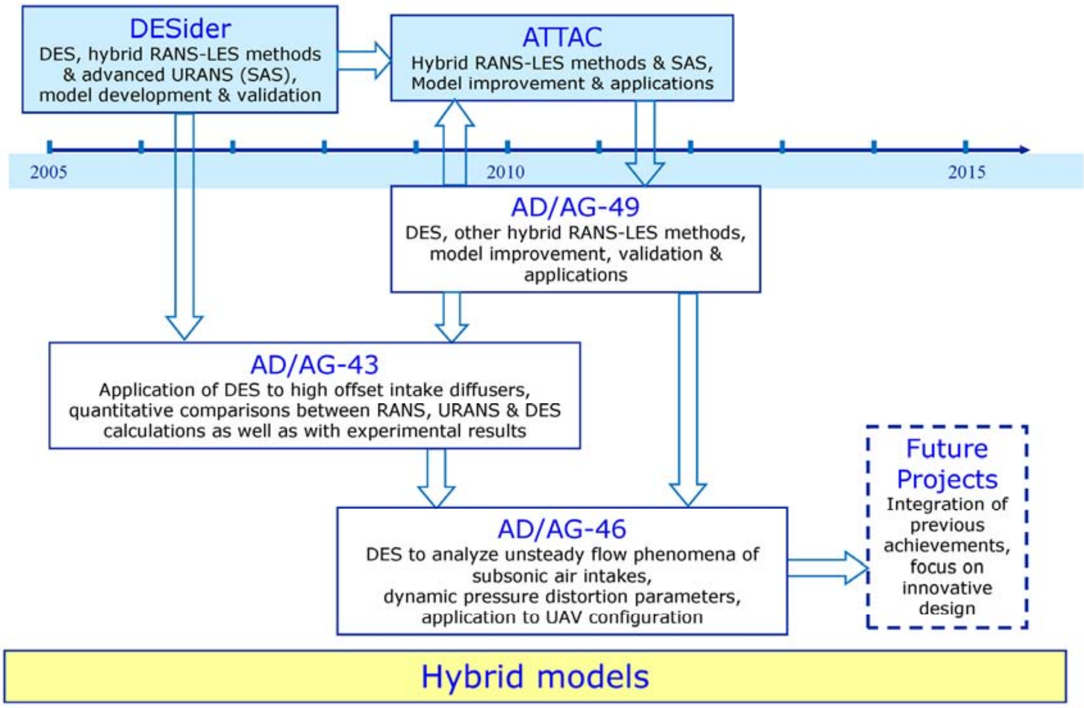


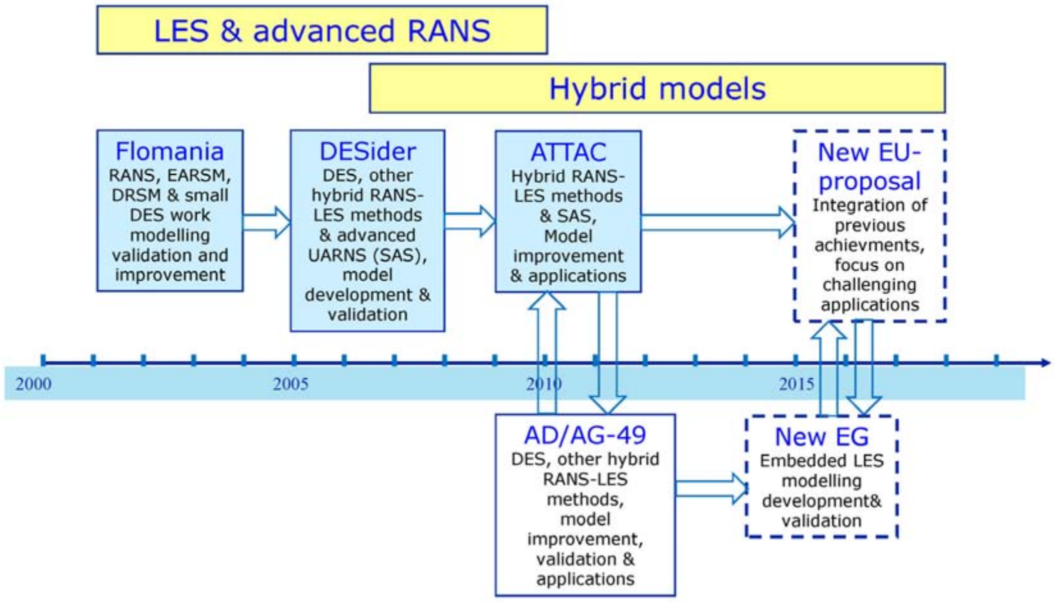
Illustration of how links are established between GARTEUR and other European programmes

The nature of many GARTEUR projects have been low TRL and benchmarking of methods etc and the possibilities to get funding for this type of projects (Level 1 projects) within the Framework Programmes has varied over time.

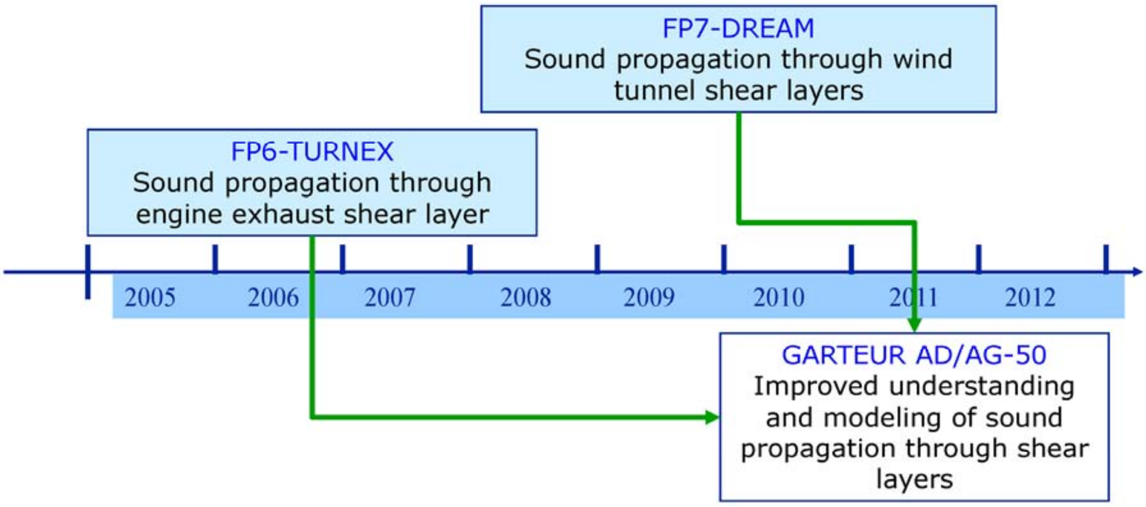
However, as illustrated in the examples on the previous pages the knowledge and methods developed within the GARTEUR projects are the basis for participation also in projects on higher TRL levels.

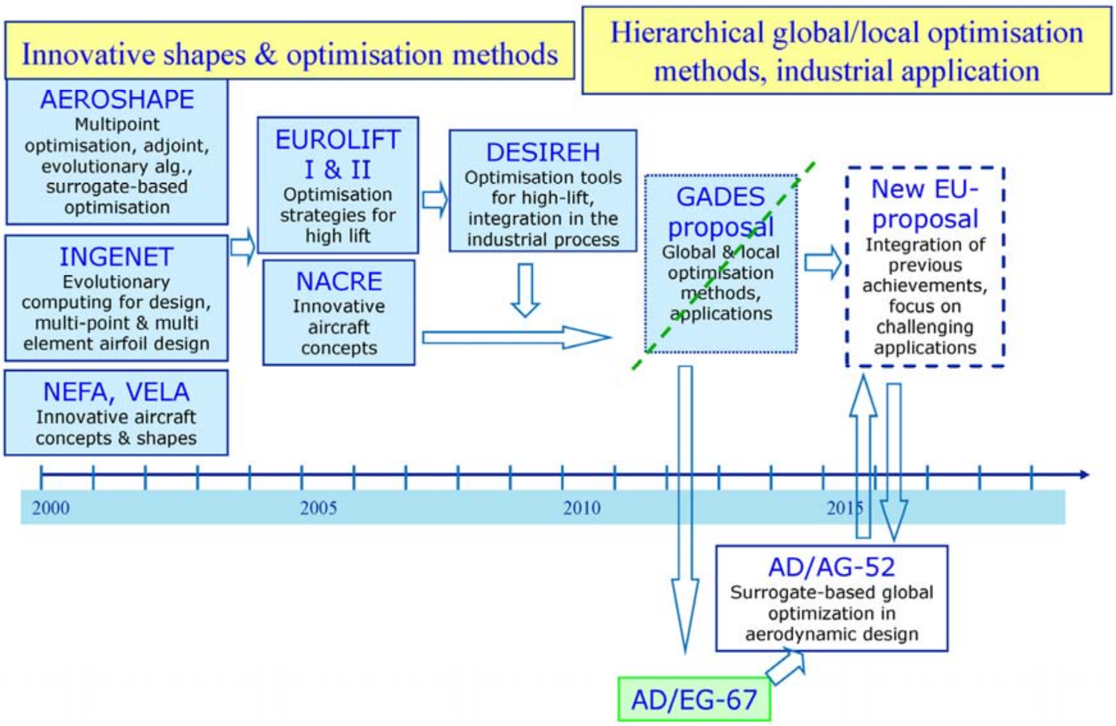
Additional illustrations of the links between GARTEUR Action Groups and EU projects, as provided by GoR Aerodynamics and GoR Helicopters, are included on the following pages.



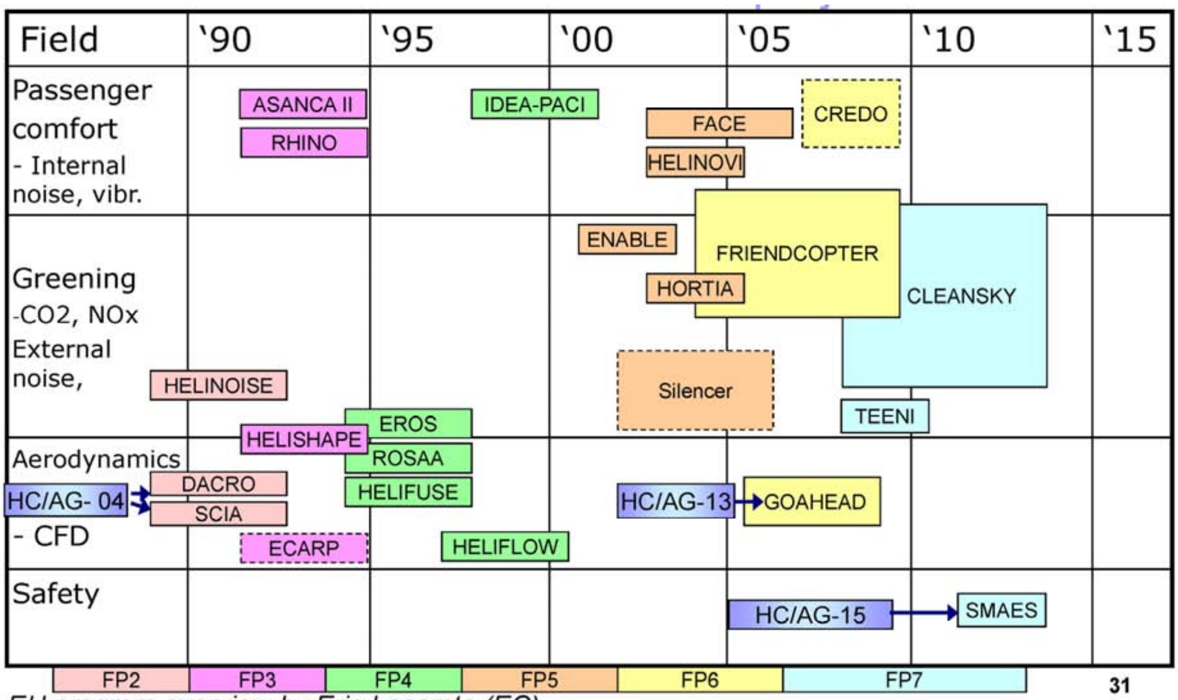


Links between EU-projects/proposals and GARTEUR AD/AG-43; AD/AG-46 and AD/AG-49

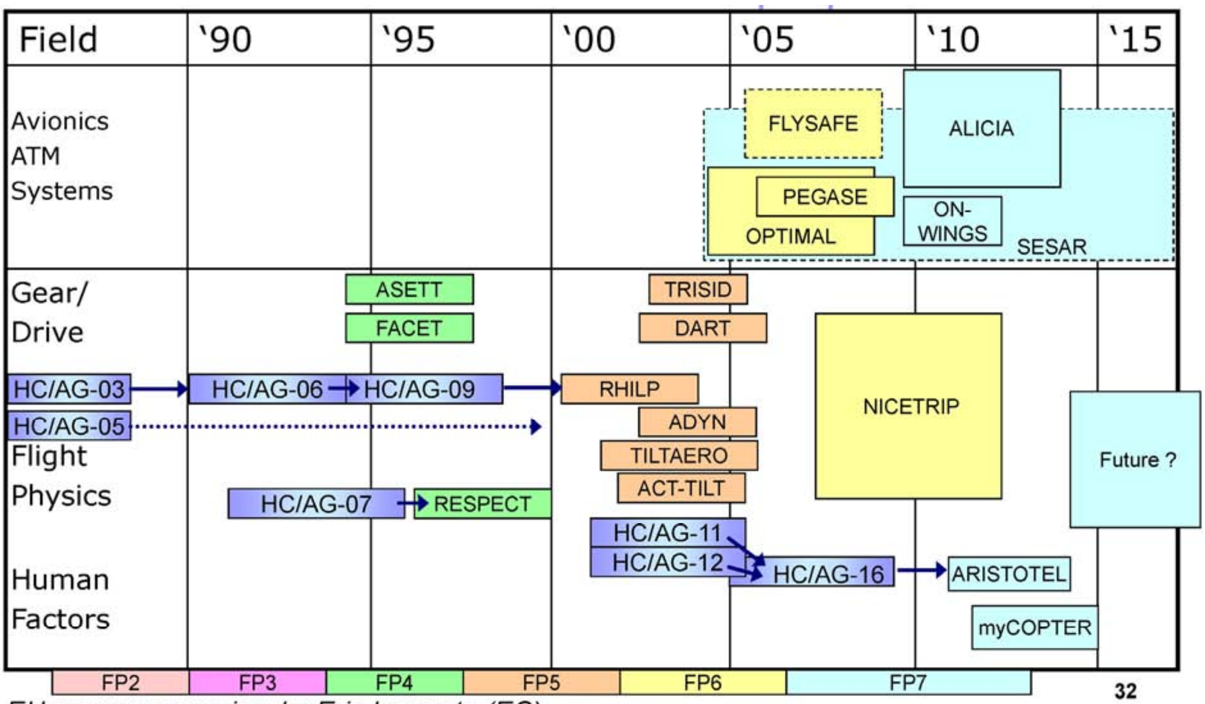




Links between EU-projects/proposals and GARTEUR AD/AG-50 and AD/AG-52



EU program overview by Eric Lecomte (EC)



EU program overview by Eric Lecomte (EC)

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

APPENDIX 1: GARTEUR Organization
(Status January 2013)

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

GARTEUR ORGANISATION

GARTEUR Chair Country 2013-2014: France
Council Chair: Dr. Hervé Consigny, France
XC Chair: Dr. Olivier Vasseur, France
Secretary: Mme Anne-Laure Delot, France

GARTEUR COUNCIL

Function	France	Germany	Italy	Netherlands	Spain	Sweden	United Kingdom
Head of Delegation	H. Consigny	F.-J. Mathy	L. Vecchione (acting)	T. de Laat	A. Moratilla Ramos	G. Hult	R. Kingcombe
XC Member	O. Vasseur	F. König	L. Vecchione	B. Thuis	P. Garcia Samitier	B. Jonsson	TBD
Other Members of Delegation	O. Dugast P. Desvallees	H. Konrad H. Hueners	D. Cucchi	H. van Leeuwen B. Oskam	J.F. Reyes-Sánchez	A. Blom E. Lindencrona	

GROUPS OF RESPONSABLES

Aerodynamics (AD)	Flight Mechanics, Systems & Integration (FM)	Helicopters (HC)	Structures & Materials (SM)
GoR AD members	**GoR FM members**	**GoR HC members**	**GoR SM members**
T. Berglind SE chair 2012-13	**P. Fabiani** FR chair 2012-13	**L. Notarnicola** IT chair 2013-14	**T. Ireman** SE chair 2011-13
E. Coustols FR	B. Korn DE	J. Hakkaart NL chair 2011-12	U. Mercurio IT
G. Mingione IT	A. Vitale IT	K. Pahlke DE	J.P. Grisval FR
H. Rosemann DE	R.C.J. Ruigrok NL	B. Demaret FR	J. Maroto ES
K. de Cock NL	M. Hagström SE	A. Antifora IT	J. Schön SE
F. Monge Gómez ES	D. Cazy FR	P. Krämer DE	P. Wierach DE
G. Schrauf DE	F. Muñoz Sanz ES	E. Zoppitelli FR	H. de Vries NL
E. Totland SE		M. White UK	
N. Wood UK		R.-H. Markiewicz UK	
Industrial Points of Contacts	**Industrial Points of Contacts**	**Industrial Points of Contacts**	**Industrial Points of Contacts**
T. Berens DE	F. Asensio-Nieto ES	HC IPoCs included above	H. Ansell SE
L.P. Ruiz-Calaver ES	L. Goerig FR		A. Barrio Cardaba ES
N. Ceresola IT	F. Karlsson SE		L. Hootsmans NL
M. Mallet FR	M. Hanel DE		R. Lang DE
D. Pagan FR			A. Riccio IT
C. Newbold UK			S. Nilsson SE
			C. Petiot FR
			W. Zink DE
			A. Foreman UK

Sweden was the GARTEUR chair country for 2010-2012 with:
Council Chair: Prof. Gunnar Hult
XC Chair: Mr Björn Jonsson
GARTEUR Secretary: Mr Anders Gustafsson

APPENDIX 2: Overview of GARTEUR Technical Activities

GARTEUR Action Groups – 6 years rolling plan 2009-2014

Regarding new action groups in preparation see chapter 5

Aerodynamics

No	Topic	2009	2010	2011	2012	2013	2014
AD/AG-34	Aerodynamics of supersonic intakes						
AD/AG-40	Performance degradation due to icing - Phase II						
AD/AG-43	Application of CFD to High Off-Set Intake Diffusers						
AD/AG-44	Application of transition crit. in NS comp. - Phase II			Report pending			
AD/AG-45	Application of CFD to predict high "G" loads	EG 57 →					
AD/AG-46	Highly Integrated Subsonic Air Intakes						
AD/AG-47	Coupling of CFD with Flight Mechanics Model	EG 62 →					
AD/AG-48	Lateral Jet Interactions at Supersonic Speeds	EG 60 →					
AD/AG-49	Scrutinizing Hybrid RANS-LES for Aero. Applic.	EG 63 →					
AD/AG-50	Effect of WT Shear Layer on Aero-acoustics	EG 64 →					
AD/AG-51	Laminar-Turbulent Transition in hypersonic flows			EG 65 →			
AD/AG-52	Surrogate-based Global Optimization Methods in Preliminary Aerodynamic Design				EG 67 →		

Flight Mechanics, Systems and Integration

No	Topic	2009	2010	2011	2012	2013	2014
FM/AG-15	PIO–analysis & test techn. for prevention - II						
FM/AG-16	Fault tolerant control						
FM/AG-17	Nonlinear analysis & synthesis techniques						
FM/AG-18	Towards Greater Autonomy in Multiple UAVs	EG 26 →					
FM/AG-19	Flexible Aircraft Modeling Methodologies	EG 27 →			Stalled 2012	??	

Helicopters

No	Topic	2009	2010	2011	2012	2013	2014
HC/AG-17	Wake Modeling with Ground Obstacles	EG 26 →					
HC/AG-18	Error Localisation and Model Refinem. for FEM	EG 27 →			Stopped 2012		
HC/AG-19	Methods for Impr. of Struct. Modeling using In-Flight Dat	EG 27 →					
HC/AG-20	Simulation/Testing for design of passive noise absorption panels		EG 28	→			

Structures and Materials

No	Topic	2009	2010	2011	2012	2013	2014
SM/AG-30	High velocity impact			Report pending			
SM/AG-31	Damage management of Composite Structures						
SM/AG-32	Damage growth in composites						
SM/AG-33	RTM Materials properties during curing			Report pending			
SM/AG-34	Damage Repair with Composites				EG 40 →		
SM/AG-35	Fatigue and Damage Tolerance Assessment of Hybrid Structures				EG 38 →		

Active (green) Closed (red)

EG-xx ⇒ : EG number xx resulting into AG number yy

APPENDIX 3: Participation in Action Groups by nation / organisations in 2012

Country	Participants	GoR (Number of Action Groups)				
		AD(9)	FM(2)	HC (3)	SM (2)	Total (16)
France	ONERA	9	2	2	1	**14**
	Industry	4	1	0	0	**5**
	Academia	0	0	1	1	**2**
Germany	DLR	8	2	1	1	**12**
	Industry	4	2	0	0	**6**
	Academia	3	2	1	0	**6**
Italy	CIRA	4	2	2	2	**10**
	Industry	3	0	1	1	**5**
	Academia	1	0	1	1	**3**
The Netherlands	NLR	5	2	3	2	**12**
	Industry	0	1	0	1	**2**
	Academia	0	0	1	1	**2**
Spain	INTA	2	1	0	1	**4**
	Industry	2	1	0	1	**4**
	Academia	0	1	0	0	**1**
Sweden	FOI	6	0	0	0	**6**
	Industry	3	0	0	2	**5**
	Academia	0	0	0	1	**1**
United Kingdom	DSTL	2	1	0	0	**3**
	Industry	3	2	2	2	**9**
	Academia	3	4	5	2	**14**

GoR	AG Number	Research Establish-ments	Industry	Academic Institutes	Total
AD	45	4	3	-	**7**
	46	3	6	-	**9**
	47	4	3	1	**8**
	48	2	2	1	**5**
	49	5	-	1	**6**
	50	4	1	1	**6**
	51	3	1	3	**7**
	52	4	3	3	**10**
FM	18	6	3	6	**15**
	19	5	3	2	**10**
HC	17	3	-	3	**6**
	19	1	2	4	**7**
	20	4	1		**5**
SM	31	2	1	-	**3**
	32	5	5	4	**14**
	34	4	2	4	**10**
	35	3	2	-	**5**

APPENDIX 4: Resources deployed within Action Groups:
Person-month and other costs in k€

GoR	AG	2009		2010		2011		2012		2013		2014*	
		pm	K€	pm	k€	pm	K€	pm	K€	pm	K€	pm	K€
AD	43	2	0	2	0								
	44	10								1	0		
	45	11	20	2	10	2	5	2	0	1	0		
	46	27	7	12	0	10	0	3	0	9	7		
	47	18	0	15	20	10	5	17	0	1	0		
	48	13	22	16	27	10	7	3	6	6	8		
	49	4	30	21	175	20	170	15	100	7	70		
	50	0	0	16	60	16	60	8	0	10	20		
	51							14	41,5	14	77		
	52									25	70		
AD TOTAL		85	79	84	292	68	247	62	147,5	74	252		
FM	15												
	16												
	17												
	18			33	6	36	6	30	6	12	8		
	19			42	6	21	2	0	0	?	?		
FM TOTAL				75	12	57	8	30	6	12	8		
HC	15	10	10										
	16	5											
	17	18	46	17	25	13	18	1	1				
	18	7	10	2	2	0	0	0	0				
	19	2		16	4	14	10	12	5	8	3		
	20						2	1	1	18	10		
HC TOTAL		42	66	35	31	27	30	14	7	26	13		
SM	31	36	50	30	30	2	10	3					
	32	31	28	20	10	4	0	2					
	33	14,5	10	0	0								
	34							6	0	50	50		
	35							1	2	11	30		
SM TOTAL		81,5	88	50	40	6	10	12	2	61	80		
GRAND TOTAL		208,5	233	244	375	158	295	118	162,5	173	353		

* NOTE: Several Action Groups are planned to end during 2013, while others are in preparation to be started during 2013 and 2014. Hence it is not meaningful at this stage to estimate resources for 2014.

APPENDIX 5: List of GARTEUR reports issued in 2012

Technical Reports

GARTEUR Number	Action Group	National Reference	Date of issue	Title	Authors	Distribution Classification Remarks
TP-172	AD/AG-47		Dec. 2012	Simulation of Flying Vehicle Motions using Computational Fluid Dynamics	B. B. Prananta et al	GARTEUR Limited
TP-173	AD/AG-43		Oct. 2012	Application of CFD to High Offset Intake Diffusers	T. M. Berens et al	GARTEUR Open
TP-174	HC/AG-17		April 2012	Helicopter Wakes Models in the Presence of Ground Obstacles	A. Filiponne et al	GARTEUR Open
TP-175	SM/AG-31		Dec. 2011	Damage Management of Composite Structures for Cost Effective Life Extensive Service (DAMOCLES III)	A. Riccio	GARTEUR Limited
TP-176	SM/AG-32		Sept. 2012	Damage Growth in Composites	A. Riccio	GARTEUR Open
TP-177	SM/AG-29		Dec. 2012	Development of a Probablistic Methodology for Rapid Interchange of Composite Materials in the Design of Composite Structures	A. Riccio	GARTEUR Limited
TP-178	AD/AG-45		Febr. 2013	Application of CFD to Predict High "g" Loads	J.-L. Hantrais-Gervois et al	GARTEUR Limited

Executive Committee and Council

GARTEUR Number			Date of issue	Title		Distribution Classification Remarks
X/D-43			April. 2012	GARTEUR Annual Report 2011		GARTEUR Open
X/D-44			April. 2012	GARTEUR Annexes to Annual Report 2011		GARTEUR Open

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).

Availability of technical reports

The GARTEUR Council decided in March 2011 the following regarding older GARTEUR technical reports:
- to make Open GARTEUR reports freely available on the website
- 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 2012 the number of reports available on the website was 165.
Another 50 reports are still GARTEUR Limited and kept by the secretariat.

APPENDIX 6: LIST OF ABBREVIATIONS

ACARE	Advisory Council for Aeronautics Research in Europe (old)
ACARE	Advisory Council for Aviation Research and Innovation in Europe (new)
AD	Aerodynamics
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
JAR	Joint Aviation Requirements
JTI	Joint Technology Initiative
NLR	National Aerospace Laboratory, NL
NS	Navier-Stokes
ONERA	Aeronautics and Space Research Centre
PIO	Pilot-In-the-loop Oscillations
PPP	Public-Private Partnership

R&T(&D)	Research and Technology (and Development)
RE	Research Establishment
RTO	Research Technology Organisation (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