ANNEX B

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES

FLIGHT MECHANICS, SYSTEMS AND INTEGRATION

Remit

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

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

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

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

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FLIGHT MECHANICS, SYSTEMS AND INTEGRATION

GoR OVERVIEW

GoR Activities

2012 has been again a very difficult year for the FM GoR. Several members suffer from significant budget reduction .

However, active participation in GoR management has taken place and two good new ideas for future EGs and AGs have been pushed forward.

Two Exploratory Groups were decided in 2012 :
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

Still, under the threat of a lack of human resources among potential partners, mainly due to the lack of GARTEUR project funding sources, the first EG28 kick-off meeting is to be held only by first semester of 2013 (23rd April 2013).

Any other new topics under discussion have been put on hold until one at least of the two EG is launched. The next GoR meeting is not scheduled until the first EG is launched, i.e. EG28 on the 23rd April 2013.

Only one action groups was active in 2012.

FM/AG-18 builds upon the valuable work of FM/AG-14 to take forward the UAV Autonomy activities in the area of machine based reasoning.

FM/AG-19 suffers from severe delays in the critical path of the research activity. This delay sums up to more than 24 months now. FM/AG-19 looks at the problem of flexible aircraft modelling – in particular the problem of cross-coupling between rigid and non-rigid structures – although this is related to the critical area of flight control design. 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.

Management Issues

The GoR met on two occasions during 2012, with good attendance at each meeting. In addition to discussing new ideas, the GoR decided to as well play a more active role in the running AGs by participating in the AG meetings. Members of the GoR did continue to support national bids for FP7 funding. Close observation of this is being maintained by the GoR. Topics from unsuccessful bids (e.g. of FP7 calls) are being considered for GARTEUR collaboration (since these are already considered a priority for nations).

Efforts have continued to increase the industrial participation, particularly by equipment/avionics partners; this will complement the group’s manufacturing representatives. However, no new participation was secured in 2012.

Future plans

During 2013 the GoR will continue efforts to establish new EGs.

The kick-off meeting of FM/EG-28 is scheduled to occur on the 23rd April 2013.

Subsequently the GoR will have its next meeting in Amsterdam and discuss EG29, decide on FM/AG-19 and propose new ways forward, either AG or EG.
The FM GoR will continue its way on spending quite some time in active discussions with the running AGs, generation of pilot papers to consider new ideas, and consideration of topics to prepare and anticipate for Horizon2020.

3-5 year rolling plan

Time-Schedule

FM GoR Research Objectives	Subjects	CAT	2010	2011	2012	2013	2014	2015
B	Towards greater Autonomy in Multiple Unmanned Air Vehicles	FM/AG-18						
A	Flexible Aircraft Modelling Methodologies	FM/AG-19			Stalled			
A	Fault Tolerant Integrated Aircraft Management System	PP		On halt				
A	Non-linear control benchmark	PP						
B	Relative Positioning for UAVs	PP			Cancelled			
B	Emergency Landing for UAVs	PP			Cancelled			
C	Small Airport Operations	PP		FP7 Network				
C	Air to air refuelling			FP7 Project RECREATE				
C	Combined formal methods and A/C methods for the verification & validation of adaptive systems, with application to safety assessment of collision avoidance systems	PP						

AG	EG	Pilot Paper	
Existing	Existing	Existing	
Planned	Planned	Planned	

FM GoR Research Objectives - Legend	
A	*Development and benefit assessment of advanced methods for analysis and synthesis of flight control systems for aircraft with both conventional and non conventional aero structural configurations.*
B	*Development of advanced methods for UAV mission automation*
C	*Development and benefit assessment of advanced aircraft capabilities into ATM/ATC related applications*

Managed and foreseen GoR activities

The following meetings were held during 2012:

- 97th GoR(FM) meeting at INTA, Spain, 29th of February / 1st of March 2012
- 98th GoR(FM) meeting at Saab, Linköping, Sweden in July 2012.

Ten national representatives attended each of the meetings during 2012 to monitor the activities of the AGs and to discuss new ideas and pilot papers.

The estimated effort associated with these activities amounts to 2,5 man-months (50 man-days) in total and the associated travel and subsistence costs are roughly 20 k€.

The following meeting is planned for 2013:

- 99th GoR(FM) meeting at NLR, Amsterdam, The Netherlands in June 2013.

Dr. Patrick Fabiani
Chairman
Group of Responsables
Flight Mechanics, Systems and Integration

GoR MEMBERSHIP

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

Chairman			
Mr. Patrick Fabiani	ONERA	France	Patrick.Fabiani@onera.fr
Vice-Chairman			
Mr. Francisco Muñoz Sanz	INTA	Spain	mugnozsf@inta.es
Members			
Mr. Antonio Vitale	CIRA	Italy	a.vitale@cira.it
Mr. Daniel Cazy	Airbus	France	daniel.cazy@airbus.com
Mr. Rob Ruigrok	NLR	The Netherlands	ruigrok@nlr.nl
Mr. Martin Hagström	FOI	Sweden	martin.hagstrom@foi.es
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Mr. Martin Hanel	EADS	Germany	Martin.Hanel@cassidian.com

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action Groups (AG)
The following FM Action Group has been active during 2012:
FM/AG-18 Towards greater Autonomy in Multiple Unmanned Air Vehicles
FM/AG-18 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.

The following FM Action Group has been stalled since 2011 and until end of 2012.
FM/AG-19 Flexible Aircraft Modeling Methodologies
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.

Exploratory Groups (EG)
Two Exploratory Groups were decided in 2012 to be launched by first semester of 2013, but under the threat of a lack of human resources among potential partners, mainly due to the lack of funding sources.

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

Future Topics
Any other new topics under discussion have been put on hold until one at least of the two EG is launched. The next GoR meeting is not scheduled until the first EG is launched, i.e. FM/EG-28 on the 23rd April 2013.

Table of Action Groups and Exploratory Groups

Subjects	ST	2009	2010	2011	2012	2013	2014
FM/AG-15 IO–analys. and test techn. for prevention, II	AG						
FM/AG-16 Fault tolerant control	AG						
FM/AG-17 Nonlinear analysis and synthesis techniques	AG						
FM/AG-18 Towards greater Autonomy in Multiple Unmanned Air Vehicles	AG	EG26=>					
FM/AG-19 Flexible Aircraft Modelling Methodologies	AG	EG27=>				?	
FM/EG-26 Machine Based Reasoning for Multiple UAVs	EG		=> AG18				
FM/EG-27 Flexible Aircraft Modelling Methodologies	EG		=> AG 19				
FM/EG-28 Non-linear flexible aircraft benchmark for flight control methods assessment	EG						
FM/EG-29 Safety assessment of flight collision avoidance systems with formal V&V, simulation and proofs	EG						

Active Closed Status December 2012

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

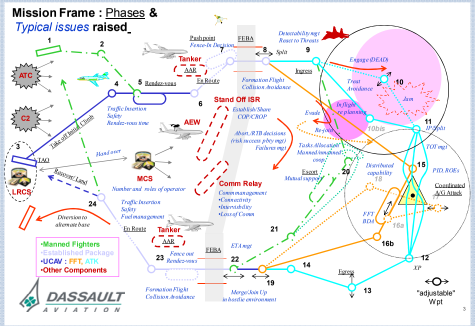
Within the aviation industry human supervisory control of complex systems has long been a requirement driven by the need to reduce air vehicle crew levels and workload, compensate for human frailty and latterly, the demands of UAVs deployed in many diverse tasks. The development of autonomous planning 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

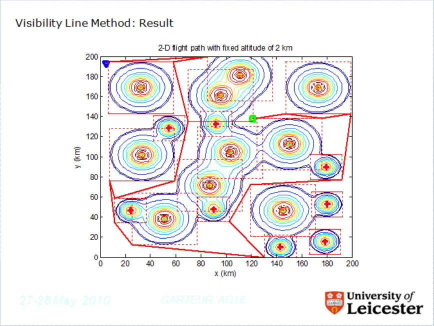
WP1 has concluded, producing an operational framework into which all of the methods addressed will be contextualised. An example framework is shown above. WP2 has developed a matrix methodology that allocates the framework functions to six broad categories of technology. These are: Automated Flight; 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

ACTION GROUP REPORTS

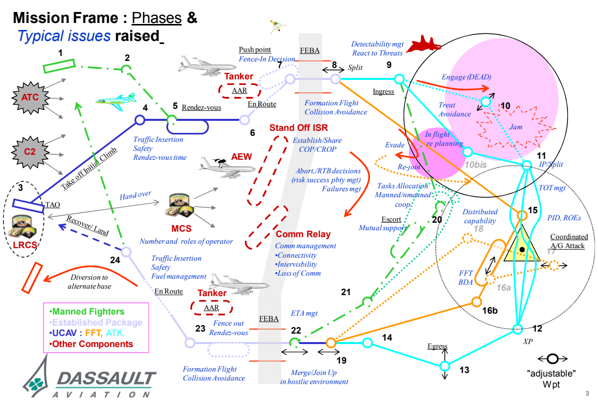
FM/AG-18	**Towards greater Autonomy in Multiple Unmanned Air Vehicles**	
Monitoring Responsable:		P. Fabiani ONERA
Chairman:		Dr. J. Platts QinetiQ

• OBJECTIVES

The objectives of the AG are to establish:

- The feasibility of definition and selection of a suitable framework to provide context and metrics for evaluation.
- The feasibility of evaluating various methods within the framework using defined metrics.
- The feasibility of developing an analysis package for evaluating autonomous systems in uncertain environments.
- A better understanding of autonomous systems and levels of autonomy (including information requirements, latency, robustness etc).
- The likelihood of spin-off applications and critical technology research areas for the future.

• MAIN ACHIEVEMENTS



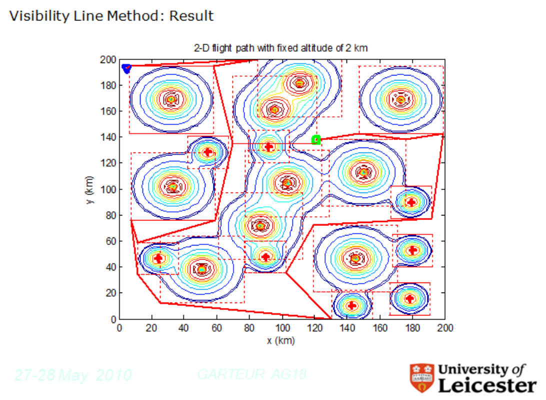
Typical mission framework showing mission phases

Work in FM/AG18 has taken place over 2011 and is on schedule. Some re-planning has taken place to accommodate changes to group membership due to funding problems of some members. Candidate methods have been identified. Following methods will be applied and further evaluated:

- Real time trajectory generation and tracking algorithm for 4D autonomous navigation
- Nonlinear Branch and Bound for path planning with avoidance
- Dual-mode cognitive automation for guidance
- Evolutionary path planner for multiple UAV in realistic environments
- Trajectory generation and mission planning and optimization for multiple UAV
- Task allocation, path planning and polynomial description of a receding horizon trajectory
- Reactive and deliberative architecture with planning based on constraint satisfaction

Work has continued on these methods and analysis metrics will be designed in the coming year to carry out the formal assessment.
Next steps will include

- Development of benchmarks and evaluation plan
- Development and improvement of candidate methods
- Evaluation of candidate methods
- Preparation of papers for exploitation at the Bristol UAV conference in May 2013.



Screenshot of Path Planning work

• MANAGEMENT ISSUES

It is planned to increase and extend the exploitation activities of this AG. E.g. it is planned to prepare papers for the Bristol UAV conference in May 2013. Therefore, the AG has been extended to the end of June 2013

- **EXPECTED RESULTS/BENEFITS**

Within the aviation industry human supervisory interaction with 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 thereby enabling a reducing in the number of operators required, or a reduction in operator workload, as well as compensating for human frailty. It is expected that the autonomous planning and decision making techniques to be developed in this AG will have application in a wide range of other domains.

- **FM/AG-18 MEMBERSHIP**

Member	Organisation	e-mail
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- **RESOURCES**

Resources		Year					Total 09-13
		2009	2010	2011	2012	2013	
Person-months	Actual/ Planned		33	36	30	12	111
Other costs (in K€)	Actual/ Planned		6	6	6	8	26

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1 Framework Description Report	06/2011		Completed
WP2 Problem decomposition Report	12/2010		Completed
WP3 Categorisation Report	12/2011	12/2012	Draft
WP4 Execution of Approach to Problem	06/2012	04/2013	On going
WP5 Results and Analysis	09/2012	04/2013	On going
WP 6 Exploitation UAV Conference in Bristol 2013 (new Task)		06/2013	

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

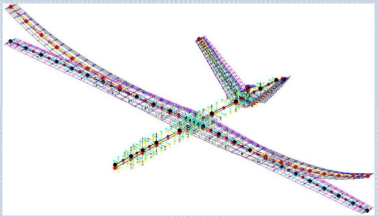
The next generation of air vehicles will have to face very challenging requirements in terms of performance, weight saving and overall performance efficiency. One way to achieve these targets is via an advanced flight control system performing multiple functions related with stabilization, envelope protection, 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

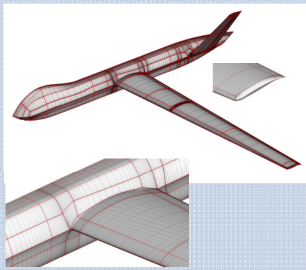
CASSIDIAN

BAE Systems

Imperial College

Univ. of Liverpool

TU Berlin



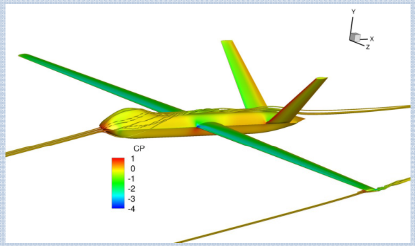
Results

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.



FM/AG-19	**Flexible Aircraft Modelling Methodologies**	
Monitoring Responsable:		F. Munoz Sans INTA
Chairman:		F. Asensio Airbus Military

- **OBJECTIVES**

The objective is to define a way of working for the integrated modeling activities, with the objective to generate an integrated aerodynamic and aeroelastic model to be used in the flight control laws design of advanced FCS. 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.
- Define a problem where the design should be challenging enough from a structural coupling point of view. It should be better is there would be a design already done using traditional methods.
- 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 applied 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.
- Perform a continuous industrial review activity in order to steer it an gathered the maximum benefit from the industrial perspective

- **MAIN ACHIEVEMENTS**

Main achievements comprise

- Requirements for software coding; draft deliver for partners review
- Flexible aircraft (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.

- **MANAGEMENT ISSUES**

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. Mitigation and recovery actions have been put in place. However, situation has not improved significantly. Due to lack of resources at management level and within the individual work packages the activity now is delayed by more than 24 months.

- **EXPECTED RESULTS/BENEFITS**

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. In order to design the control laws algorithm within the flight control system it is essential to get precise 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 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.

- **AG MEMBERSHIP**

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- **RESOURCES**

Resources		Year					Total 09-13
		2009	2010	2011	2012	2013	
Person-months	Actual/ Planned		42	21	0/21	18	102
Other costs (in K€)	Actual/ Planned		6	2	0/4	2	14

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1 Model Implementation & data Handling– D1.1 Definition of functional requirements	03/2010		Completed
WP1 – D1.2 Requirements for SW Coding	07/2010	01/2012	Draft
WP1 – D1.3 Model architecture coding	03/2011	03/2012	Draft
WP1 – D1.4 Implementation	08/2011	12/2012	
WP2 Mathematical Formulation – D2.1 General Review	03/2010		Completed
WP2 – D2.2 Model Formulation for CS design	07/2010		Completed
WP2 – D2.3 High Level Model	07/2011	06/2013	
WP3 Model Development D3.1 General review	06/2010	06/2013	Draft
WP3 D3.2 Integrated Process Definition	09/2010	06/2013	Draft
WP3 D3.3 Specific Application	04/2011	06/2013	
WP3 – D3.4 Specific for MvsM	12/2011	12/2013	
WP4 Model Validation – D4.1 Basic Validation Philosophy	06/2010		completed
WP4 – D4.2 Test Procedures	06/2011	06/2013	
WP4 – D4.3 Application	02/2012	06/2013	
WP5 Application – D5.1 Design requirements & Application	08/2010		completed
WP5 – D5.2 Design & assessment	12/2011	06/2013	
WP 5 – D5.3 Comparison of Results	04/2012	09/2013	
WP6 Industrial Review – D6.1 Assessment of Integrated Approach	12/2010	09/2013	
WP6 – D6.2 Final Report	06/2012	12/2013	

FM/AG-19 STALLED SINCE 2011
PLANS WILL BE REVIEWED IN 2013

ANNEX C

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES

HELICOPTERS

Remit

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

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

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

- Decrease costs (development and operation) through CFD and comprehensive calculation tools, validated with relevant tests campaigns
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines, ...)
- Increase security, safety
  - Security studies, UAVs, advanced technologies for surveillance, rescue and recovery,
  - Flight mechanics, flight procedures, human factors, new commands and control technologies,
  - Increase crashworthiness, ballistic protection, …
- Integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations)
- Tackle environmental issues:
  - Greening, pollution,…
  - Noise (external, internal),...
- Progress in pioneering: breakthrough capabilities

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

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

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

TABLE OF CONTENTS

HELICOPTERS

GoR OVERVIEW

GoR activities

The members of GoR for Helicopters represent the major national research centres and helicopter manufacturers in the European Union involved in civil and military rotorcraft related research. Currently, it is noticeable that the two European helicopter manufacturers are the world leading ones.

This membership enables the GoR to act as a highly effective forum in its primary function of promoting collaborative research through Exploratory Groups and Action Groups. It has been successful in establishing collaborative research programmes, at a non-competitive level, to the benefit of the European rotorcraft community, this includes both governmental and industrial interests. In addition, the GoR represents a unique forum within Europe for the interaction of the research establishments and industry, for the exchange of knowledge and understanding in the field of rotorcraft research and technology. An increasing number of University teams are associated to the activities of the action groups, with a real added value. Since 2011 the University of Liverpool is an active member of the GoR. The Helicopter GoR is a kernel for ideas for new research projects and supported the preparation of several EU proposals.

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

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

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

Management issues

The chairmanship in 2012 was held by Joost Hakkaart (NLR). Vice Chairman is Lorenzo Notarnicola who will take the chairmanship in 2013.

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

In the CleanSky Joint Technology Initiative and specially for the Green Rotorcraft ITD, the GoR members have been active in the past years. Since 2012, the GoR members contributed in various ways in setting up the CleanSky 2 Fast Rotorcraft IADP Projects. In the view of the HC-GoR, this aspect is advantageous for all, GARTEUR and EU, industry and research establishments. In practice the Exploratory Groups are used both for the generation of proposals for continued GARTEUR activity within an Action Group, normally at a relatively low level of effort, to analyse the state of the art for new topics and to define the framework and specification of further common research programmes, including EU proposals. In general, these activities are complementary, with some EU projects based on earlier GARTEUR research, and GARTEUR Action Groups benefiting from the outcome of EU funded activities. This applies in particular by using extensive wind tunnel and flight test databases, as well as any kind of valuable validation data.

During the reporting period, the GoR(HC) held two meetings:

- 65th GoR Meeting: 07-08 February '12, University of Liverpool, Liverpool UK
- 66th GoR Meeting: 09-10 October '12, Politecnico di Milano, Milan Italy

The main business of the meetings was to discuss about further topics and to implement the 3-5 year planning process as well as to present the status of the current AGs and EGs. The GoR meetings were used to harmonize the views and the involvement of members regarding preparations for proposals for FP7. These meetings were also used to discuss about CleanSky JTI building and goals, as well as future issues to be considered. Furthermore the dissemination of GARTEUR results on international conferences like the European Rotorcraft Forum (ERF) and the Annual Forum of the American Helicopter Society (AHS) was harmonized and supported.

In 2012 the activities in the HC-AGs were at a low level. 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.

Future Topics

The following topics are being considered for future Exploratory Groups, together with general Safety related problems. The CleanSky JTI Green Rotorcraft ITD is gathering the environmental issues. So, the next issues to be explored by GoR(HC) should not be linked to environmental topics but should be oriented towards safety and comfort topics in order to extend the use of helicopters.

These topics can be:

- 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

At least three of these ideas (Forces on obstacles in Rotor Wakes, CFD based flow prediction for complete helicopters, Wind Turbine wake influence on h/c operations) are expected to become an EG in 2013.

Active HC/AGs

HC/AG-17 “Wake Modelling in Presence of Ground Obstacles” has been launched in June 2008 and although in 2011 activities were low, it’s in the concluding phase. Results were presented during ERF2011 in Gallarate, Italy in a paper entitled, “Rotor Wake Modelling in Ground Effect Conditions”, by A. Filippone, R. Bakker, P.M. Basset & B. Rodriguez, R. Green, B. Kutz, F. Bensing & A. Visingardi. The final report for this AG (TP-174) was completed in 2012.

HC/AG-18 “Data and Methods for Error Localisation and Model Refinement of Structural Dynamic Finite Element Models” has been launched for a 3 years duration. Due to difficulties in the starting phase this AG is still not yet really started. The council agreed to stop this AG during their fall meeting in 2012.

HC/AG-19 “Methods for Improvement of Structural Dynamic Finite Element Models Using In-Flight Test Data” has been launched June 2008 for a 3 years duration. Due to difficulties in the starting phase this AG will need an extension of about two years. In 2012 good progress has been made. The council accepted a prolongation up to the end of 2013

HC/AG-20 “Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction” has been launched by GoR in 2011. Finally, the chairman was able to organise a kick-off meeting by the end of 2012. Actual start is expected early 2013.

Running Exploratory Groups

HC/EG-29 “Intelligent Lifeing & HUMS” was launched in 2011, and is expected to really start early 2013.

The exploratory group on “Simulator fidelity” (HC/EG-30) has run smoothly in 2012 and is expected to result in an Action Group early 2013.

In 2012, GoR decided to launch HC/EG-31 on “Helicopter Conceptual Design”.

Furthermore, for three new EGs draft pilot papers were issued and are expected to be launched early 2013.

Generating new topics for common studies

The 3–5 year planning will continue to be implemented and was presented in more details to the Council in the Autumn 2012 meeting in Paris. This list is implemented with new topics according to the GoR discussions.

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

Topic	ST	2009	2010	2011	2012	2013	2014	2015	2016
Wake Modelling with Ground Obstacles	HC/AG17	EG26 =>				=> EG ?			
Eror Localisation and Model Refinem. for FEM	HC/AG18	EG27 =>			X				
Methods for Impr. of Struct. Modell. In-Flight Data	HC/AG19	EG27 =>							
Simulation/Testing for design of passive noise absorption panels	HC/AG20			EG28 =>					
Testing/Modelling for Interior Noise Investigation	HC/EG28			=> AG20					
HUMS	HC/EG29								
Simulator fidelity	HC/EG30					=> AG			
Conceptual design of Helicopters CoDHe	HC/EG31								
Testing/Modelling for Interior Noise Investigation	ID		=> EG28						
Intelligent Lifeing & HUMS	ID			=> EG29					
(Pioneering)	ID								
Basic Acoustics;	ID								
Acoustic Monitoring	ID		=> no EG						
(HC Integration into ATM)	ID								
(Centrifugal Effects on Boundary Layer)	ID								
Forces on Obstacles in Rotor Wake; AG17 follow-up	ID								
Simulation Fidelity	ID				=> EG30				
(Synergies between Civil and Military Systems)	ID								
Conceptual Design of Helicopters	ID				=> EG31				
(Sand/dust Engine protection)	ID								
Wind turbine wake influence on h/c operations	ID								
Fuselage Scattering Effects for Exterior/Interior Noise Reduction	ID								
Aerodynamics & CFD Simulation	ID								

( ): no pilot paper issued yet.
no ( ): pilot paper has been issued.

3-5 year Rolling Plan

The Environmental issues are included in the studies of the Green Rotorcraft Integrated Technological Demonstrator, within the Clean Sky JTI programme, launched by European industries and partially funded by EU. The programme of rotorcraft related studies is included in GRC and will last 7 years. The GoR members, are associates (research centres) and leaders (industry) in this type of EU contract.

Since 2012, the GoR members contributed in various ways in setting up the CleanSky 2 Fast Rotorcraft IADP Projects.

Foreseen GoR activity

Two meetings are planned in 2013; the first one on 18-19 February 2013 at Eurocopter, Marignane, France and the second one on 25-26 September in Germany.

Ir. Joost Hakkaart
Chairman (2011-2012)
Group of Responsables Helicopters

GoR MEMBERSHIP

Membership of the Group of Responsables Helicopters (end 2012)

Chairman			
Joost Hakkaart	NLR	The Netherlands	Joost.hakkaart @nlr.nl
Vice-Chairman			
Lorenzo Notarnicola	CIRA	Italy	l.notarnicola@cira.it
Members			
Blanche Demaret	Onera	France	blanche.demaret@onera.fr
Antonio Antifora	AgustaWestland	Italy	antonio.antifora@agustawestland.com
Philipp Krämer	ECD	Germany	Philipp.Kraemer@eurocopter.com
Elio Zoppitelli	Eurocopter	France	Elio.Zoppitelli@eurocopter.com
Klausdieter Pahlke	DLR	Germany	klausdieter.pahlke@dlr.de
Mark White	Uni of Liverpool	United Kingdom	mdw@liverpool.ac.uk
Observer			
Richard Markiewicz	Dstl	United Kingdom	rhmarkiewicz@mail.dstl.gov.uk

HC-GoR visiting Politecnico di Milano during the 66th GoR meeting (9-10 October 2012);
Pierangelo Masarati (host POLIMI), Antonio Antifora, Mark White, Klausdieter Pahlke, Joost Hakkaart, Blanche Demaret, Lorenzo Notarnicola, Elio Zoppitelli.

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Table of participating organisations

	HC/AG & HC/EG						
	AG17	AG19	AG20	EG30			
Research Establishments							
ONERA	□		■	□			
DLR			□	□			
CIRA	□		□				
NLR	□	■	□	□			
Dstl							
Industry							
EC				□			
ECD							
AgustaWestland		□		□			
LMS (Belgium)		□					
BAE Systems				□			
CAE				□			
SMEs							
MICROFLOWN			□				
Other (operator)							
Bristow Helicopters				□			
Academic Institutes							
University of Liverpool (UK)		□		■			
University of Manchester (UK)	■						
University of Glasgow (UK)	□						
University of Bristol (UK)		□					
University of Brunel (UK)		□					
University of Delft (NL)				□			
University of Roma La Sapienza (It)		□					
University of Stuttgart (D)	□						

□ = Member ■ = Chair

Total yearly costs of HC/AG and HC/EG programmes

	2008	2009	2010	2011	2012	2013	2014
Person-month	53	42	35	27	14	35	35
Other costs (k€)	58	66	31	30	7	30	30

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

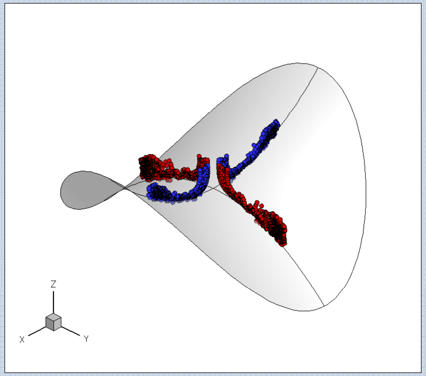
Agusta-Westland Merlin in brown-out landing.

Programme/Objectives

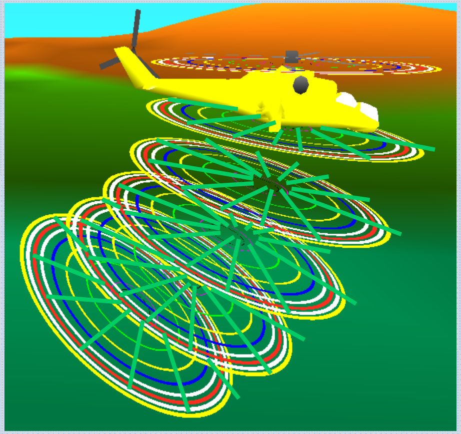
Research activities were launched in 2008 under the umbrella of the GARTEUR organisation in order to improve the physical understanding of helicopter wakes in confined spaces and to define criteria for quantifying the helicopters susceptibility. The GARTEUR Helicopter Action Group 17 (HC/AG-17) comprises 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.

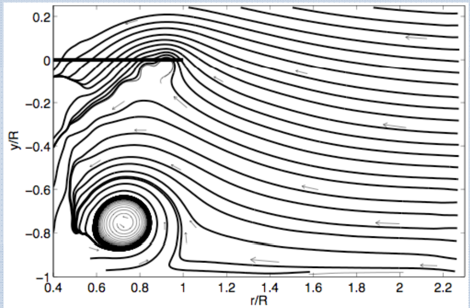


Helicopter Wakes in Saddle-Shaped Ground plane.



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)

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

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.)

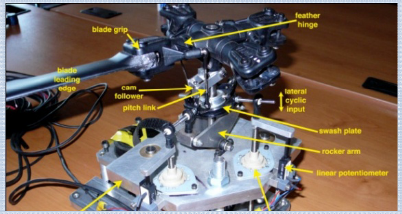
Advancement of some numerical methods for the prediction of ground effects.

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

HC/AG-17	**Wake Modelling in the Presence of Ground Obstacles**	
Monitoring Responsable:		Dr. K Pahlke DLR
Chairman:		Prof. A. Filippone University of Manchester

- **OBJECTIVES**

The 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.

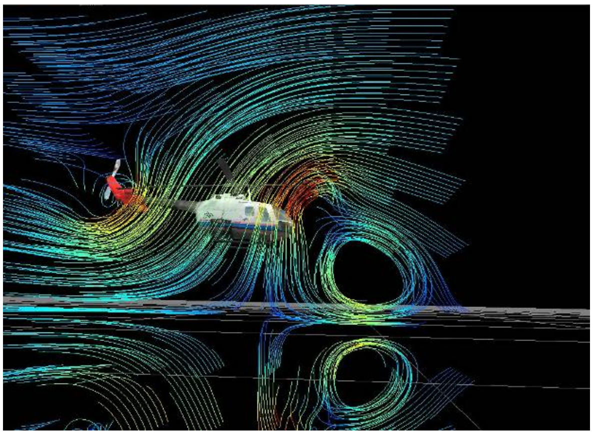
Eurocopter Cougar in brown-out.

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.

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

- **MAIN ACHIEVEMENTS**

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.

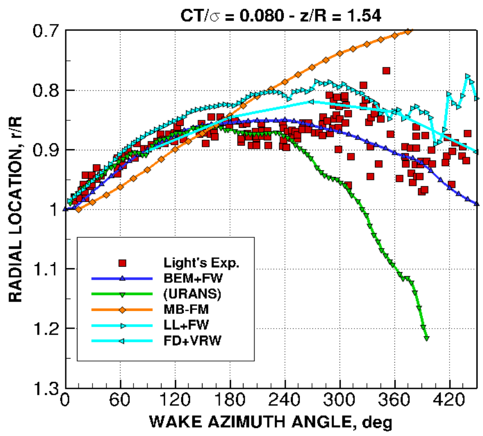
Analysis includes cases of a variety of ground obstacles (vertical walls, inclined walls, saddle planes, etc.)

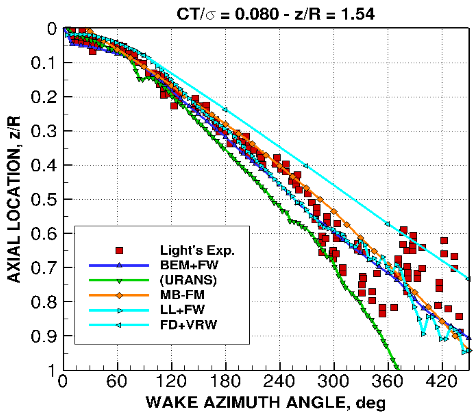
Advancement of some numerical methods for the prediction of ground effects.

Wind tunnel scale measurements of ground effects in hover and forward flight, 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 Modelling in Ground Effect Conditions", 37th ERF, Sept. 2011, Gallarate (VA), Italy.





- **MANAGEMENT ISSUES**

The Kick-Off meeting was hosted by University of Glasgow, UK, in June 2008. Four technical meetings took place: 10-12 February 2009 at Onera, Salon de Provence, France, 25-26 Jan. 10 at NLR, Amsterdam, 21-22 Sept. 2010 at University of Manchester and 22-23 Febr. 2011 at Univ. of Stuttgart.

- **RESULTS/BENEFITS**

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.

Final report (TP-174) was finalised in 2012.

Based on the results obtained, a new EG is initiated to study "Forces on Obstacles in Rotor Wake"

- **HC/AG-17 MEMBERSHIP**

Member	Organisation	e-mail
Antonio Filippone c	Manchester University	a.filippone@manchester.ac.uk
Antonio Visingardi	CIRA	avinsingardi@cira.it
Ian Roberts	*QinetiQ*	*iroberts@qinetiq.com*
Richard Bakker	NLR	richard.bakker@nlr.nl
Pierre-Marie Basset	ONERA	basset@onera.fr
Okko Boelens	NLR	okko.boelens@nlr.nl
Benjamin Kutz	Stuttgart University	kutz@iag.uni-stuttgart.de
Richard Green	Glasgow University	Richard.Green@glasgow.ac.uk

- **RESOURCES**

Resources		Year					Total 08-12
		2008	2009	2010	2011	2012	
Person-months	Actual/ Planned	A4 P4	A18 P17	A17 P19	A13 P16	A1 P1	A53 P57
Other costs (in K€)	Actual/ Planned	A7 P7	A46 P47	A25 P30	A18 P15	A1 P1	A97 P100

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: Review Existing Database	Dec 2008	Dec 2008	Dec 2008
Task 2: Extension of Models	June 2009	Dec 2009	Dec 2009
Task 3: 1st-Stage Correlations	Dec 2009	Dec 2010	Dec 2010
Task 4: 2nd Stage Correlations	March 2011	Dec 2011	Dec 2011
Task 5: Reporting	June 2011	Dec 2012	Feb 2013

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

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

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

Background

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

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

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

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

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

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

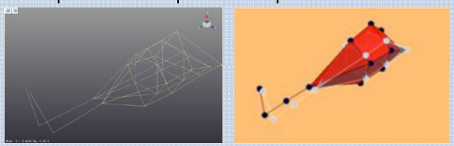
Other recommendations with respect to ground vibration testing are considered in the closely related GARTEUR Action Group HC/AG-18.

Programme/Objectives

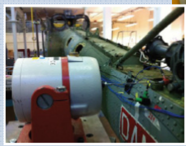
Objectives
The main purpose of this AG is to explore methods and procedures for improving finite element models through the use of in-flight dynamic data. For the foreseeable future it is expected that validated finite element models will be the major tool for improving the dynamic characteristics of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

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

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



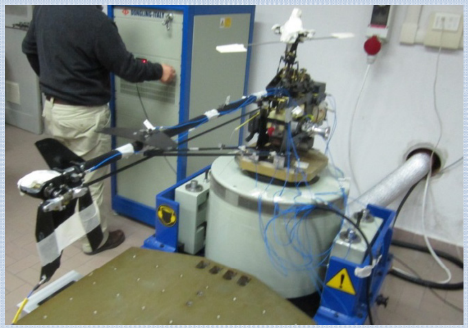
Traditional analysis versus OMA analysis



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

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

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

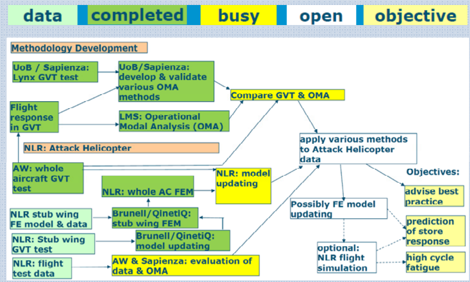


The third data set will be based on a discontinued commercial helicopter model from AW .

Results

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

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



Members of the HC/AG-19 group are:

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-19 **Methods for Improvement of Structural Dynamic FE Models using in Flight Test Data**

Monitoring Responsable: J. Hakkaart, NLR

Chairman: H. van Tongeren, NLR

- **OBJECTIVES**

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.

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.

- **MAIN ACHIEVEMENTS**

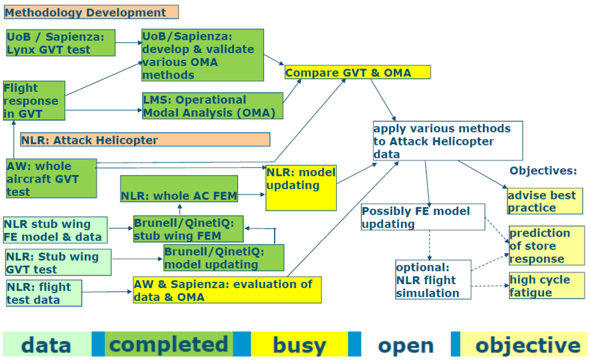
Three sources of flight test data are available to the action group:

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 an 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 its disposal. A finite element model is available. The model has been reworked to represent the actual mass and configuration in a new ground vibration test that was conducted in January 2013. Additional flight tests are foreseen in June 2013.
The advantage of this helicopter is that it is always available for additional ground vibration and flight tests.

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

The available experimental flight test data for validation purposes was reviewed and made available to the partners (through secure web access) by NLR. The partners started to analyse the data and to update their FE modes.



For the attack helicopter the stub wing models were simplified in order to reduce the total model size. The FE model and mass distribution of have been reworked to represent the helicopter that has been subjected to a GVT in January 2013. The model will be tuned with the GVT results. This work has been delayed due to high the work load for other projects at NLR.

The available experimental flight test data has been processed and transition to hover flight data has been performed by AW and provided good results. Some known vibration modes and frequencies could be derived from the measurements. The flight test data will be used to further improve the FE model.

Work on methods development at the universities has been completed. In 2013 methods are to be applied to the available flight data. Reporting will commence in 2013.

- **MANAGEMENT ISSUES**

After the Kick-Off meeting on 24th June 08 the first technical meeting took place on 20-21 Nov. 08 at Bristol University. There were no technical meetings in 2009. During 2010 two new members joined: University of Rome La Sapienza and LMS from Belgium. The last meeting took place 3-4 November 2011 at Bristol university. This AG effectively started in May 2010. Therefore the duration will be extended until 2013. The next meeting is expected to take place in May 2013. QinetiQ has left Garteur AG-19 in 2011.

- **EXPECTED RESULTS/BENEFITS**

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.
The ultimate objective for the operator would be a more reliable prediction of high cycle fatigue behaviour and thus usage life of the structure through a more reliable analysis model. Fatigue analyses are not part of the AG-19 project.

- **HC/AG-19 MEMBERSHIP**

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Trevor Walton	Agusta Westland Ltd	Trevor.Walton@agustawestland.com

- **RESOURCES**

Resources		Year						Total
		2008	2009	2010	2011	2012	2013	
Person-months	Actual/ Planned	A3 P3	A2 P3	A16 P6	A14 P18	A12 P10	P8	A47 P42
Other costs (in K€)	Actual/ Planned			A4 P4	A10 P10	A5 P5	P3	A19 P22

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: model updating based on ground vibration tests	2009	2013	2013
Task 2: Prediction of configuration changes on FRF behaviour	2011	2013	2013
Task 3: How to measure and use in-flight dynamic data for the extraction of modal parameters that include the effects of aerodynamic loads, and rotating machinery	2011	2013	2013
Task 4: Vibration prediction based on hub load predictions for the flight test conditions	2011	2013	2013
Task 5: Reporting	2011	2013	2013

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

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

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

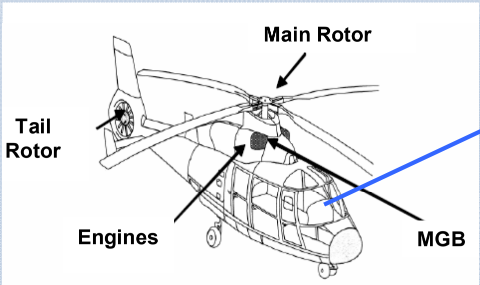
2) to design composite trim panels with industrial requirements and simulate acoustic performances of treatments after integration in cabin

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)

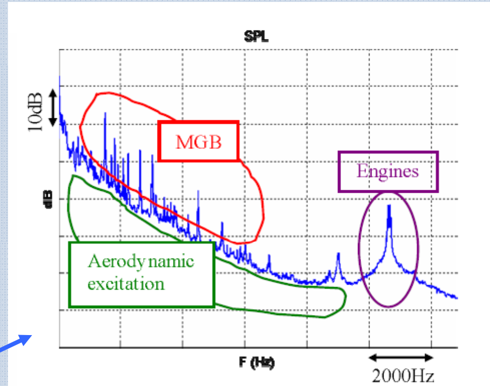


The activities in the new HC/AG-20 constitute the conclusion of HC/EG-28 and explore the points 2 to 4:

• 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

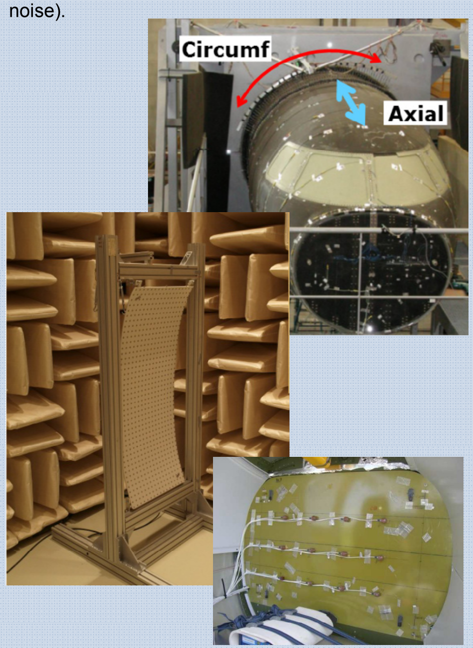
• applying different types of experimental techniques to characterize composite trim panel acoustic radiating in both a standardized test set –up and a generic helicopter cabin.

• 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

HC/AG-20	**Cabin internal noise : simulation methods and experimental methods for new solutions for internal noise reduction**
Monitoring Responsable:	B. Demaret ONERA
Chairman:	Dr. F. Simon ONERA

- **OBJECTIVES**

EG28, 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 AG20.

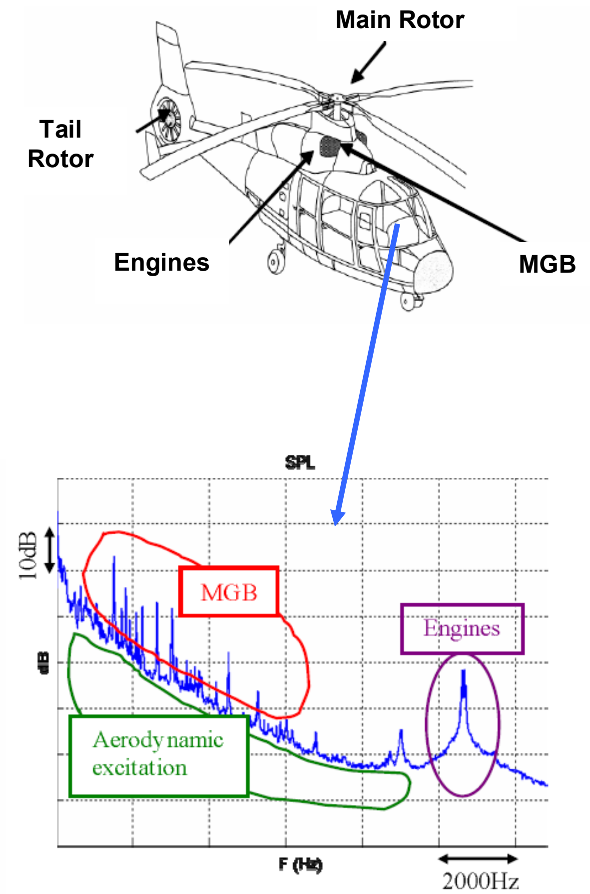
The EG28 conclusions listed the following needs:

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)

- **ACTIVITIES**

The activities in the new AG20 constitute the conclusion of EG28 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.

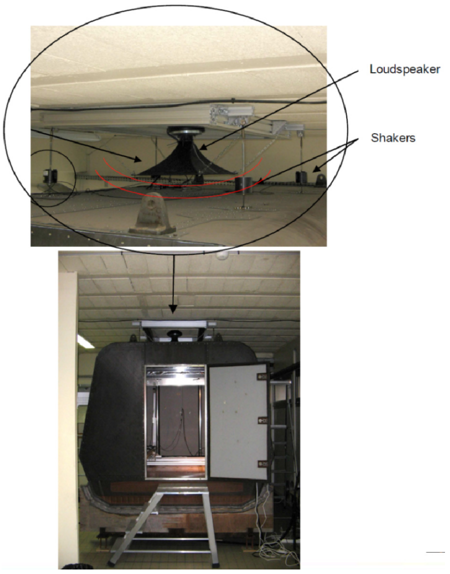


- **MANAGEMENT ISSUES**

The Chair was able to organise the kick-off meeting via a webex on October 18th, 2012. During the meeting the membership, resources and work packages were discussed and confirmed. Actual starting date will be January 1st, 2013

- **EXPECTED RESULTS/BENEFITS**

Benchmark of the appropriateness of tools for complex configurations (multiple anisotropic layers with various mechanical characteristics, effect of confined medium on internal noise).



- **HC/AG-20 MEMBERSHIP**

Member	Organisation	e-mail
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Rik Wijntjes	NLR	Rik.Wijntjes@nlr.nl
Thomas Haase	DLR	Thomas.Haase@dlr.de
Frank Simon	ONERA	frank.simon@onera.fr
Pasquale Vitiello	CIRA	p.vitiello@cira.it

Expression of interest :
PoliMI, Italy - Gian Luca Ghiringhelli

- **RESOURCES**

Total resources have been confirmed during the kick-off meeting and have been split tentatively in years.

Resources		Year					Total
		2012	2013	2014	2015	2016	
Person-months	Actual/ Planned	A1	P18	P20	P18		A1 P57
Other costs (in K€)	Actual/ Planned	A1	P10	P28	P28		A1 P67

- **PROGRESS/COMPLETION OF MILESTONE**

The planning is as defined by participants, but the AG20 is still waiting for Kick Off Meeting

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: **Benchmark on simulation and experimental techniques to design and characterize composite trim panels**	T0+ 18M	2015	
1.1: Requirement of non structural components	T0+ 3M	2013	
1.2 Simulation of non structural components	T0+ 12M	2013	
1.3 Development of optimization procedures	T0+ 12M	2013	
1.4 Development of new “no brick two sides PU intensity method".	T0+ 18M	2013-14	
1.5: Optimization of hybrid (active-passive) or tuned absorbers, viscoelastic patches (added materials).	T0+ 12M	2013	
1.6 Manufacturing of small samples and added materials	T0+ 15M	2014	
1.7: Preliminary tests of small samples and added materials	T0+ 21M	2014	
1.8: Manufacturing of trim panels	T0+ 15M	2014	
1.9: Tests of trim panels with added materials in laboratory set-up.	T0+ 21M	2014	
1.10: Validation of simulation methods	T0+ 24M	2014	
1.11: Test of trim panel(s) with added materials in ONERA generic helicopter cabin	T0+ 33M	2015	
1.12: Analysis and comparison of results	T0+ 12M	2015	
Task **2 Test procedures to separate correlated and uncorrelated acoustic sources in generic helicopter cabin**			
2.1: Requirement of procedures	T0+15	2014	
2.2: Test of procedures for separation of sources : Campaign 1	T0+24	2014	
2.3: Test of procedures for separation of sources : Campaign 2	T0+33	2015	
2.4: Analysis and comparison of results	T0+36	2015	

HC/EG-30	**DEVELOPMENT OF NEW CRITERIA FOR ROTORCRAFT SIMULATION**
Monitoring Responsable:	Richard Markiewicz Dstl
Chairman:	Mark White University of Liverpool

The GARTEUR HC/EG30 was established to examine the challenges that exist in the definition of rotorcraft simulation fidelity.

- **OBJECTIVES**

The first objective of the EG was to examine the state of play of current research and industrial practices related to defining metrics for rotorcraft simulation fidelity.
And subsequently, make recommendations for a focussed activity for a future Action Group to examine critical aspects of simulator fidelity

- **PROGRESS**

The Kick-off meeting was organised at the Univerity of Liverpool on 14 February 1212. During this meeting the scope of interest was defined and interested parties defined.
During the follow-on at ONERA/HELISIM on 16 August 2012 the areas for an follow-on AG have been defined.

- **RESULTS/BENEFITS**

The results of the EG have been reported and ToR for a follow-on Action Group have been defined.
The principal objective of the Action Group (AG) is to gain a better understanding of the various components that contribute to the definition and perception of rotorcraft simulation fidelity. This may subsequently result in the development of new criteria for fidelity assessment. This activity would require an examination of the influence of the flight loop tolerances on predicted fidelity assessment together with an investigation of the role of simulator cueing on subjective or perceived fidelity assessment. The research outcomes would be in the form of new metrics which would define rotorcraft simulation fidelity boundaries together with guidelines for the subjective fidelity assessment process. It is anticipated that the outputs from this AG would be used to enhance the fidelity criteria that exists in current and emerging flight simulation qualification standards for rotorcraft.

- **Workplan**

Existing models (and flight test data where possible) will be used to provide the framework for the evaluation of the different validation techniques. Maximum unnoticeable added dynamics envelopes have been proposed to define regions of acceptable levels of mismatch in equivalent-system matching processes. GARTEUR AG-09 developed time and frequency domain modelling criteria based on statistical methods; the use of this technique for model validation will be further investigated. A modified ADS-33E-PRF (Handling Qualities Requirements for Military Rotorcraft) time-domain cross coupling metric has been proposed for fidelity assessment to improve on the rotorcraft simulator qualification requirement for proof of match data to show “correct trend and magnitude”. The output form this work will be the definition of new criteria for rotorcraft flight simulation model validation.
Validated models will be used during for perceived fidelity assessment, both in examining the effect of the cueing and virtual environment on subjective evaluation of fidelity but also to refine existing techniques to obtain quantitative measures of perceived fidelity.

- **PROPOSED AG MEMBERSHIP**

Member	Organisation	e-mail
M.D. White C E. Timson G. Meyer	University of Liverpool	mdw@liverpool.ac.uk
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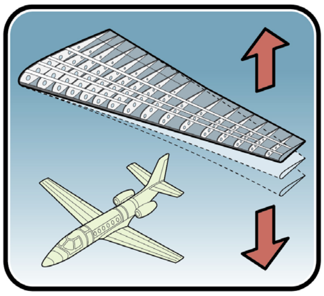
TBD	Eurocopter	
C. Emmanuele	AgustaWestland (Training Academy)	

Monitoring Responsable: Joost Hakkaart (NLR)

- **RESOURCES**

Resources		Total		
		2013	2014	
Person-months	Actual/ Planned	A P24	A P24	A P48

ANNEX D



ANNUAL REPORT FROM THE GROUP OF RESPONSABLES

STRUCTURES AND MATERIALS

Remit

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

The GoR SM is active in initiating and 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.

TABLE OF CONTENTS

GOR OVERVIEW

GoR activities

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

The activities on high velocity impact are aimed to the increase of safety of aircraft structures and to the reduction of design and certification costs by improving numerical approaches for simulation of bird strike on pre-stressed structures and by predicting damage caused by impact from foreign objects. Emphasis is put on novel/hybrid materials and structures with complex geometries.

The activities on Damage Management of Composite Structures for Cost Effective Life Extensive Service have resulted in a comprehensive methodology for damage management of composite aircraft structures, based on an integrated approach towards design, inspection, assessment and repair. A high level of confidence in this methodology is pursued by demonstration on a significant scale. The methodology benefits the design of more damage tolerant structures, and on the other hand, simplifies inspection, assessment and repair procedures in case damage has occurred.

Based on the emerging needs related to the composites usage in aerospace applications, the main objective of the activities on Damage Growth in Composites is the development of integrated numerical/experimental methodologies capable to take into account the presence of damage and its evolution in composite structures from the early phases of design (conceptual design) up to the detailed FEM analysis and verification phase. The results expected from these integrated methodologies are the improvement of composite components performances by optimising the weight according to damage tolerant design philosophies and the enhancement of the allowables by modifying the safety concepts and criteria thus decreasing or removing the safety factors related to the presence of damage.

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

The structure of aircraft in service will obtain various types of damage e.g. from impact loading. It is therefore important to have effective repair methods. Damages caused by impact are in general much more severe in composite structures than in metals structures. Reparability of such damage is an important consideration in the selection of composites for aircraft applications. Repair techniques both for civil and military aircraft structures are defined through the development of numerical/experimental methodologies. The following issues are addressed: repair criteria, design of patches and repair strategies, analysis of the repair, manufacturing and test, repair strategies and technology, effective repair methods.

Aircraft structures are subjected to dynamic loading such as landing loads, separation loads, birdstrike etc. The analysis methods for prediction of dynamic loads are continuously evolving which in many cases lead to prediction of higher load with shorter duration. The structures are generally design using these peek loads which generally lead to conservative designs and overweight structures. New activities within GoR SM will address this topic.

Although the specific topics vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas on future activities. In several cases the results of the collaboration have led to research proposals which have been submitted successfully to the EC to be granted by the Framework Programmes and to EDA to be granted by MoD:s. Furthermore, some collaborations have formed the basis of relevant national programmes. Besides strengthening links between EREA members, the collaborative research programme satisfies a primary industry requirement and participation by the industry is particularly valuable.

Management issues

The GoR meets twice a year to monitor Action Group and Exploratory Group activities; the AG:s and EG:s themselves meet at various locations in Europe, with the Monitoring Responsable from the GoR present, if necessary. The estimated cost for the working time and travel and subsistence is about 200 k€ per annum. During 2012, the GoR SM has started to recover from the situation caused by the UK withdrawal three years ago. Two new Action Groups and one Exploratory Group have started. Three final reports have been prepared.

Future plans

Research on structures and materials will provide data, methods and procedures for the improvement of the design process, structural safety and reliability, cost effectiveness, certification procedure and passenger comfort of future aircraft in general. Improved data quality and accuracy of prediction are direct results of the research performed. With the intense competition in civil aeronautics, this is of great importance. Such progress can be directly translated into advantages in a commercial sector. Prediction accuracy and certainty of performance enhancements are of major importance.

All mentioned research activities imply important gains in the usability of procedures and improved understanding of their limitations. They will provide valuable knowledge that is shared between the partners and thus reduces the effort for each of them. Furthermore, they will enable the industry to make progress in the design process and in the production of structures. Besides, other benefits of the results lead to improvement in fuel efficiency and therefore to a lower demand on natural resources.

Rolling plans for SM/AGs and SM/EGs

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 ➔		
SM/EG-39	Design for High Velocity Impact on Realistic Structures						
SM/EG-40	Sizing of aircraft structures subjected to dynamic loading						

Managed and foreseen GoR activity

In 2012, the GoR(SM) held two meetings:

- 65th meeting on May 8 at NLR, The Netherlands
- 66th meeting on October 17 at FOI, Sweden

The Industrial Points of Contacts were invited to all meetings.

At these meetings, the GoR was informed on the progress of the current Action Groups and Exploratory Groups by the monitoring Responsables. Issues related to the AG and EG were discussed and recommendations were made.

In 2013, GoR meetings are planned as follows:

- 67th meeting on May 22 at Cassidian, Germany
- 68th meeting on October 17 at EADS-IW or ONERA, France

Dr. Tomas Ireman
Chairman
Group of Responsables
Structures and Materials

GOR MEMBERSHIP

Current membership of the Group of Responsables Structures and Materials

Chairman			
Dr. Tomas Ireman	SAAB	Sweden	tomas.ireman@saabgroup.com

Vice-Chairman			
Vacant			

Members			
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Dr. Henri de Vries	NLR	The Netherlands	henri.de.vries@nlr.nl
Mr. Jose Maroto Sanchez	INTA	Spain	marotosj@inta.es
Mr. Umberto Mercurio	CIRA	Italy	u.mercurio@cira.it
Dr-Ing. Peter Wierach	DLR	Germany	peter.wierach@dlr.de
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Dr. Walter Zink	Airbus	Germany	walter.zink@airbus.com
Dr Sören Nilsson	SICOMP	Sweden	soren.nilsson@sicomp.se
Dr Andy Foreman	Qinetiq	United Kingdom	adforema@qinetiq.com
Dr Caroline Petiot	EADS-IW	France	caroline.petiot@eads.net

*) Left the GoR during 2012 (has not been replaced yet)

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action Groups (AG)

The following Action Groups were active during 2012:

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

- SM/AG-32: Damage growth in composites.
  The work within this AG has been completed and final report has been written.

- SM/AG-34: Damage repair with composites.
  This AG started in the second half of 2012 and is a result from EG-40.

- SM/AG-35 Fatigue and Damage Tolerance Assessment of Hybrid Structures.
  This AG started in the second half of 2012 and is a result from EG-38.

Exploratory Groups (EG)

The following Exploratory Groups were active during 2012:

- SM/EG-38: Fatigue and Damage Tolerance Assessment of Hybrid Structures.
  This EG resulted in the start of AG-35 (with the same name as the EG).
- SM/EG-39: Design for high velocity impact on realistic structures.
  This EG is close to become an AG
- SM/EG-40: Damage repair with composites.
  This EG resulted in the start of AG-34 (with the same name as the EG).
- SM/EG-41: Sizeing of aircraft structures subjected to dynamic loading.
  This EG has just formally started

Future topics

The following topics for future Exploratory Groups are discussed:

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

The following topics have not received sufficient interest by the GoR-SM members and industrial point of contacts and are therefore dropped from the list of potential new EG:s:

- Fatigue of NCF (Non Crimp Fabrics)
- Damage tolerance of mechanical systems and system installations

Table of participating organisations

• = Member ■ = Chair

SM/AG number	31	32	33	34	35
Research Establishments					
ONERA		•			
DLR		•	•		•
CIRA	■	■	•	•	
NLR	•		■		■
INTA		•		•	
FOI				•	•
CNR		•		•	
Industry					
EADS München		•			
ESI					
BAE Systems					
QinetiQ	•	•		•	
SAAB		•		•	•
SICOMP		•	•		
SONACA					
ALENIA		•			
POLIYWORX			•		
FOKKER					•
Academic Institutes					
IABG					
CAA					
CSL					
Politecnico di Milano					
Imperial College		•		•	
University of Nantes		•			
LTU		•		•	
University of Naples		•			
UT			•		
SUN				■	
NTNU				•	

Total yearly costs of SM/AG research programmes

	2007	2008	2009	2010	2011	2012	2013
Man-month	133,5	108	102,5	50	6	12	61
Other costs (k€)	238	117	128	40	10	2	80

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

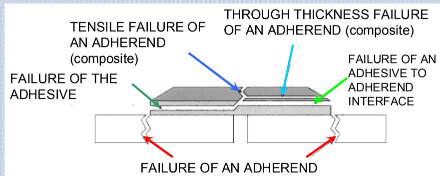
WP 5 EFFECTIVE REPAIR METHODS

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.



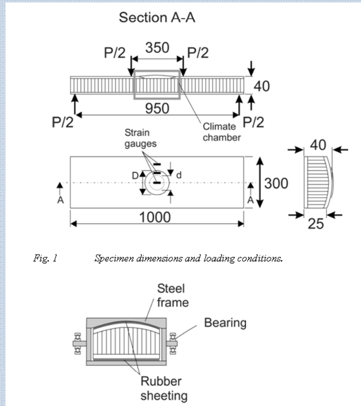
Failure modes in adhesively bonded repair will be analysed

Expected Results

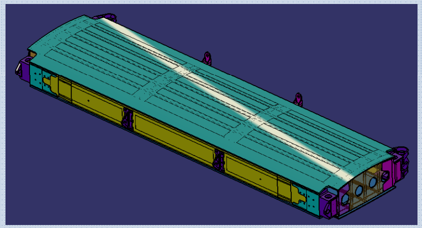
The effective outcomes can be summarized in:

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 · AleniaAermacchi Una Società Finmeccanica · QinetiQ · NLR · Institute of Composite and Biomedical Materials · The Composites Centre for research, modelling, testing and training in advanced composites · FOI · NTNU – Trondheim Norwegian University of Science and Technology · SICOMP · LULEÅ TEKNISKA UNIVERSITET · INTA · SAAB TECHNOLOGIES

ACTION GROUP REPORTS

SM/AG-34	**Damage Repair with Composites**	
Monitoring Responsable:		U. Mercurio CIRA
Chairman:		Dr. A. Riccio SUN

- **OBJECTIVES**

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

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

This objective addresses the following issues: repair criteria, design of patches and repair strategies, analysis of the repair, manufacturing and test, repair strategies and technology, effective repair methods

- **STATEMENT OF WORK**

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

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.

EXPECTED RESULTS/BENEFITS

The effective outcomes can be summarised in:

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

- **SM/AG-34 MEMBERSHIP**

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- **RESOURCES***

Resources		Year				Total 12-15
		2012	2013	2014	2015	
Person-months	Act./ Plan.	6 / 10	50	40	60	160
Other costs (in K€)	Act./ Plan.	0 / 20	50	60	50	180

* some figures have yet to be confirmed

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1 Report	Oct 2014	Oct 2014	
WP2 Report	Apr 2015	Apr 2015	
WP3 Report	Apr 2015	Apr 2015	
WP4 Report	Apr 2015	Apr 2015	
WP5 Report	Oct 2015	Oct 2015	
Final Report	Oct 2015	Oct 2015	

GARTEUR — GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

Action Group Chairman: 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

SM/AG-35	**Fatigue and Damage Tolerance Assessment of Hybrid Structures**	
Monitoring Responsable:		H.P.J. de Vries NLR
Chairman:		R.P.G. Veul NLR

- **OBJECTIVES**

The main objectives are listed below:

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

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

- **MAIN ACHIEVEMENTS**

The AG proposal has been finalised and all parties have sent their commitment letters.
The work planned has been divided in the following tasks and phases:

Task 1: Determination of a test spectrum
In this task 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 (e.g. for attachment areas between a warm fuselage and a cold wing) 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

- **MANAGEMENT ISSUES**

The proposal is periodically discussed and updated and presented at the GoR meeting in April 2012. Kick-off was expected to take place in 2012, but had to wait until all official Letters were signed by all parties. Kick-off is now planned for early 2013.

- **EXPECTED RESULTS/BENEFITS**

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

- **SM/AG-35 MEMBERSHIP**

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Hans Ansell	SAAB	hans.ansell@saabgroup.com

- **PLANNED RESOURCES**

Resources		Year				Total 12-15
		2012	2013	2014	2015	
Person-months	Act./ Plan.	1	11	11	10	33
Other costs (in K€)	Act./ Plan.	2	30	41.5	35	108.5

- **PROGRESS/COMPLETION OF MILESTONE**

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

EXPLORATORY GROUP REPORTS

SM/EG-39 **Design for High Velocity Impact on Realistic Structures**

Monitoring Responsable: J. Maroto, INTA

Chairman: L. Iannucci, Imperial college

- **Objectives**

To establish a detailed work programme.
To determine relevant material characterization required for modeling high performance fibers and composites.
To identify important parameters to be investigated for design relevant to high velocity impact.
To establish a fabrication/testing matrix for realistic components on the programme.

- **Benefits**

The fabrication, test and certification/validation of composite components and structures can be extremely expensive, especially when testing shock/explosive/crash events or bird strike. Whilst advanced simulations will never eliminate the testing of structures, numerical modelling can study the effect of different structural and materials parameters, typically enabling new novel structural concepts to be validated without an extensive fabrication and testing programme. This leads to a considerable reduction in conceptual design, thus significantly reducing the time-to-design duration.

- **Progress**

A draft work programme has been prepared. The project tasks are summarised hereafter:

Proposed Work package breakdown:
Task 1: Material characterisation for potential designs
Testing of fibres or laminates, temperature and volume effects, high rate testing from existing projects and in-house data.
Task 2: Fundamental characterisation of relevant materials
Testing associated with missing information from task 1.
Task 3: Review of high velocity resistance designs
Detailed review of existing designs.
Task 4: Modelling strategies for features relevant to high velocity design
Modelling sub-component impacts using novel designs or materials.
Task 5: Realistic design of representative components for high velocity impact
Design of full size designs using numerical techniques.
Task 6: Fabrication of representative components
Fabrication of designs.
Task 7: Testing of representative components
Impact testing of selected high velocity resistance designs.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
ONERA	France	B Langrand
ESI	France	A Kamoulakos
DLR	Germany	S Ritt
NLR	The Netherlands	R Houten
QinetiQ	UK	M Willows
EADS	Germany	P Starke
SONACA		E Maillard
SICOMP	Sweden	R Juntikka
CIRA	Italy	Rosario Borrelli
SUN	Italy	Francesco Scaramuzzino
Imperial College	UK	Lorenzo Iannucci

SM/EG-41 Sizing of aircraft structures subjected to dynamic loading

Monitoring Responsable: J. Schön, FOI

Chairman: P-O. Marklund, SAAB

- **Objectives**

The objective is to answer the question:
How do we deal with impulse loading in structures from a strength point of view?

- **Benefits**

We are constantly getting better in predicting dynamic loads through analyses and tests such as:
- Landing
- Store separation including ”down the rail”
- Obstacle run over
- Etc…

Improved analysis methods and more refined analyses results in is a trend towards finding higher loads with shorter time span.

Structures in the aircraft industry are sized mainly using static methods. If peak loads are used in a static manner it may result in a conservative design.

If the effects of dynamic loading can be properly accounted for and incorporated in the design and analysis procedures, it is expected that a lot of conservatism can be reduced and thereby save weight. There may also situations for which the design and analysis procedures may be changed in order to maintain or increase flight safety.

Key issues to be addressed are:

- Loading rate effects such as different failure loads; different buckling loads and buckling modes; and different failure modes
- Dynamic response analysis and especially how to account for non-linearities
- Sharing of test data and experiences
- Working procedures e.g. more FE-analyses – ”Virtual testing” like in the automotive industry and simplified approaches

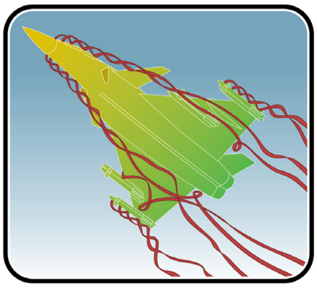
- **Progress**

The EG was formally started at the GoR fall meeting. The work will start with a workshop in the spring 2013. Potential EG members, other than those that already have shown interest, will be invited to the workshop.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
FOI	Sweden	J. Schön
NLR	The Netherlands	TBD
UNINA2	Italy	TBD
CIRA	Italy	TBD
EADS-IW	France	
SAAB	Sweden	Per-Olof Marklund

ANNEX A



ANNUAL REPORT FROM THE GROUP OF RESPONSABLES

AERODYNAMICS

Remit

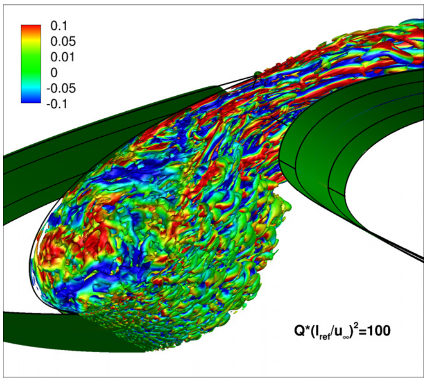
GoR AD initiates and organises basic and applied research in aerodynamics, often coupled to other disciplines. Recent and on-going research activities have been and are devoted to:

- 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.

The activities are both computational and experimental with some emphasis on computations. Research on measurement techniques and experiments for validation purposes are carried out. Recent action groups, involving both computations and experiments, have been dealing with how to improve correction procedures of measurements and how to scale experiments to conditions corresponding to industrial applications. Numerical studies sometimes give insight to the mechanisms of basic flow and in other cases are used to analyse integrated aerodynamic features of aerial vehicles.

GoR AD pursue to fill gaps and to do complementary research, preferably covering both military and civil aspects. The research activities are well coordinated with the EU and NATO/STO (formerly RTO) aeronautical research programmes and there are often collaborations between projects in different programmes. Sometimes GoR AD-projects initiate activities in research fields that later lead to EU-proposals, other times GoR AD projects complement activities in on-going EU-projects.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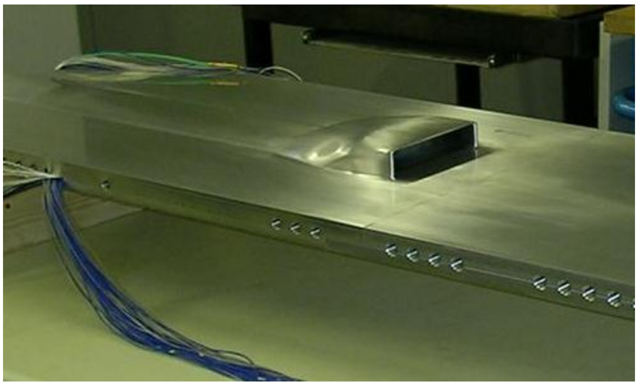

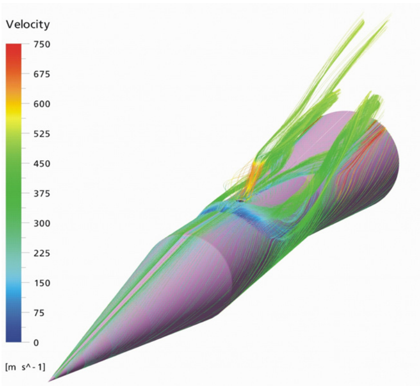
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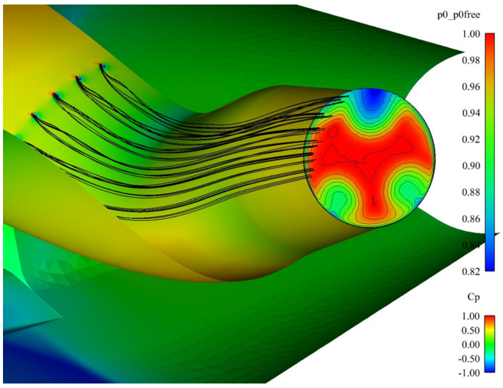
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TABLE OF CONTENTS

AERODYNAMICS

GoR-AD OVERVIEW

GoR activities

During 2012 one Action Group, AD/AG43: “Applications of CFD to High Offset Intake Diffusers”, was completed. One new Action Group was launched at the end of 2012: AD/AG-52: “Surrogate-based Global Optimization Methods in Preliminary Aerodynamic Design”, chaired by INTA.

Nine Action Groups have been running throughout 2012:

AD/AG43: “Applications of CFD to High Offset Intake Diffusers” is applying URANS (Unsteady Reynolds-Averaged Navier-Stokes) computations and Detached Eddy Simulations (DES) for predictions of aerodynamic flows through intake diffusers. The Action Group will submit one paper for the Special GARTEUR Paper Session at the AIAA Science and Technology Forum and Exposition 2014 (former AIAA Aerospace Sciences Meeting). The AG delivered the final report (TP-173) in October 2012.

The activities in AD/AG-44 “Application of transition criteria in N-S computations - Phase II” ended in an unfortunate way in 2010 with participants that retired and others that left their organisation before work with the final report had started. The GoR chairman has had a dialogue with the AD/AG-44 chairman about a simplified report including introduction, participant’s internal reports and executive summary. A final report is expected before next GoR-meeting in February 2013.

AD/AG-45 “Application of CFD to predict high “G” loads” is in the phase of completing the final report. The purpose of AD/AG-45 has been to investigate the maturity of CFD methods to tackle the load envelope of a civil aircraft. Mesh and turbulence models were found to have significant impact on the computational results. Both the unstructured and the structured methods have been able to produce results for the modelling of MLA (Manoeuvre Load Alleviation). The final report (TP-178) is expected in the beginning of 2013.

The aim for AD/AG-46 “Highly Integrated Subsonic Air Intakes” is to enhance predictions of intake performance parameters, especially of dynamic intake distortion, by applying time-accurate CFD methods. This improvement prepares the groundwork for engine/intake compatibility assessment with accuracy levels meeting industrial demands. During the design process for innovative intake development, advanced computational methods could be employed early in order to assess unsteady flow behaviour. A major goal of AD/AG-46 is to advance these methods and assess their application for industrial purposes. Fundamental experimental studies of intake design parameters are carried out in order to advance the knowledge of innovative design. The duration of the AG has been extended until mid-2013. The Action Group will submit five papers for the Special GARTEUR Paper Session at the AIAA Science and Technology Forum and Exposition 2014 (former AIAA Aerospace Sciences Meeting).

The main objective for AD/AG-47 “Coupling of CFD with Flight Mechanics” is to provide a platform to communicate and validate the development and applications of CFD coupling to flight mechanics models.
In addition studies of non-commanded flight mechanics motion caused by non-linear aerodynamic phenomena have been carried out. Based on the results of the selected test cases, it may be concluded that the participants have improved the readiness of their algorithms to analyse motions of flight vehicles requiring non-linear aerodynamic modelling. Furthermore, participants have applied their methods in both national and international projects: in Perseus and FAST20XX projects for trajectory simulations of launching vehicles, in IMPULSE and EU-ALEF projects for gust response simulation, etc. The final report (TP-172) was delivered early 2013.

The primary objective of AD/AG-48 “Lateral Jet Interactions at Supersonic Speeds” is to analyse the effect of the hot-gas jet from CFD simulations, and to define the most appropriate similarity parameters for ground-test facilities using cold-gas jet. The idea is to be able to translate wind-tunnel tests conducted using jets of cold air to free flight conditions with jets of hot multi-species gases. The first expected benefit, the assembly of a bibliography on similarity parameters is available now. The definition of the most appropriate similarity parameters based on these new CFD results is in progress. The duration of the project has been extended until the end of 2013.

The overall objectives of AD/AG-49 “Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications” are to scrutinize, improve and assess some selected hybrid RANS-LES approaches in simulations of aerodynamic flows and ultimately and to provide “best-practice” guidelines for industrial use relevant to aeronautic applications. The AD/AG-49 work contributes to a comprehensive understanding and assessment of hybrid RANS-LES modelling of typical aerodynamic flow physics, and to further modelling improvement. The results will facilitate “correct and effective” use of hybrid RANS-LES methods in aeronautical applications. The duration of the project is extended until mid-2013.

AD/AG-50 “Effect of wind tunnel shear layers on aeroacoustic tests “ have investigated the effects of open jet shear layers on acoustic wind tunnel measurements. Aeroacoustic wind tunnel tests are generally conducted in open jet wind tunnels, implying that the sound from the model has to pass through the open jet shear layer. This causes refraction, spectral broadening, and loss of coherence between the signals at different microphones which complicate the interpretation of acoustic measurements substantially. An empirical method has been developed to retrieve the correct acoustic power of tones measured outside the shear layer. Through DLR/NLR experiments, the transition from weak to strong scattering could be demonstrated for the first time. This project yielded better understanding of shear layer effects, improved correction procedures and improved shear layer characteristics. Tools have been developed to improve the quality of aeroacoustic wind tunnel testing substantially. Work performed within the Action Group has led to an AIAA paper and more conference papers and/or journal articles are expected. The final report is planned to be delivered in April 2013.

The main objective of AD/AG-51 “Transition in hypersonic flows” is to improve knowledge and methods dedicated to prediction and triggering of laminar/turbulent transition in hypersonic flows. The Action group activity is split into three work packages relating to natural and triggered transition. The main goal of the first package is to build a well-documented experimental database, which will be used as validation tool during the numerical studies. The second work package is dedicated to the extension of existing natural transition criteria to supersonic flows (M>1.6) and their implementation into 3C3D and elsA codes. The last work package consists in applying the new criteria to the configurations provided by the partners using LST approach (four different codes) and RANS criteria.

Three Exploratory Groups have been running throughout 2012:

AD/EG-66 “Receptivity and Transition Prediction” has been delayed by potential partners who have not responded to an outline of the AG-proposal. At the first meeting the 6th of March at DLR Göttingen, Airbus, Saab, Piaggo, CIRA, DLR, FOI, ONERA, ONECERT, DASSAULT and Imperial College participated. Main objective of the proposed activities is to understand the effects of surface irregularities and perturbations in incoming flow on transition in three-dimensional flows and efficiency of transition control methods. Following topics have been suggested for studies: acoustic receptivity in 3D boundary-layer flows, receptivity on perforated wall used for suction control (DNS), receptivity to free-stream vortices and effects of steps and gaps. The chairman Ardeshir Hanifi will send in a proposal for a new AG in the beginning of 2013. Partners involved in the proposal are: FOI, DLR, CIRA, ONERA, Imperial College and EADS. Duration of project is 3 years (early 2013- early 2016).

AD/EG-67 sent in a proposal for an AG in October 2012, the proposal was accepted and a new action group AD/AG-52 “Surrogate-based global optimization methods in aerodynamic design” was formed. The starting date for AD/AG-52 is January 1, 2013 and a first meeting is planned at the end of January. The duration of the project is three years. The Chairman is Esther Andrés from INTA and Monitoring Responsable is Fernando Monge.

The objectives of AD/EG-68 “Fluidic and Synthetic Jets” are specified in a document including a proposal of WBS. A brainstorming workshop is planned in March.

Management issues

AD/AG-52 “Surrogate-based global optimization methods in aerodynamic design” has a member from a non-GARTEUR country, Brno University of Technology. The participation of Brno University of Technology has been approved by the GARTEUR Council.

Looking at the 6-year rolling plan, it can be seen that the original duration of the AGs is often extended with 1 ½ to almost 3 years. This means that the actual duration of GoR AD AGs is about 5 years rather than 2 ½ - 3 years. This reflects the fact that GARTEUR activities are funded by internal means and therefore sometimes are put far down in the participant priority list. Another important factor explaining the delays is that GARTEUR projects often comprise tough technical challenges, involving substantial technical risks.

It is still unclear whether UK will take over the chairmanship 2014. This is the most important management issue for 2013. Norman Wood from Airbus UK will continue to be the vice chairman for GoR AD until 2014. Due to the unclear situation, NLR has to be prepared to eventually take over the chairmanship for GoR AD already 2014.

Dissemination of GARTEUR activities and Results

The Special GARTEUR Paper Session that will be held at the AIAA Science and Technology Forum and Exposition 2014 (former AIAA Aerospace Sciences Meeting)" in January 2014 is organised by Thomas Berens. The first paper in this session will be an introduction of GARTEUR, non-technical, presented by a GARTEUR official (Council or XC). Six technical papers will be presented at the session; the papers describe research that has been done in AD/AG-43 and AD/AG-46.

AD/AG-45 and AD/AG-48 presented papers at the 47th 3AF Symposium of Applied Aerodynamics, March 2012. An improved version of AD/AG-48s paper will be published soon in the International Journal of Engineering Systems, Modelling and Simulation. AD/AG-50 has submitted an AIAA paper 2010-3762 “Finite element solutions of a third-order wave equation for sound propagation in sheared flow” by D. Casalino (CIRA). More conference papers and/or journal articles are expected from AD/AG-50.

Future plans

Few AGs have been launched the last couple of years concurrently as several AGs are extended the duration of their activities substantially. Eight action groups AD/AG-43-50 all planned to finish 2012. Only AD/AG-43 did finish 2012, but AD/AG-44, AD/AG-45, AD/AG-47 and AD/AG-50 are expected to finish in the beginning of 2013. There is no way that GoR AD can compensate for this huge reduction in AGs. In order to boost up the pace of launching new action groups, new ways to emerge proposals for exploratory groups are tested.

A continuation of AD/AG-49: “Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications” is expected to start before the end of 2013. A one page outline for a new exploratory group will be presented at the first GoR AD-meeting 2013.

Two teams have been formed to provide basis for new EGs around the topics:

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

The group will exploit the results of AD/AG-47 and FM/AG-19. The mandatory case will consist of a manoeuver simulation with control surface input. The focus of the proposed exploratory group is aerodynamic loads for severe manoeuvers.

- Thrust vectorization

GoR AD has already 2003 launched an exploratory group on a similar topic, AD/EG-55: “Fluidic Control of Jets” which generated substantial industrial interest. For various reasons it never turned into an action group. The idea this time is to investigate technique that can be applied both for 2D military nozzles and for circular civil nozzles.

Both teams will present one page outlines at the first GoR-meeting 2013. Hopefully at least one of the new topics can be launched as an action group at the end of the year. New topics under discussion are: flow control with plasma and comparisons of experimental measurement techniques.

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

Cat	Topic	2009		2010		2011		2012		2013		2014	
AD/AG-43	Application of CFD to High Off-Set Intake Diffusers												
AD/AG-44	Application of transition criteria in NS computations - Phase II							**Report pending**					
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	Scrutinizing Hybrid RANS-LES for Aero. Applic.	**EG63**	➔										
AD/AG-50	Effect of WT Shear Layer on Aero-acoustics			**EG 64**	➔								
AD/AG-51	Laminar-Turbulent Transition in hypersonic flows					**EG65**	➔						
AD/AG-52	Surrogate-based Global Optimization Methods in Preliminary Aerodynamic Design							**EG67**	➔				
AD/EG-66	Receptivity and Transition Prediction												
AD/EG-68	Fluidic and Synthetic Jets												

Active Closed

Managed and foreseen GoR activity

In 2012 the GoR AD held two meetings, the first at DLR Göttingen in Germany on February 14th-15th. The second meeting was held at NLR Amsterdam in The Netherlands on October 9th -10th.

In 2013 the first meeting will take place at Airbus Broughton in UK, on February 19th-20th, 2013. The date and location for the second meeting in Spain are still to be decided.

Torsten Berglind
Chairman (2012-2013)
Group of Responsables Aerodynamics

GOR MEMBERSHIP

Torsten Berglind is the chairman and Norman Wood is the vice chairman until the end of 2013.

Current membership of the Group of Responsables Aerodynamics

Chairman			
Mr. Torsten Berglind	FOI	Sweden	torsten.berglind@foi.se

Vice-Chairman			
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ACTION GROUP AND EXPLORATORY GROUP REPORTS

Table of participating organisations: AD/AGs and AD/EGs

	AD/AG								AD/EG	
	45	46	47	48	49	50	51	52	66	68
Research Establishments										
CIRA					□	□	□	□	□	
DLR	□	□	□			□	□		□	□
DSTL										
FOI	□	□	□	□	■			□	■	□
INTA					□			■		
NLR	□		■		□	■			□	
ONERA	■	□	□	□	□	□	■	□	□	■
Industry										
Airbus Military		□	□					□		
Airbus Operations GmbH									□	□
Airbus Operations Limited	□								□	■
Airbus Operations S.A.S.						□				
Alenia Aeronautica	□	□	□					□		□
Dassault-Aviation		□							□	□
CASSIDIAN		■	□							
MBDA-F		□		□			□			
MBDA-LFK				□						
QinetiQ										
Saab	□	□						□		
Academic Institutes										
City University of London									□	
Imperial College									□	
ISL				■			□			
Southampton Un. -ISVR						□				
TU Munchen					□					
UAH								□		
Univ. BwM *(Universität der Bundeswehr München)*							□			
University of Liverpool			□							
UNIS								□		
Von Karman Institute *(VKI)*							□			
VUT								□		

□ = Member ■ = Chair

Total yearly costs of AD/AG research programmes

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	12,5	77
	52									25	70	25	70
AD TOTAL		85	79	84	292	68	247	62	147,5	74	252	37,5	147

pm = Person-months
k€ = other costs

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

AD/AG45: Application of CFD to predict high "G" loads

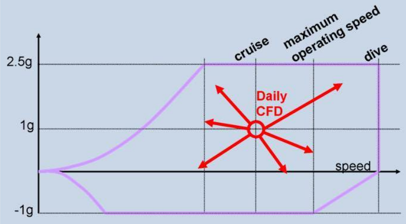
Action Group Chairman: Dr Jean-Luc Hantrais-Gervois, ONERA
(Jean-Luc.Hantrais-Gervois@onera.fr)

Background

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

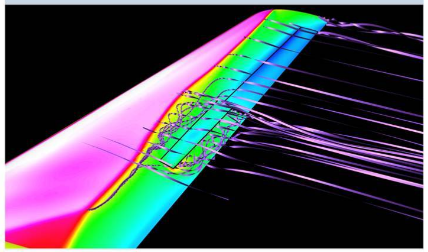
High g conditions
control surfaces (spoiler, aileron), high lift coefficient (flow separation), high transonic Mach number

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)



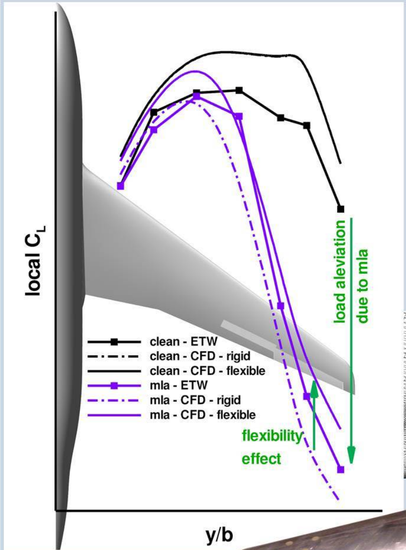
Programme / Objectives

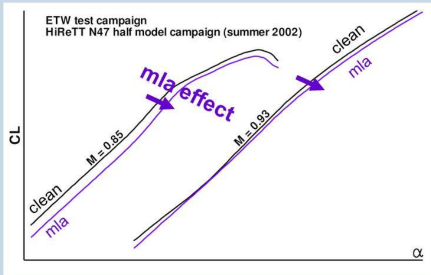
Objectives of AD(AG45)
investigate structured and unstructured numerical approaches to feed an industrial loads process

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)

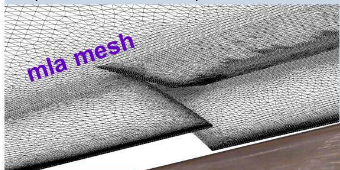


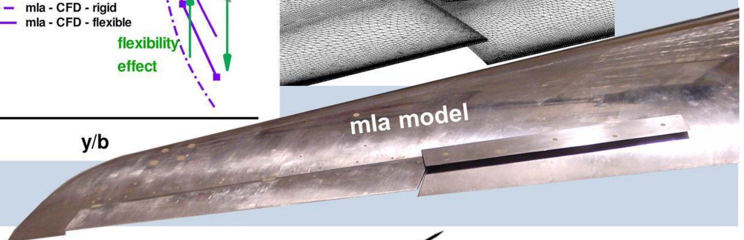


Experimental test cases
HiReTT data
ETW wind tunnel test at high Reynolds number
Clean wing and manoeuvre load alleviation configuration

Configuration clean wing
clean wing body configuration
representative of a modern large civil aircraft

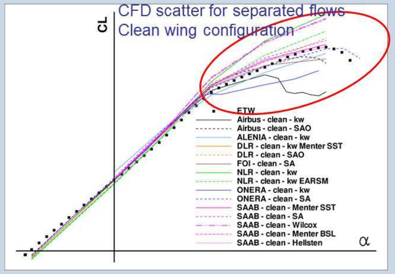
Configuration MLA (manoeuvre load alleviation)
same as configuration + outer wing control surfaces
aileron deflected 10º up
spoiler deflected 10º up



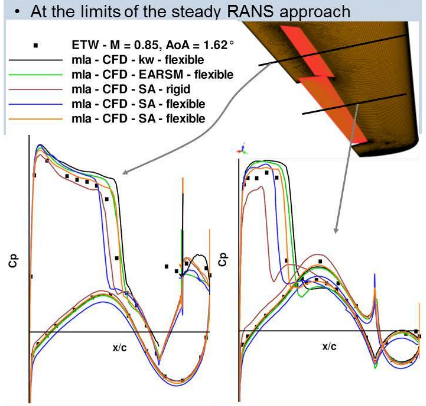


AIRBUS AleniaAeronautica DLR FOI NLR ONERA SAAB

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

AD/AG-45	Application of CFD to predict high "G" loads
Monitoring Responsable:	E. Coustols ONERA
Chairman:	J.-L. Hantrais-Gervois ONERA

- **OBJECTIVES**

The purpose of AD/AG-45 is to investigate the maturity of CFD methods to tackle the load envelope of a civil aircraft. Several topics need to be tackled such as the meshing issues related to geometries with control devices or the turbulence modelling with detached flows (induced by the deflected control surfaces or by the high "g" condition). The impact of the elasticity of the wing is also a key issue as far as control surface effectiveness is concerned.
In order to investigate these topics, the AD/AG-45 partners use state of the art RANS and meshing techniques (unstructured and structured). Several turbulence models are evaluated and different coupling strategies are investigated. The CFD exercises are backed up by the HiReTT half model experiments featuring a civil aircraft wing in clean configuration and with manoeuvre load alleviation devices (overlapping spoiler and aileron, both 10º up – MLA configuration, see
Figure 1).

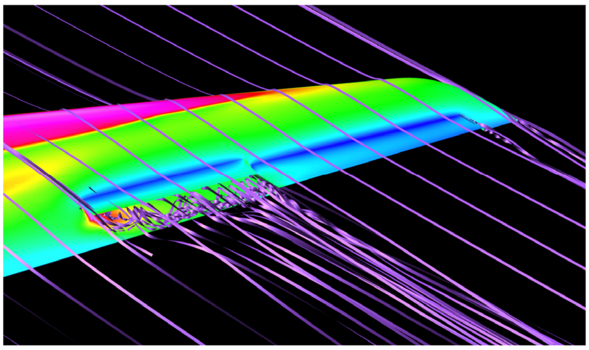


Figure 1. Manoeuvre Load Alleviation configuration (MLA).

- **MAIN ACHIEVEMENTS**

The main outcome from the validation exercise is the discrepancy in the prediction of the cases with heavy flow separations (especially on the MLA configuration but also on the clean wing). The conclusion is that high g conditions are not as accurately predicted as lower g conditions with actual RANS strategies.

Among the topics of this group, it was found that the structured or unstructured methodology is not decisive for the quality of the results. Nevertheless, unstructured strategies enable to achieve meshes more rapidly than structured methods. The exact meshing of the MLA configuration did not prove to be mandatory to achieve correct loads.

If wing flexibility improves significantly the CFD results up to flow separation onset (absolute values and also increments between the clean and MLA configurations), this is not sufficient to model properly the heavy flow separation.
The rigid then flexible calculations underlined that if coupled simulations enable to reach better results with respect to the experiment, it combines compensating errors from both the aerodynamics and the structure. Thus, a careful aeroelastic validation requires both the validation of the aerodynamic results (aerodynamic coefficients and pressure distributions) and the validation of the deformed shapes. In the future, it would be of great help to tackle configurations with tuned finite element models and deformation measurements in the wind tunnel.

For turbulence models (on appropriate meshes) contrasted results are obtained at high-lift. Thus dedicated mesh and turbulence model sensitivity studies need to be carried out. Some models where invalidated. On the other hand the Spalart-Allmaras and some kω models gave reasonable results (but no general good behaviour could be achieved at high-lift). The tendency to separate early of the kω Menter SST has been underlined for separation triggered by geometry (control surfaces) and separation caused by physics (wing flow breakdown). There is thus still room for turbulence model enhancements in the future (possibly with the help from higher order approaches such as DES or LES).

A synthesis paper has been presented at the 2012 AAAF conference:
Hantrais-Gervois J.-L., Sawyers D., Rampurawala A., Ceresola N., Heinrich R., Tysell L., van Muijden J., Totland E., *AG45 - application of CFD to predict high g loads*, 47th Symposium of Applied Aerodynamics AAAF, Paris, March 26-28, 2012.

- **Management issues**

The group is active since May 2008 and the technical activities have come to an end in 2011. The reporting of all the activities has begun at the end of 2011. A chapter breakdown has been agreed between the partners and the data for cross plotting are made available on the AirTN server. Each chapter has been finalised at the end of 2012. The report will be issued in January 2013.

- **Expected results/benefits**

The results achieved in this group provide a representative picture of the RANS results at high g conditions. Mesh and turbulence discrepancy indicate the perspective to pursue the turbulence modelling activity with the help of higher order methods.

As for the modelling of the MLA, both the unstructured and the structured methods have been able to produce results, the unstructured method being easier to handle. The results achieved in this group represent a good starting point for the improvement of both methods.

On the whole, rich information has been shared among the partnership about the different meshing strategies, the CFD simulations and the aeroelastic coupling procedures.

- **AD/AG-45 MEMBERSHIP**

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- **RESOURCES**

Resources		Year					Total 08-12
		2008	2009	2010	2011	2012	
Person-months	Actual	22.3	10.5	1.9	1.9	1.9	38.5
Other costs (in K€)	Actual	30.0	20.0	10.0	5.0	0.0	65.0

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1.1 data review	May 2008		report ready
Task 1.2 CFD clean	Feb. 2009		report ready
Task 1.4 CFD MLA	May 2009		report ready
Task 2.1 MLA meshing	Nov. 2008		report ready
Task 2.2 mesh coarsening	Oct. 2009		report ready
Task 3.1 turbulence mod.	Aug. 2009		report ready
Task 4.1 assess. for loads	Mar. 2010		report ready
reporting	June 2010	Jan. 2013	to be issued in 2013

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

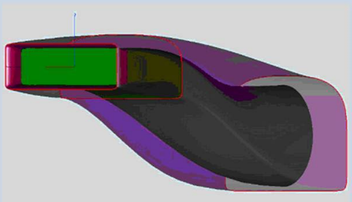
Action Group Chairman: Dr Thomas Berens, CASSIDIAN (Thomas.Berens@cassidian.com)

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

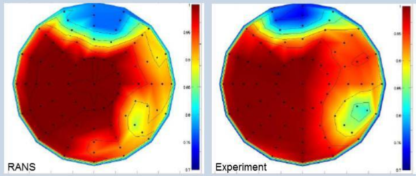
Programme/Objectives

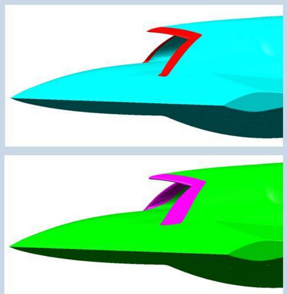
Main objectives of AD/AG-46: (1) to investigate the capability of modern CFD methods (Detached Eddy Simulation DES) to analyze unsteady flow phenomena of highly integrated subsonic air intakes, (2) to support innovative design for advanced subsonic aerial vehicles, and (3) to assess the flow behavior 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.

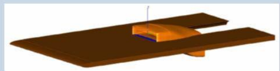
Partners: CASSIDIAN, ONERA, FOI, AIRBUS Military, DLR, SAAB, MBDA, Alenia, Dassault-Aviation

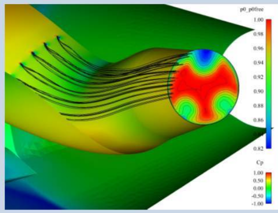
Activity: Numerical simulations for the EIKON UAV intake wind tunnel model with a variety of CFD methods and validation with T1500 wind tunnel test data; experimental investigations with a generic intake wind tunnel model in the cryogenic WT DNW-KRG at DLR Göttingen for parametric studies.





- 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



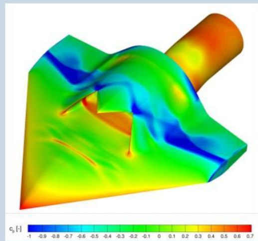


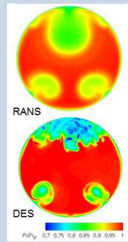
CASSIDIAN (AN EADS COMPANY), FOI, DLR, SAAB TECHNOLOGIES, ONERA THE FRENCH AEROSPACE LAB, AIRBUS MILITARY, MBDA MISSILE SYSTEMS, AleniaAeronautica A Finmeccanica Company, DASSAULT AVIATION

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.

AD/AG-46	**Highly Integrated Subsonic Air Intakes**
Monitoring Responsable:	Dr. T. Berens CASSIDIAN
Chairman:	Dr. T. Berens CASSIDIAN

- **OBJECTIVES**

The objectives of Action Group AG46 are aimed at the investigation of the capability of modern CFD methods (Detached Eddy Simulation DES) to analyze unsteady flow phenomena of subsonic air intakes and to support innovative design for highly integrated intakes of advanced subsonic aerial vehicles. The computational prediction of the instantaneous total pressure distribution in the engine face as the basic parameter for the assessment of dynamic intake distortion and engine/intake compatibility is most challenging.
The flow behavior at the intake cowl due to complex multi-disciplinary lip shaping and the impact of the design on intake internal flow and performance represent another major topic regarding this area of research.
Computational flow simulations within these fields of interest and their accuracy levels will be compared with experimental data.
A parametric study of innovative intake design features accompanied by basic experimental investigations will address fundamental intake design issues and should contribute to a better understanding and correlation of installed performance predictions.
As results best practice advice for innovative intake design and for the application of modern hybrid numerical simulation methods is expected.

- **MAIN ACHIEVEMENTS**

Thirteen tasks were defined to achieve the objectives of the Action Group. The geometry of a UAV (EIKON) which was designed and wind tunnel tested at FOI serves as a basis for the numerical simulations of unsteady internal flow in subsonic air intakes. Tasks 1, 2, 3, 4, 5, and 8 were completed until 2011.
In 2012 the following tasks, already started earlier, were continued: Task 6 "CFD Computations for a UAV Configuration" featuring extensive Navier-Stokes simulations, Task 9 "Numerical Study on Intake Lip Shaping" comprising an alternative cowl design and its impact on intake performance, Task 11 "Intake Internal Flow Control" investigating the application of micro-jets as active flow control devices in the duct with new numerical models, and Task 12 "Experimental Parametric Study of Intake Design" comprising testing of an intake wind tunnel model in order to address fundamental design issues of highly integrated configurations.
Task 7 "Comparison of CFD and Test Results" and Task 10 "Boundary Layer Diversion versus Ingestion" were initiated in 2012, the latter by simulating boundary layer diversion effects with an upstream Euler wall. Task 13 "Reporting" will be concluded with the final AD/AG-46 report.

Fig. 1 displays ZDES results for Test Case 1 (ONERA, structured grid) with Mach number and surface pressure distributions.

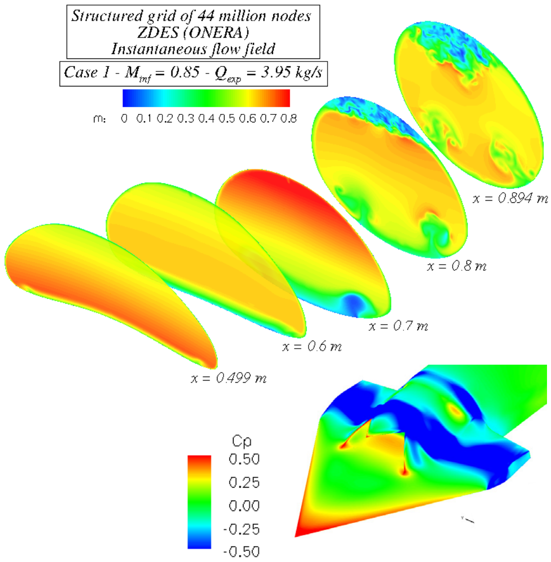


Figure 1 Instantaneous intake flow field from ZDES computations by ONERA (Mach number in x=const planes and surface pressures).

Fig. 2 shows the corresponding Mach number distributions in the symmetry plane of the EIKON model and a comparison with RANS results.

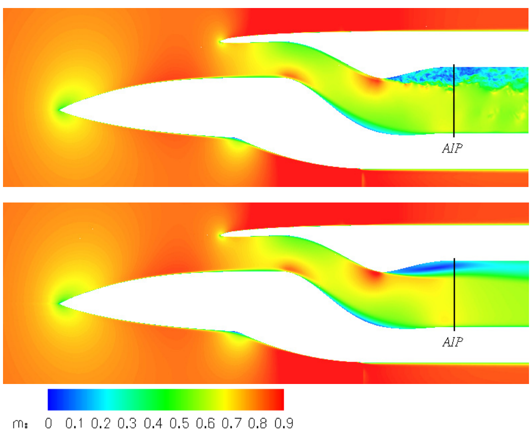


Figure 2 Mach number distributions from ZDES (top) and RANS (bottom) computations (ONERA) for Test Case 1.

The unsteady character of the intake flow field is clearly revealed in Fig. 3. The instantaneous results show low total pressure regions at the top and bottom of the intake duct with varying shapes, different sizes, and deviating intensities.

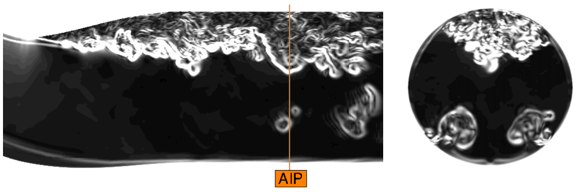


Figure 3. Schlieren-like visualization of the flow field in the symmetry plane and in the Aero-dynamic Interface Plane (AIP) for Test Case 1 (ONERA).

Within Task 12, experiments on the influence of ingesting boundary layers into a high aspect ratio diverterless S-duct intake were performed in the cryogenic blowdown wind tunnel DNW-KRG in Göttingen and will be continued in 2013.

Originally it was planned to finish AG46 in 2010. Labor intensive tasks, however, especially Tasks 6, 9, 10 and 12 require more time and resources than anticipated. In addition, planned resources were cut between 2010 and 2012 leading to considerable delays. Work will continue in 2013, and AG46 will be concluded until December.

- **MANAGEMENT ISSUES**

In 2012 the work plan and time schedule were periodically updated according to resources and budget cuts. No group meetings could be held.

- **EXPECTED RESULTS/BENEFITS**

Within AD/AG-46, the basis for time-accurate predictions of intake performance parameters and especially of dynamic intake distortion should be enhanced in order to prepare the groundwork for engine/intake compatibility assessment with accuracy levels meeting industrial demands. Mid-term prospects for fulfilling these requirements and for successfully applying these methods for project oriented work are considered most promising.
During the design process for innovative intake development, advanced computational methods could be employed early in order to assess unsteady flow behavior. The knowledge of the accurate impact of specific flow characteristics on intake performance and also especially on intake/engine compatibility could lead to design improvements before expensive wind tunnel tests would be performed for a final aerodynamic assessment. A major goal of AG46 is to advance these methods and assess their application for industrial purposes.

Fundamental experimental studies of intake design parameters will advance the knowledge innovative design requires and should verify theoretical approaches through correlation.

- **AD/AG-46 MEMBERSHIP**

Member	Organization	e-mail
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L. Zurawski	MBDA	ludovic.zurawski@mbda-systems.com

- **RESOURCES**

Resources		Year						Total 08-13
		2008	2009	2010	2011	2012	2013 updated	
Person-months	Actual/ Planned	A21 P21	A27 P27	A12 P18	A10 P15	A3 P12	P9	A73 P102
Other costs (in K€)	Actual/ Planned	A7 P7	A7 P7	A0 P7	A0 P0	A0 P7	P7	A14 P35

- **PROGRESS/COMPLETION OF MILESTONES**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: Output Definition	June 2008	Dec. 2009	Dec. 2009
Task 2: Data Post-Processing Procedures	Sep. 2008	Oct. 2008	Oct. 2008
Task 3: Provision of Experimental Data UAV	June 2008	June 2009	June 2009
Task 4: Provision of Geometry UAV Config.	Mar 2008	June 2008	June 2008
Task 5: CFD grid Generation UAV Config.	Sep. 2008	May 2010	June 2011
Task 6: CFD Computations	June 2010	June 2013	ongoing
Task 7: Comparison of CFD and Test Results	Aug. 2010	Oct. 2013	ongoing
Task 8: WT and Model Geometry Effects	Mar. 2009	Sep. 2009	Sep.2009
Task 9: Numerical Study on Intake Lip Shaping	June 2010	May 2013	ongoing
Task 10: Boundary Layer Diversion versus Ingestion	Aug. 2010	July 2013	ongoing
Task 11: Intake Internal Flow Control	June 2010	May 2013	ongoing
Task 12: Experimental Parametric Study of Intake Design	June 2010	Apr. 2013	ongoing
Task 13: Reporting	Dec. 2010	Dec. 2013	ongoing

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

AD/AG47: Coupling of CFD with Flight Mechanics Model

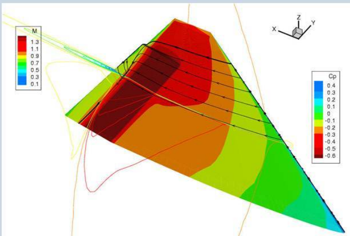
Action Group Chairman: Dr Bimo Prananta, NLR (Bimo.Prananta@nlr.nl)

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

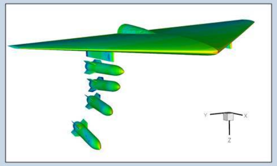
Programme/Objectives

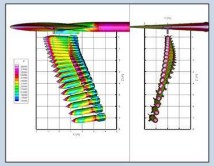
Main objectives of AD/AG-47: (1) to provide a platform to communicate and validate the development and applications of CFD coupling to flight mechanics models; (2) to gain knowledge on non-commanded flight mechanics motion caused by non-linear aerodynamic phenomena; (3) to define a suitable test set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

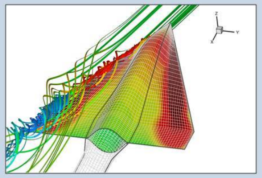
Activities: Numerical simulations of aerodynamics coupled to flight mechanics and validations using wind-tunnel data

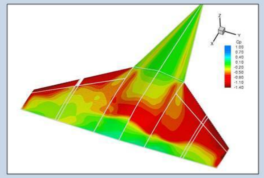
Case 1 AGARD store release
- availability of test data
- needs complex grid handling



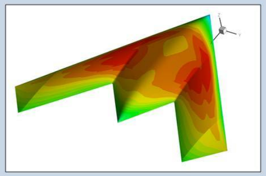


Case 2 rolling motion of wings
- non-linear aerodynamics
- vortex breakdown
- transonic abrupt stall



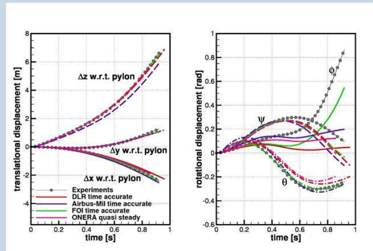


Case 3 longitudinal motion of UCAV
- realistic configuration



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

AD/AG-47	**Coupling of CFD with Flight Mechanics Model**
Monitoring Responsable:	K.M.J. de Cock NLR
Chairman:	Dr. B.B. Prananta NLR

THE GARTEUR AD/AG-47 IS ESTABLISHED TO HARNESS THE MATURITY OF UNSTEADY CFD METHODS FOR MOVING RIGID BODIES FOR RESEARCH IN FLIGHT MECHANICS. CFD BECOMES A VIABLE OPTION TO TESTING FOR CASES WHEN THE AIRCRAFT MOTION IS CONSIDERED TO BE DANGEROUS OR DIFFICULT TO REALISE DURING TESTING.

- **OBJECTIVES**

The objectives of the action group on coupling of CFD to flight mechanics models can be formulated as:

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.

The group has defined a set of test cases to reach these objectives.

- **MAIN ACHIEVEMENTS**

The group has finalised its activities in all defined Tasks within the GARTEUR AD/AG-47. Final results, conclusions, lessons-learned and benefit have been discussed with the Aerodynamic Group of Responsable during its meeting in Amsterdam. The activities are concluded with the delivery of final report.

Task 1 of AD/AG-47 has been used to verify and validate their development of the coupling between CFD and flight mechanics model. All partners employ nonlinear six degree-of-freedom rigid body equations of motion for the flight mechanics model. It is however interesting to note that various approaches are selected by partners for representing the attitude parameter, i.e. using the Euler angles, the quaternion and the rotation matrix. Two methods for grid handling are used, i.e. the Chimera overset grid approach and a combination of grid deformation and regridding. Various predictor-corrector types of flight mechanics-CFD iterations are applied by partners leading to fully implicit scheme in time. The AGARD test case of AFRL finned store release test case is selected for validation. The case concerns a release of a store from asymmetric wing configuration at transonic flow. The store undergoes a relatively complex motion during the release as shown in Figure 1.

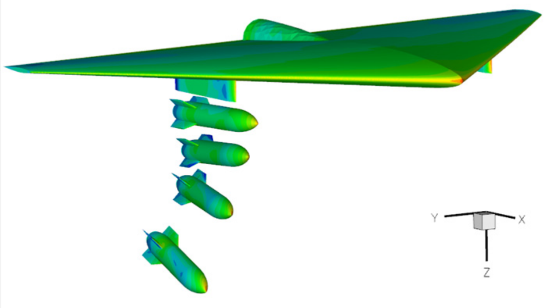


Figure 1. Separation of a finned missile.

Two types of simulations are carried out with different aerodynamic approach: time-accurate approach and quasi steady approach. The experimental data obtained from captive trajectory measurement is closely related to the second approach. Typical results of simulations in terms of displacements are shown in Figure 2.

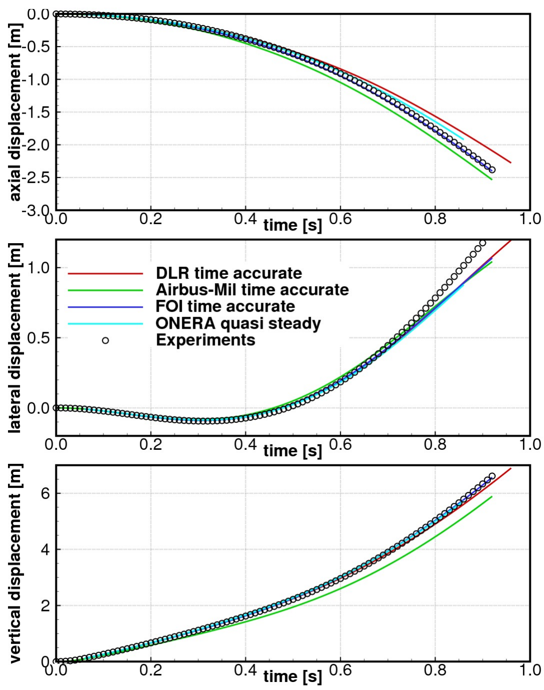


Figure 2. Trajectory coordinates as a function of time.

Typical for flight mechanics problem, the motion is relatively slow with respect to aerodynamic unsteadiness. Therefore, a quasi-steady approach with assumed values of aerodynamic damping produces good results. Based on the results of Task 1 it may be concluded that the selected methods and implementations have been validated.

Task 2 “One-DOF rolling motion” test cases have been selected to focus on certain types of flow nonlinearities, i.e. the AeroSUM delta wing for flow non-linearity due to vortex breakdown and SiS fighter type wing for transonic flow non-linearity. The behaviour of AeroSUM delta wing with flaperon input including vortex breakdown and nonlinear friction at the rolling axis can be simulated properly by partners. For the SiS wing case, an abrupt wing stall phenomenon is obtained by imposing a pitching motion to a free-to-roll SiS wing with a leading edge irregularity. However, various parameters study lead only to a much lower intensity compared to the level reported in the literature. Further study is needed.

Task 3 “Three-DOF longitudinal motion of generic aircraft” concerns simulation of the DLR F-17 UCAV model, also known as Stability And Control CONfiguration (SACCON), representing a modern flying wing configuration. For the present study inertia data of DLR F-17 is derived from Northrop YB-49 flying wing. Simulations are limited to abrupt symmetric manoeuvre with elevator input including check-back.

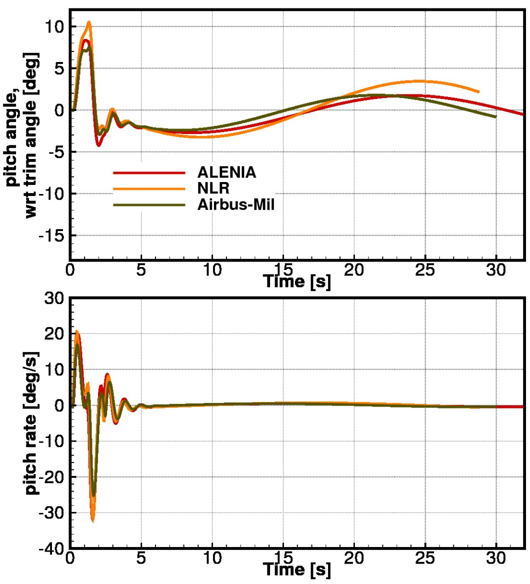


Figure 3. Pitch angle and pitch rate for the abrupt symmetric manoeuvre.

For the present preliminary study, the initial flight condition is a level flight. Typical results in terms of pitch angle and pitch rate are shown in Figure 3. It can be seen that the DLR F-17 UCAV behaves like a normal aircraft with a mix between a highly damped short period oscillation and a lightly damped phugoide mode. The difference between these responses can be seen from the angle-of-attack response, shown in Figure 4. For the short period response the angle-of-attack oscillates while for the phugoide mode the aircraft has enough time to response by oscillating in the altitude leading to small angle-of-attack variation. In other words the pitch angle follows the path of the aircraft.

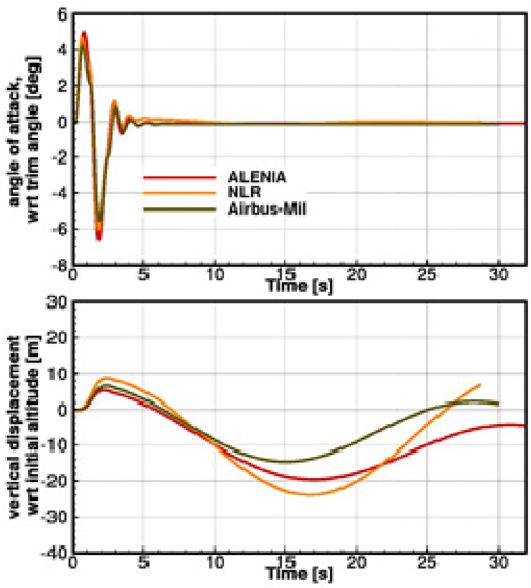


Figure 4. Pitch angle and pitch rate for difference between damped short period oscillation and a lightly damped phugoide mode.

- **Management issues**

Nothing special needs to be mentioned.

- **Expected results/benefits**

Based on the results of the present activities, it can be concluded that the partners have improved the readiness of their algorithms to analyse motions of flight vehicles requiring non-linear aerodynamic modelling. Furthermore, partners have applied their methods in both national and international projects, e.g. in Perseus and FAST20XX projects for trajectory simulations of launching vehicles, in IMPULSE and EU-ALEF projects for gust response simulation, etc.

AD/AG-47 membership

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- **Resources**

Resources		Year					Total 08-12
		2008	2009	2010	2011	2012	
Person-months	Actual/ Planned	A7 P12	A18 P26	A15 P29	A10 P14	A17 P0	A67 P67
Other costs (in K€)	Actual/ Planned	A16 P20	A20 P40	A20 P45	A5 P14	A0 P0	A61 P105

- **Progress/Completion of milestone**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
EG62-TC1.1	April. 2009	Feb. 2010	Feb 2011
EG62-TC1.2	April 2009	Feb. 2010	Feb 2011
EG62-TC2.1	Jan. 2010	Sept. 2010	Mar 2011
EG62-TC2.2	Jan. 2010	Sept. 2010	Jun 2011
EG62-TC2.3	Jan. 2010	Sept. 2010	Jun 2011
EG62-TC3.1	Feb. 2010	May 2012	May 2012
EG62-TC3.2	Feb. 2010	May 2012	May 2012
Final report	Sept. 2010	Dec 2012	Dec 2012

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

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

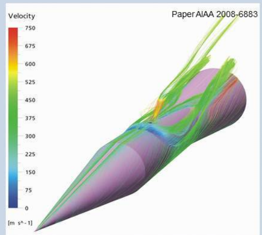
Action Group Chairman: Dr Patrick Gnemmi, ISL (patrick.gnemmi@isl.eu)

Background

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

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

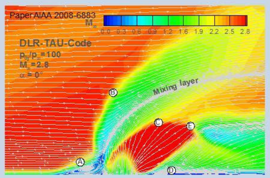
Challenge: defining the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet



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

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

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



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

Programme/Objectives

Main objectives of AD/AG48: (1) to accurately predict by CFD the steady-state aerodynamics of the interaction of 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

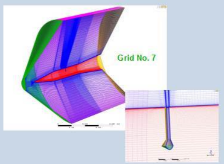
Focus: (1) numerical simulation validations of the interaction of cold-air and hot-gas jets with the cross-flow of supersonic missiles using different Reynolds-Averaged Navier-Stokes (RANS) codes and experimental data from DLR Cologne and ONERA/MBDA-France; (2) numerical simulations for the replacement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

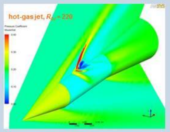
Partners: DLR Cologne, FOI, ISL, MBDA-France, MBDA-LFK, ONERA

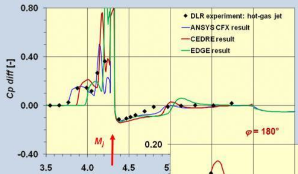
Activity: numerical simulations with different RANS codes and validations using high-quality wind-tunnel data

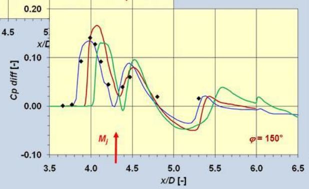
DLR Cologne configurations:

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





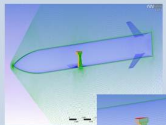


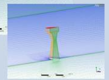


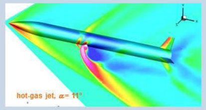
Differential pressure-coefficient distribution on the DLR missile surface, hot-gas jet, R_{0J} = 220

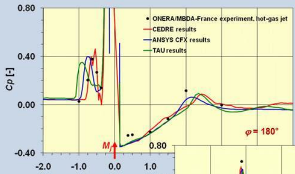
ONERA/MBDA-France configurations:

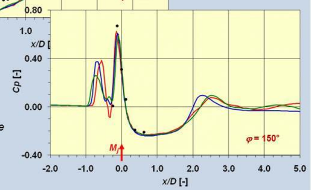
- supersonic flow Mach 2.01, $\alpha = 0°$ and 11°
- cold-air and hot-gas jets
- ejection pressure ratio of 81 and 137











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

DLR FOI ISL MBDA MISSILE SYSTEMS ONERA THE FRENCH AEROSPACE LAB

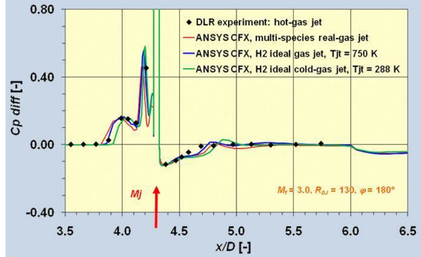
Results

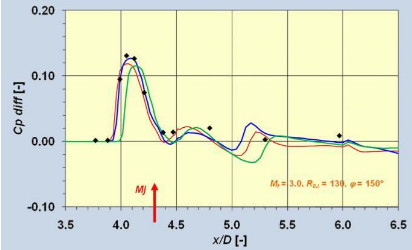
Prediction of cold-gas and hot-gas lateral jet interaction with missile cross-flow

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

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

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





AD/AG-48	Lateral Jet Interactions at Supersonic Speeds
Monitoring Responsable:	E. Coustols ONERA
Chairman:	Dr. P. Gnemmi ISL

- **OBJECTIVES**

In the past, the aerodynamic interference between the exhaust jet and a missile cross-flow has been investigated mainly from wind-tunnel tests.
The problems encountered in wind-tunnel testing concern the simulation of the flight conditions: Reynolds number, pressure ratio, jet gas. For the two first parameters, duplication of the flight conditions is often possible during wind-tunnel tests, or if not, extrapolation can be made confidently (using CFD for example). The third problem related to the effect of the jet gas is the most difficult. Knowing that wind-tunnel tests are generally conducted using cold air as a jet, whereas in free flight it is a hot gas coming from the combustion of propellants, similarity parameters must be considered.
The primary objective of this action group is to deeply analyse the effect of the hot-gas jet from CFD simulations, and to define the most appropriate similarity parameters for ground-test facilities using cold-gas jet.

- **MAIN ACHIEVEMENTS**

The AD/AG-48 exists since October 1st, 2008. Different meetings took place at ONERA in October 2008, at MBDA-LFK in April 2009, at DLR Cologne in March 2010, at MBDA-France in August 2010, at ISL in October 2011 and at ONERA in April 2012.

The bibliography on similarity parameters studies has been detailed (task 1). The provision of the geometry and of the experimental data of DLR Cologne (task 2) and ONERA/MBDA-France configurations (task 4) and the provision of the corresponding grids (tasks 3 and 5 respectively) have been achieved. The reports of tasks 1, 2 and 3 have been uploaded on the NLR website (AirTn server) and distributed.
One objective was dedicated to the validation of the numerical simulation for each configuration: 4 DLR cases (task 6) and 4 ONERA/MBDA-France cases (task 7). The goal is considered to be reached in spite of some discrepancies between the used codes. A paper has been presented at the 47th International Symposium of Applied Aerodynamics on March 26-28, 2012 in Paris and the improved version will be published soon in the International Journal of Engineering Systems, Modelling and Simulation.

For DLR cases, computations were achieved for Mach number 3.00, for cold-air and hot-gas jets having an ejection ratio R_{0J} of 130 and 220. The differential pressure-coefficient distribution obtained by the codes on the DLR missile model was successfully compared to the measurements (poster). As a main result, Table 1 compares the computed aerodynamic coefficients; the experimental ones are currently not available.

	Jet nature	R_{0J}	C_x	C_N	Cm(G)	Xcp/Lref
ANSYS CFX (ISL)	cold air	130	0.6523	0.0601	-0.0228	0.857
		220	0.6535	0.0839	-0.0319	0.858
	hot gas	130	0.6494	0.0676	-0.0347	0.991
		220	0.6503	0.0821	-0.0427	0.998
	Jet nature	R_{0J}	C_x	C_N	Cm(G)	Xcp/Lref
CEDRE (MBDA-France)	cold air	130	0.6110	0.0590	-0.0210	0.837
		220	0.6150	0.0810	-0.0300	0.850
	hot gas	130	0.6080	0.0660	-0.0320	0.960
		220	0.6120	0.0820	-0.0410	0.980
	Jet nature	R_{0J}	C_x	C_N	Cm(G)	Xcp/Lref
EDGE (FOI)	cold air	130	0.6604	0.0532	-0.0196	0.777
		220	0.6608	0.0729	-0.0273	0.777
	hot gas	130	0.6564	0.0752	-0.0389	0.923
		220	0.6592	0.0870	-0.0452	0.925

Table 1. Computed aerodynamic coefficients for DLR cases.

ANSYS-CFX, Edge and CEDRE provide very coherent results: discrepancies are less than 8% for the drag coefficient C_X, 15% for the normal-force coefficient C_N and 18% for the pitching-moment coefficient *Cm(G)* determined at the gravity centre *G*.

For ONERA/MBDA-France cases, computations were carried out for the Mach number of 2.01, for angles of attack of 0 and 11°, for cold-air and hot-gas jets having ejection ratios R_{0J} of 81 and 137, respectively. The pressure coefficient distribution obtained by the codes on the ONERA/MBDA-France missile model was compared to the measurements (poster).
Table 2 compares the computed and measured aerodynamic coefficients. ANSYS-CFX, CEDRE and TAU provide coherent normal-force coefficients and coherent pitching-moment coefficients for the angle of attack of zero: the discrepancies are less than 10% for the normal-force coefficient (except TAU) and are less than 30% for the pitching-moment coefficient. The codes also provide coherent normal-force coefficients for the angle of attack of 11°, but the pitching-moment coefficients have large discrepancies. These differences are significant despite the good distribution of the calculated surface pressure compared to the measured one. This could be due to the influence of the interaction of the jet wake on the fins, but there is no measurement that can confirm that.

ONERA/ MBDA-France Experiment	Jet nature	Case	*AoA* [°]	C_N	*Cm(G)*	*Cm(G)/CN/ Lref*
	cold air	OMF1	0	-0.321	0.076	-0.254
		OMF2	11	1.209	-0.043	-0.038
	hot gas	OMF3	0	-0.218	0.047	-0.231
		OMF4	11	1.237	-0.051	-0.044

CEDRE (ONERA)	Jet nature	Case	*AoA* [°]	C_N	*Cm(G)*	*Cm(G)/CN/ Lref*
	cold air	OMF1	0	-0.294	0.056	-0.204
		OMF2	11	1.291	-0.112	-0.093
	hot gas	OMF3	0	-0.197	0.036	-0.196
		OMF4	11	1.341	-0.121	-0.097

TAU (MBDA)	Jet nature	Case	*AoA* [°]	C_N	*Cm(G)*	*Cm(G)/CN/ Lref*
	cold air	OMF1	0	-0.252	0.050	-0.213
		OMF2	11	1.273	-0.099	-0.083
	hot gas	OMF3	0	-0.197	0.035	-0.191
		OMF4	11	1.221	-0.069	-0.061

ANSYS CFX (ISL)	Jet nature	Case	*AoA* [°]	C_N	*Cm(G)*	*Cm (G)/C_N /Lref*
	cold air	OMF1	0	-0.319	0.055	-0.185
		OMF2	11	1.014	-0.022	-0.023
	hot gas	OMF3	0	-0.230	0.032	-0.149
		OMF4	11	0.986	0.022	0.024

Table 2. Measured and computed aerodynamic coefficients for ONERA/MBDA-France cases.

The final objective of the study deals with investigations on similarity parameters which allow the hot-gas jet to be replaced by a cold-gas one in ground-test facilities. This cold-gas jet should reproduce the effects of the hot-gas jet in wind-tunnel or shock-tunnel experiments. The previous DLR and ONERA/MBDA-France hot-gas jet configurations serve as reference cases and many numerical simulations were achieved. Other computations are in progress for DLR cases (task 8) and for ONERA/MBDA-France cases (task 9).

Due to the amount of computations the members have to be done and face to the very difficult subject, the end of AD/AG-48 previously scheduled in March 2011 is again shifted and it will be near the end of 2013.

- **Management issues**

The AirTN server of the NLR website is still in used in order to exchange of the large amount of data provided by the members.
Unfortunately, since November 2009, MBDA-Deutschland (formerly MBDA-LFK) does not participate anymore to the work of the group, and consequently the chairman decided to withdraw Klaus Weinand from the member list.
Matthieu Ardonceau changed his activities within MBDA-France and Christophe Nottin replaces him.
Friedrich Seiler from ISL retired in May 2011.

- **Expected results/benefits**

The first expected benefit which is the assembly of a bibliography on similarity parameters is available now.

The development of a calibration of the CFD codes based on experimental data using both cold and hot multi-species gases is done. The analysis of the main differences resulting from the use of cold and hot multi-species gases is also done and the group concentrates its efforts now on new numerical simulations for the final benefit of the study.
Finally, the definition of the most appropriate similarity parameters based on these new CFD results is in progress.

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M. Leplat	ONERA	michel.leplat@onera.fr

- **RESOURCES**

Resources		Year						Total 12-13
		2008	2009	2010	2011	2012	2013	
Person-months	Actual/ Planned	5.4 5.4	13.1 14.4	16.5 15.2	10.5 12.2	3.0 1.4	 6.0	48.5 53.6
Other costs (in K€)	Actual/ Planned	5.45 5.45	22.40 26.30	26.80 25.50	7.00 22.00	6.00 5.45	 8.00	67.65 92.70

- **PROGRESS/COMPLETION OF MILESTONE**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: Bibliography	Dec. 2008	Dec. 2010	Finished Reported
Task 2: Experimental data of DLR configuration	Nov. 2008	Jan. 2009	Finished Reported
Task 3: CFD grid for DLR configuration	Dec. 2008	Jul. 2009	Finished Reported
Task 4: Experimental data of ONERA/MBDA-F config.	Nov. 2008	Apr. 2009	Finished
Task 5: : CFD grid for ONERA/MBDA-F config.	Dec. 2008	Nov. 2009	Finished
Task 6: Validation of CFD on DLR configuration	Sep. 2009	Nov. 2010	Finished
Task 7: Validation of CFD on ONERA/MBDA-F config.	Sep. 2009	Feb. 2012	Finished
Task 8: Further CFD on DLR configuration	Sep. 2010	Jan. 2013	Mostly finished
Task 9: Further CFD on ONERA/MBDA-F config.	Sep. 2010	June 2013	Mid way
Task 10: CFD results analysis	Dec. 2010	Aug. 2013	In progress
Task 11: Most appropriate similarity parameters	Dec. 2010	October 2013	In progress
Task 12: Reporting	March 2011	December 2013	

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 AG49 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/AG49: 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.

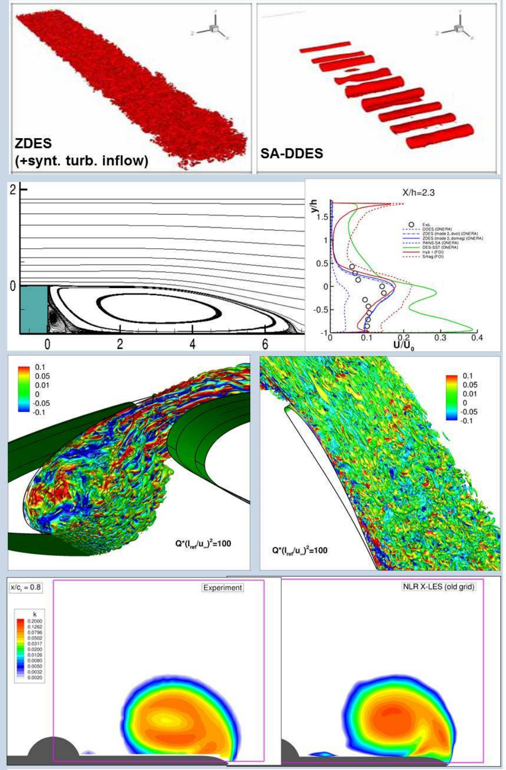
Work plan: The work in AG49 is divided into three tasks. Task 1 and Task 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3

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

- Exploration and further improvment of modelling and turbulence-resolving capabilities based on a number of test-case computations using different hybrid RANS-LES models
- Assessment 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:

- Futher 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.
- All AG members have computed the test cases planned. Further refined computations have been being conducted.
- Partners 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.*
- Cross 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.
- Experimental data for all TCs are available for modelling validation and calibration.
- Comparative studies are being conducted for modelling evaluation.
- Along 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..
- Ongoing 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-49 Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications

Monitoring Responsable: T. Berglind, FOI

Chairman: Dr S.-H. Peng, FOI

- **OBJECTIVES**

The overall objective of AD/AG-49 is to scrutinize, improve and assess some selected hybrid RANS-LES approaches in simulations of aerodynamic flows and, ultimately, to provide “best-practice” guidelines for industrial use relevant to aeronautic applications.
Along with further modelling improvement, an emphasis has been placed on a comprehensive exploration of turbulence-resolving capabilities in computations of four different Test Cases (TC), using hybrid RANS-LES methods. By means of cross comparisons, the *pros and cons* of these modelling approaches, as well as related numerical aspects, have been investigated in comparison with available experimental data.

- **MAIN ACHIEVEMENTS**

In 2012, AD/AG-49 had the M30 meeting, hosted by INTA (Madrid, 19-20 April), at which the AG members had reported respective work progress in line with the AG work plan. Apart from TC 2.2 (round leading-edge Delta wing), cross comparisons have been conducted with results from AG members for test cases TC1.1, TC 1.2 and TC 2.1.
A number of test-case computations have been conducted, and have been being further refined, using different hybrid RANS-LES models. Agreed by all AD/AG-49 members and approved by GARTEUR GoR, the activities of AD/AG-49 will be completed by 31 March 2013. The final AD/AG-49 meeting has been scheduled on 7-8 March 2013 at FOI, by then the AD/AG-49 work will be summarized. As a continuation of AD/AG-49 work, the setup of a new EG has been agreed and will be launched after AD/AG-49 in 2013.
In **Task 1**, computations of two fundamental TCs, mixing layer (TC 1.1) and backward-facing step (BFS, TC 1.2), have been carried out, upon which some modelling improvement and investigation of related numerical issues have been undertaken. In computation of the mixing layer (***TC 1.1***) by FOI, INTA, NLR and ONERA, it is shown that existing conventional hybrid RANS-LES models (including DES and DDES) are not able to capture the initial development of mixing-layer instabilities. Improvement of different degrees has been shown in predictions by NLR using stochastic X-LES, by ONERA using synthetic turbulent inflow conditions with ZDES and, to a less extent, by FOI using the HYB0 model with an energy-backscatter LES mode. NLR’s computations show further that reduced dissipative sources may play a significant role for improved predictions, the same is thru with improved modelling as done by FOI, NLR and ONERA.

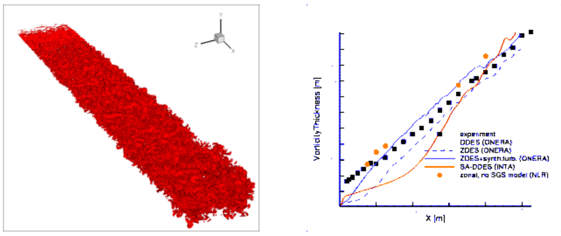


Figure 1. TC 1.1: Mixing layer. Resolved structures (left) and vorticity thickness (right).

The BFS flow (***TC 1.2***) has been computed by CIRA, FOI, ONERA and TUM-AER, using LES, HYB0, SST-DES, ZDES and WMLES methods. The computations in Task 1 have enabled to conduct modelling validation against available experimental data. The two TCs in this task have shown that it is significant to correctly model/resolve the upcoming boundary layer in the simulation of downstream flow properties.

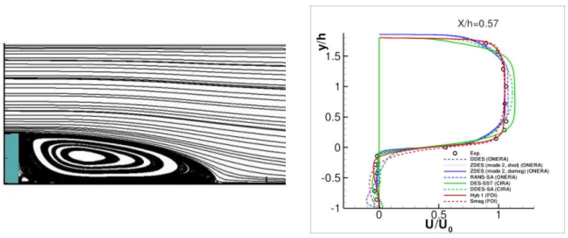


Figure 2. TC1.2: BFS. Time-averaged streamlines (left) and mean velocity profile at x/h =1.1.

In **Task 2,** DLR, FOI, NLR, ONERA and TUM-AER have conducted computations on the F15 high-lift configuration (***TC 2.1***) using SA-DES, SA-DDES, SA-IDDES, HYB0, X-LES (based on k-ω and EARSM), ZDES and WMLES, with a large set of results available for cross comparisons and modelling assessment. Apart from using improved modelling approaches, it has been shown that grid resolution and the span wise extension of computational domain gives important impact on the prediction.
For TC 2.2 (VFE-2 Delta wing), computations are being performed by CIRA, FOI, and TUM-AER, using SST-DES, HYB0 and WMLES, respectively.

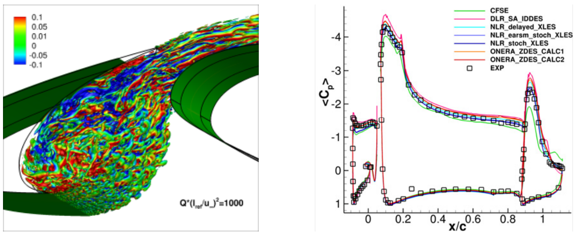


Figure 3. TC 2.1: Resolved structure in the slat cove (left) and surface pressure distributions (right, only part of results included for illustrative purpose).

NLR has completed X-LES computations on two different grids for the sharp-leading-edge Delta-wing. The final cross plotting for TC2.2 will be reported at the AG final meeting and included in the final summery report.

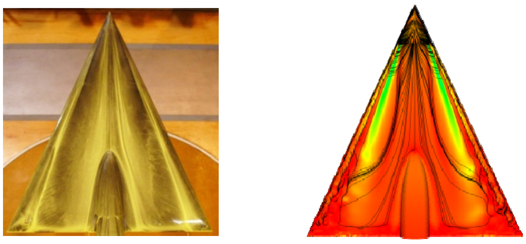


Figure 4. TC 2.2 Round LE Delta wing. Exp. visualization (left) and HYB0 computation (right).

In summary, a large set of results have been produced on all the test cases using a number of different hybrid RANS-LES methods. Improved modelling has been reported, and some modelling-related numerical issues have also been addressed. On-going modelling assessment has been reported using the computations for TCs 1.1, 1.2 and 2.1. Evaluation with the computations for TC 2.2 will be reported at the final meeting. In line with its overall objectives, the achievement is anticipated by the completion of the AG activities before this summer.

- **RESOURCES**

Resources		Year					Total
		2009	2010	2010	2012	2013	2012
Person-months	Actual/ Planned	A3 P4	A21 P20	A20 P16	A15 P15	A0 P7	A59 P62
Other costs (in K€)	Actual/ Planned	A20 P30	A175 P171	A170 P166	A100 P100	A0 P70	A465 P537

- **COMPLETION OF MILESTONES**

Work package	Planned		Actual
	Initially	Currently (updated)	
Kick-off meeting	25 Sept. 2009		25 Sept. 2009
Specification of all TCs	Oct 2009		Oct. 2009
Experimental data of TCs 1.1, 1.2 and 2.1	Feb. 2010		Feb. 2010
Grids and preliminary computations of all TCs	April 2010		April 2010
TC 2.2 experimental data	April 2010	Feb. 2012	Jan. 2012
M6 AG meeting	April 2010		April 2010
1st set of results of all TCs	Oct. 2010		Oct. 2010
M12 AG meeting	Oct. 2010		Oct. 2010
Improved computations of TC1.1 and TC 2.1	Dec. 2010		Dec. 2010
M18 AG meeting	April 2011		April 2011
First cross comparisons for TC 1.1 and TC 1.2	Oct. 2011		Oct. 2011
M24 meeting	Oct. 2011		Oct. 2011
Further cross comparison of TC 1.1, 1.2 & 2.1	April 2012		April 2012
M30 meeting	April 2012		April 2012

- **BENEFITS**

The AD/AG-49 work contributes to a comprehensive understanding and assessment of hybrid RANS-LES modelling of typical aerodynamic flow physics, and to further modelling improvement. The project will provide aeronautic industries with "best practice" guidelines, and highlight respective advantages and disadvantages of selected approaches in turbulence-resolving simulations of aerodynamic flows. Consequently, the CFD tools used by AG members will be improved. The results will facilitate "*correct and effective*" use of hybrid RANS-LES methods in aeronautical applications.

- **AG MEMBERSHIP**

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***NOTE: M. Meyer (TUM) left for EADS-IW end of 2011, and S. Hickel will take over his role in AD/AG-49.**

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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)

The 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

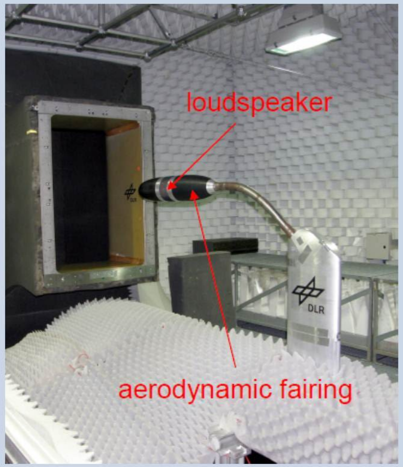
The Programme

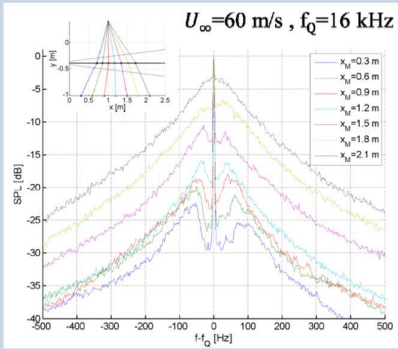
Objectives of AD/AG-50
- To improve the understanding of shear layer effects;
- To quantify the magnitude of shear layer effects, including the dependence on different parameters;
- To develop procedures to correct for shear layer effects;
- To investigate the possibilities to reduce shear layer effects.

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



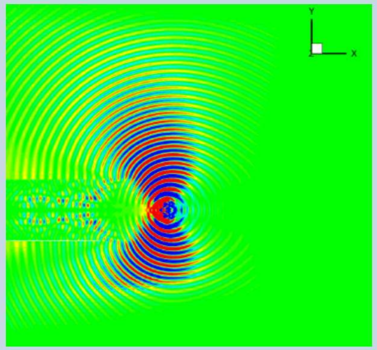


Results

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-50	Effect of open jet shear layers on aeroacoustic WT testing
Monitoring Responsable:	K. de Cock NLR
Chairman:	P. Sijtsma NLR

- **OBJECTIVES**

AD/AG-50 investigated the effects of open jet shear layers on acoustic wind tunnel measurements. Aeroacoustic wind tunnel tests are generally conducted in open jet wind tunnels (see Figure 1). The sound from the model has to pass through the open jet shear layer, which causes refraction, spectral broadening, and loss of coherence between the signals at different microphones. These effects depend on geometry, Mach number and frequency, and are presently only partially understood. As a result they hamper the interpretation of acoustic measurements substantially (e.g., for open rotors).

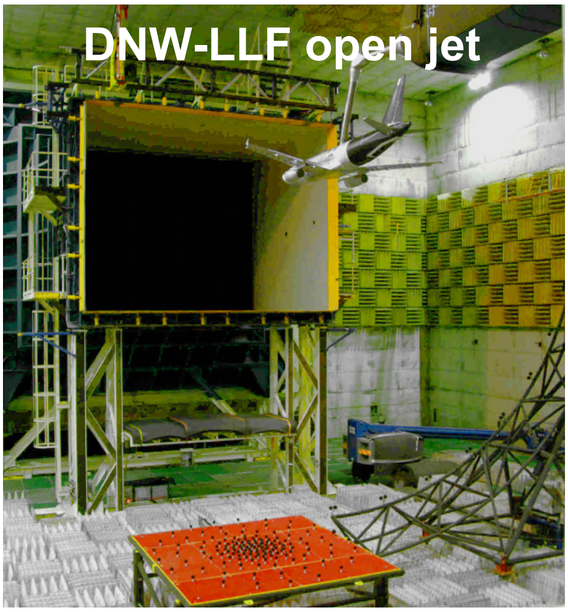


Figure 1. DNW-LLF open jet wind tunnel.

The objectives of AD/AG-50 were therefore (1) to improve the understanding of shear layer effects, (2) to quantify the magnitude of shear layer effects, including the dependence on different parameters, (3) to develop procedures to correct for shear layer effects, and (4) to investigate the possibilities to reduce shear layer effects. In order to achieve these objectives, experimental and computational studies were performed. Joint experimental and computational test cases were defined and the dependence of shear layer effects on wind speed, frequency, and shear layer thickness was systematically investigated. The aim was to substantially improve the quality of aeroacoustic testing.

- **MAIN ACHIEVEMENTS**

AD/AG-50 started in January 2010 for duration of 3 years. At the beginning of the project a deliverable scheme was defined and agreed by the partners. Progress meetings were held every 6 months, hosted by several partners.

The experimental test program is fully completed. ONERA carried out experiments in the B2A facility to study the aerodynamic/acoustic properties of wire-mesh material. This material, which can be considered to be acoustically open and aerodynamically closed, may be used as test section wall for aeroacoustic wind tunnel measurements, replacing the thick shear layer (see Figure 2) by a thin boundary layer. The B2A tests indicated that the wire-mesh sheet can indeed be considered as aerodynamically closed, and that the acoustic attenuation should be low enough to allow good acoustic measurements.

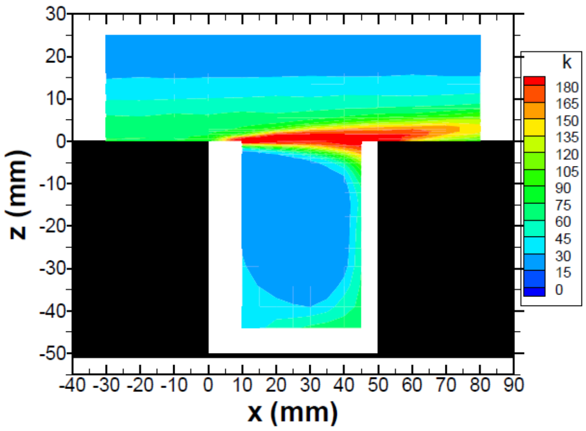


Figure 2. Thick shear layer.

DLR and NLR carried out acoustic and aerodynamic measurements in the open jets of the DNW-PLST, NLR-KAT and DLR-AWB wind tunnels, to characterize spectral broadening as a function of wind speed, frequency, geometry and shear layer thickness. The test conditions for the different facilities were complementary and partly overlapping; in order to study whether shear layer effects are universal or facility-dependent.
Detailed analysis of the experimental results from the different facilities showed, in general, strong similarities. This enabled the development of an empirical method to retrieve the correct acoustic power of tones from "haystacks" measured outside the shear layer. Other concepts to reduce shear layer effects were also investigated. The use of porous Kevlar material proved to be beneficial. In addition to the DLR/NLR experiments, ISVR analysed spectral

broadening using an existing high quality database from QinetiQ's round jet facility. Herewith, the transition from weak to strong scattering could be demonstrated for the first time.

The first part of the computational work consisted of a comparison between existing correction methods for shear layer refraction from different partners. Most partners use Amiet-like thin-layer methods, which assume ray acoustics. Calculations for thin-layer benchmark cases were performed by CIRA, NLR and ONERA, showing that the ray acoustics assumption is generally valid for calculating sound refraction by a shear layer. Computations using more advanced methods yielded good agreement between the two partners.

The second part of the computational work package consisted of advanced numerical calculations of (1) a parallel flow, (2) a diverging mixing layer, and (3) the complete AWB wind tunnel set-up (see Figure 3). CIRA have provided benchmark results for cases 1 and 2. Using a full 3D Euler method in perturbative form, ONERA compared their results to the CIRA benchmarks, showing good agreement.

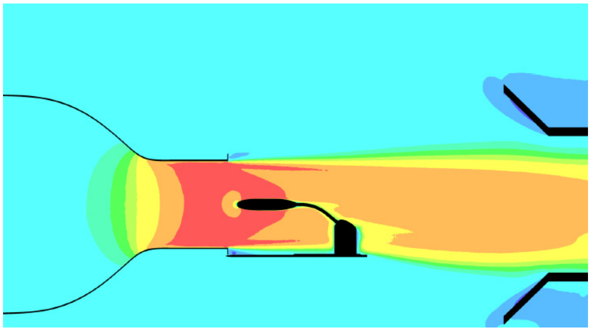


Figure 3. The AWB wind tunnel set-up.

- **Management issues**

Stefan Oerlemans (NLR) is on a one-year sabbatical. As chairman of the GARTEUR AD/AG-50 Group, he is replaced by Pieter Sijtsma.

A number of deliverables could not be finished on time. Therefore, it was decided to extend the 3-years period by 3 months.

- **Results/benefits**

This project yielded better understanding of shear layer effects, improved correction procedures and improved shear layer characteristics. Tools have been developed to improve the quality of aeroacoustic wind tunnel testing substantially. Work performed within the Action Group has led to AIAA paper 2010-3762 "Finite element solutions of a third-order wave equation for sound propagation in sheared flow" by D. Casalino (CIRA). More conference papers and/or journal articles are expected.

- **AD/AG-50 MEMBERSHIP**

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- **RESOURCES**

1. Resources			Year			Total
		2010	2011	2012	2013	
Person-months	Actual/ Planned	16/ 21	16/ 20	8/ 17	10	40/ 58
Other costs (in K€)	Actual/ Planned	60/ 80	60/ 80	0/ 20	20	120/ 180

- **COMPLETION**

The analysis is completed, but the reporting is still on-going. The following deliverables are expected in the first 3 months of 2013:

1.3a - DLR - Analysis of test results
1.3d - ISVR - Analysis of test results
2.2c - ONERA - Results for thin layer calculations
2.4d - DLR - Aerodynamic CFD results
2.5d - DLR - Acoustic CAA results
3.2 - NLR - Synthesis report

The final report is expected to be delivered in April 2013.

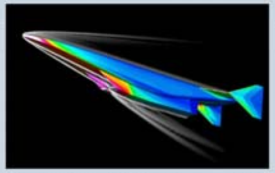
GARTEUR — GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

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

Background

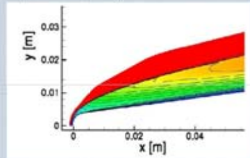
Transition laminar/turbulent:
Thrust-drag balance and air intake adaptation (air breathing hypersonic vehicles)
Heat fluxes (re-entry vehicles)



Different experimental data sources in Europe

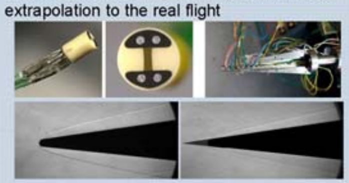
Increasing capability of CFD :
Need of tools/methods to predict laminar/turbulent transition in hypersonic using RANS code

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

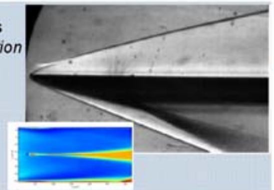
- Schlieren
- Heat flux measurement
- Interferometry

Mach=[4-8]
Re=[1.4 – 14] 10^6/m

case 3 – Hypersonic forebody
Natural and triggered transition
- 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, MBDA, ONERA, Universität der Bundeswehr München, von Karman Institute

AD/AG-51	**Laminar/Turbulent transition in hypersonic flows**	
Monitoring Responsable:		D. Pagan MBDA-F
Chairman:		J. Perraud ONERA

- **OBJECTIVES**

The objective of this Action Group is to improve knowledge and methods dedicated to the prediction and triggering of laminar/turbulent transition in hypersonic flows.

- **PROGRESS**

Launching of a new action group, AD/AG51, was decided in September 2011. It is dedicated to laminar-turbulent transition prediction and control in hypersonic flows. Seven members participate to this Action Group: six from research establishments (CIRA, DLR, ISL, ONERA, UniBwM and VKI) and one from industry (MBDA-F). VKI is not a member of the GARTEUR organization but all partners agreed to welcome the institute into the team and VKI was accepted by the GARTEUR council in January 2011.

The Action group activity is split into three work packages relating to natural and triggered transition. The main goal of the first package is to build a well-documented experimental database, which will be used as validation tool during the numerical studies. All the partners agree on four available wind-tunnel experiments carried out by DLR, ISL, MBDA-F and VKI. These experiments focus on flight regimes with Mach number between 4 and 10 and altitudes up to 40 km with either natural or triggered transition.

DLR has provided wind tunnel test results on JAXA cone (M=7.4 and Re= [1.5-6.8] 10^6/m) with heat-flux measurements carried out by using coaxial thermocouples and time resolved surface pressure measurements. Newly-manufactured DLR cone model and associated wind-tunnel results with second mode instabilities observation may come after.
ISL has provided shock tunnel test results on a sharp cone and on a blunt conical nose (M=6; Re=23.5 10^6/m and 9.6 10^6/m) with interferometry visualisation and heat-flux measurements.

MBDA-F has provided extracts of wind tunnel test results obtained at ITAM (M= [4-8], Re= [6.1– 49.4] 10^6/m) with Pitot pressure, oil flow and Schlieren visualizations. TSP results relating to the triggering device will be also provided.
The VKI will provide a part of an existing database obtained on a flat plate with ramp-shaped roughness triggers. Experiments at Mach 6 on a cone with unsteady pressure transducers, IR camera will come soon.

The second work package is dedicated to the extension of existing natural transition criteria to supersonic flows (M>1.6) and their implementation into 3C3D and elsA codes. Extension of AHD criterion developed by Dr. Arnal has been presented. With no gradient pressure and adiabatic walls, compressibility effects have been validated up to Mach 4 (outer edge value). Gradient pressure and wall temperature effects are in good progress for completion of this criterion before its application on test cases (e.g. LEA forebody at Mach 4)

The last work package consists in applying the new criteria to the configurations provided by the partners using LST approach (four different codes) and RANS criteria.
The work plan aims at benchmarking all these numerical methods on a selected geometry before assessing it over the overall test cases. ISL cones (sharp and blunted tip) will be used as the first reference. See p.8 of the minutes of meeting number 1for further details. First Navier-stokes axisymmetric computations will be done on a common set of 2D meshes. Then laminar boundary layer profiles will be compared and validated before selection for LST computations. Validation of the results will be performed according to ISL shock tunnel experiments.

The action group will also investigate the effect of wind tunnel facilities (turbulence level, etc.) on transition.

A study of passive triggering devices will also be conducted, based on experimental and numerical results. VKI is very active in this topic with both experimental (LIF unsteady flow visualisation methods) and numerical work.

- **MEETINGS**

The Kick-off meeting took place at ONERA Toulouse on 1st February 2012.

Progress meeting number 1 was held at VKI Rhose-St-Genèse on 22nd of November 2012.

Next meeting in CIRA May 2013, to be confirmed at a video conference in March 2013.

- **AD/AG-51 MEMBERSHIP**

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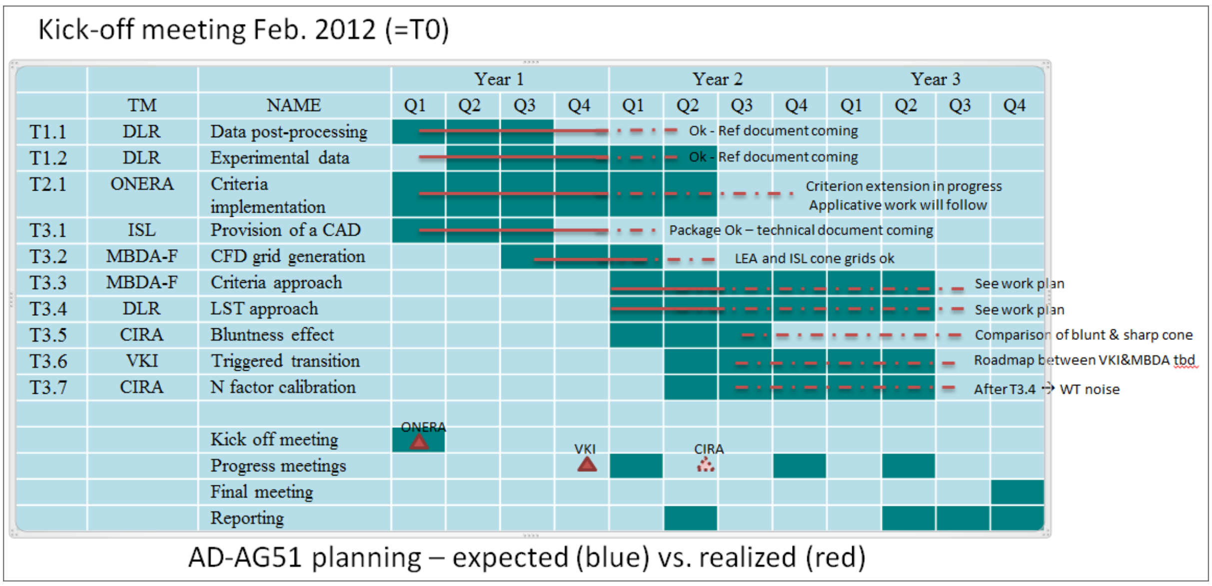
- **RESOURCES**

Partner	*Year 1*	*Year 2*	*Year 3*	*Partner Total Budget*
CIRA	**2.0**	**2.0**	**2.0**	**6.0**
DLR	**1.0**	**2.0**	**2.0**	**5.0**
ISL	**2.0**	**1.5**	**1.0**	**4.5**
MBDA	**2.5**	**2.0**	**2.0**	**6.5**
ONERA	**3.0**	**3.0**	**3.0**	**9.0**
UniBwM	**1.0**	**1.5**	**1.5**	**4.0**
VKI	**2.5**	**2.0**	**2.0**	**6.5**
Total	**14**	**14.0**	**13.5**	**41.5**

- **PROGRESS/COMPLETION OF MILESTONES**

Work package / Task	*Progress*
WP1 / 1.1 : data processing	Done– report expected in Feb. 2013
WP1 / 1.2 : provide experimental database	Done – report expected in Feb. 2013
WP2 / 2.1 : extended AHD criteria development	To be finished and assessed
WP3 / 3.1 : CAD database	Done
WP3 / 3.2 : Grid generation	ISL cones, LEA forebody, ready to compute
WP3 / 3.3 : RANS approach for natural transition	To be done - see work plan 3.3/3.4
WP3 / 3.4 : LST computations	To be done – see work plan 3.3/3.4
WP3 / 3.5 : Bluntness effect on transition	Links to 3.3/3.4 (sharp and blunt cones)
WP3 / 3.6 : Triggered transition analysis	Roadmap to be clairifed between MBDA and VKI
WP3 / 3.7 : WT N factor calibration	LST comparisons of different WT results

- **Time plan of activities**



AD/EG-67	Surrogate-based global optimization methods in aerodynamic design
Monitoring Responsable:	F. Monge INTA
Chairman:	E. Andrés INTA

The GARTEUR AD/EG67 was established to investigate the application of surrogate-based global optimization (SBGO) methods in aerodynamic shape optimization.

- **OBJECTIVES**

The objectives of this Action Group are

1. Off-line assessment of surrogate modelling techniques for computation of the fitness function;
2. On-line assessment of surrogate-based global optimization strategies as for their consistency with surrogates and feasibility for shape design;
3. Evaluation of Design of Experiments (DoE) techniques given a certain geometry parameterization;
4. Demonstration of the applicability and CPU time savings by the use of SBGO.
5. Provision of "best practice" guidelines for the industrial use of SBGO in shape optimization

In order to achieve these objectives, computational studies will be performed, and specific challenges will be addressed as:

1. "Curse of dimensionality" for high dimensionality problems (n>>10).
2. Proper error metrics for comparison (RMSE, Maximum Error ....).
3. Efficient DoE techniques, adaptive DoE strategies for "optimal" selection of training points towards validation error mitigation.
4. Reduction of the design space (parameterization sensitivity, ranking of design parameters, geometric filtration and gradient information).
5. Handling constraints with surrogates, alternative formulations of constraints.
6. Improvement of surrogate accuracy at fixed computational budget (variable fidelity methods, …)

Common computational 2D and 3D test cases are defined and the different methods proposed by each partner will be evaluated and compared.

- **PROGRESS**

An Exploratory Group kick-off meeting was held in Madrid on the 25 and 26th of January, 2012. As the result of the Exploratory Group, a proposal for the establishment of an Action Group has been prepared and accepted in the GoR meeting on the 25th of October. The starting date for the AD/AG-52 is January 1, 2013 and a first meeting is planned by the end of January. The duration of the project is three years.

- **BENEFITS**

This AG is expected to yield better understanding of SBGO techniques and their application to aerodynamic shape optimization. At the end of the proposed AG, the involved partners will have improved global shape optimization capabilities and valuable knowledge of the selected set of techniques. Through the proposed activities, it is expected that some "best practice" guidelines will be concluded and, consequently, facilitating the use of surrogate-based global optimization methods in aeronautic industries. It is also foreseen that the AG will lead to several publications, either as conference papers or as journal articles.

- **AG MEMBERSHIP**

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- **RESOURCES PLANNED**

Resources	Year			Total
	2013	2014	2015	
Person-months	24.7	24.7	24.7	74.1
Other costs (in K€)	70	70	70	210