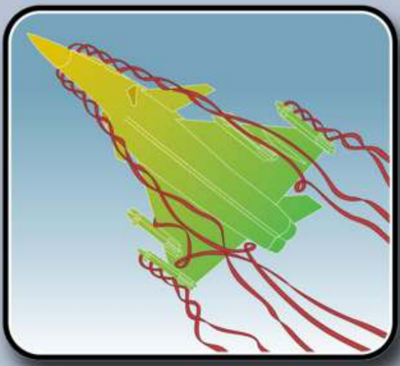
GARTEUR

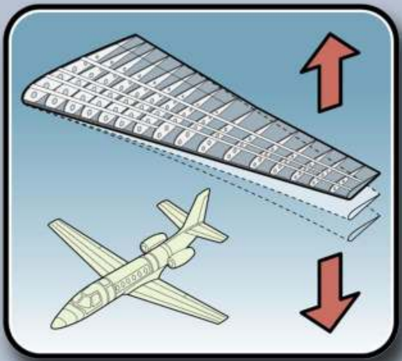
GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

Document X/D 52

GARTEUR
Annexes to the Annual Report 2015





May 2016

www.garteur.org

GARTEUR X/D 52

Annexes to the GARTEUR Annual Report 2015 (X/D 51)

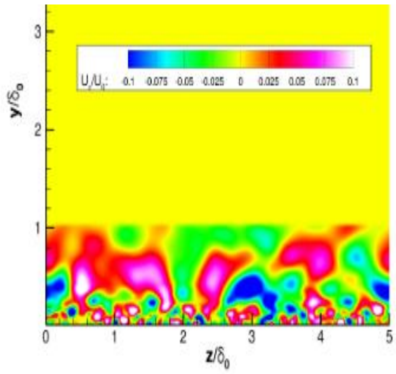
This report gathers the Annual Reports from the GARTEUR Groups of Responsables (GoRs).

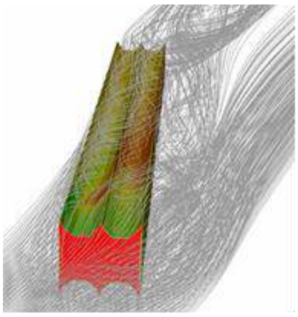
TABLE OF CONTENTS

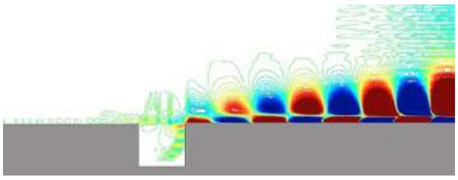
Blank page

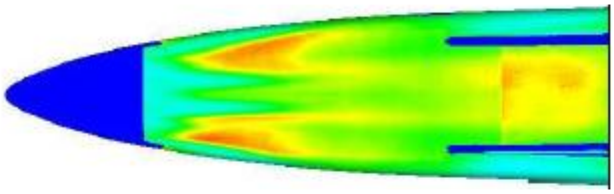
ANNEX A

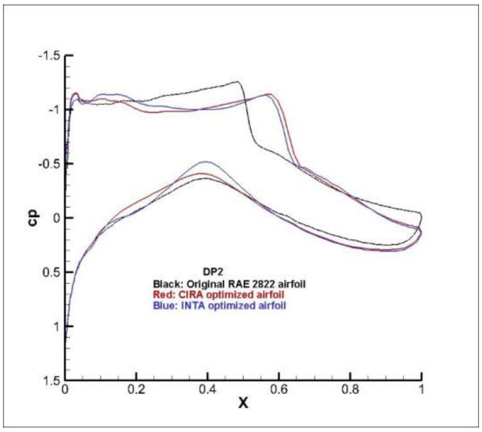
ANNUAL REPORT FROM THE GROUP OF RESPONSABLES “AERODYNAMICS”

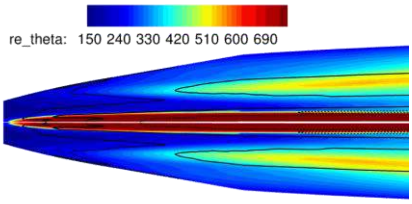












Remit

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

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

- Aerodynamics;
- Aero-thermodynamics;
- Aero-acoustics;
- Aero-elasticity;

- Aerodynamic Shape optimum;
- Aerodynamics coupled to Flight Mechanics;
- Aerodynamics Systems integration.

In general terms the work consists of both computational and experiment aspects of aerodynamics with the emphasis on the provision of data to validate the computational approaches. In addition, the experimental activity has resulted in improvement of measurement techniques, and further understanding of basic flow physics in a number of areas.

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

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

TABLE OF CONTENTS

AERODYNAMICS

GoR-AD OVERVIEW

GOR ACTIVITIES

During 2014 there were 2 Action Groups, namely AD/AG-46 "Highly Integrated Subsonic Air Intakes" and AD/AG-48 "Lateral jet interactions at supersonic speeds" that were completed. In both cases the work had been completed in 2013 and only reporting needed to be completed within 2014. One new Action Group was launched AD/AG-54 "RANS-LES Interfacing for Hybrid RANS-LES and embedded LES approaches", and was well prepared by the members of AD/EG-69.

Five Action Groups have been active in 2015.

- AD/AG-51 "Laminar/Turbulent Transition in Hypersonic flows".

  The object of this programme of work was to improve knowledge of the flow and methods dedicated to the prediction of and factors leading to the triggering of Laminar/Turbulent boundary layer transition on bodies in hypersonic flow. Work consisted of both wind tunnel tests and CFD prediction, and has concentrated on the Mach number range of 4 to 10 at atmospheric condition appropriate for 30 km altitude, and has made use of 4 different wind tunnel facilities, thus allowing inter tunnel comparisons to be made. A major output of the work will be the methodology to interpret the CFD data to full scale conditions. Work started in 2012 was planned to finish by the end of 2014, but an extension to mid-2015 has been agreed. The group Chairman is Jean Perraud of ONERA.

- AD/AG-52 "Surrogate-based global optimisation methods in aerodynamic design".

  A current issue in aircraft design is the need to have the ability to determine aerodynamic characteristics rapidly and accurately within the design process. This programme of work is associated with looking at the use of surrogate methods in the design of aerodynamic shapes. Design of experiments (DoE) techniques have been tested against reference geometries allowing cost / accuracy studies between different approaches to be made. A major output of the work is best practice guidelines for industrial use of SBGO methods in shape optimisation. The work was started in February 2013 and was expected to be completed by December 2015. An extension of the programme from the original finish date to the end of December 2016 was agreed by the GoR in 2015. The AD/AG-52 Chairperson is Esther Andrés (INTA) and Fernando Monge (INTA) is the Monitoring Responsible.

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

  The main object of this project was to understand the effects of surface irregularities and disturbances in the oncoming flow on transition in three dimensional onset flows, and the evaluation of transition control techniques. The work covers both experiment and associated numerical calculations. The project started in September 2013 and is expected to be completed in September 2016. The AD/AG-53 Chairperson is Ardeshir Hanifi (FOI), and monitoring responsible Torsten Berglind (FOI).

- AD/AG-54 "RANS-LES Interfacing for Hybrid and Embedded LES approaches".

  AG54 arose out of work started in EG69. The main objective of this project is make use of a comprehensive and transnational effort to explore, and further develop theoretical methods, in order to improve RANS-LES coupling in the context of Embedded LES (ELES) and Hybrid RANS-LES methods thus enabling the "Grey Area" problem to be resolved. Both zonal and non-zonal approaches have been taken. The project started in April 2014, and is scheduled to be completed in April 2017. The work in this project is a follow on from that in AD/AG-49.

- AD/AG-55 “Countermeasure Aerodynamics”
  AG-55 arose out of preliminary studies carried out in EG-71 and was launched in October 2014, with an expected finishing date of the end of 2016. The work is divided into two work packages, the first deals with the dispersion of chaff using both Eulerian and Lagrangian approaches to calculate the dispersion pattern of the chaff downstream of the aircraft together with parametric studies. The second work package deals with the aerodynamics characteristics of burning flares, and their resulting trajectories. The focus is on achieving an improved understanding of the effects of burning on the aerodynamic characteristics of flares which change both size and shape after release. Work will include both methods development and the procurement of experiment data with which to validate the models. The Chair-Person of AD/AG-55 was Dr. O. Grundestam (FOI) and the Monitoring Responsible is Torsten Berglind (FOI). In mid-2015 Dr. Grundestam left FOI, as a result of which, Torsten Berlind has replaced him as Chairman for AD/AG-55.

- AD/EG-70 “Plasma for Aerodynamics”
  Work in this topic had failed to gather sufficient interest and so has been delayed again. The view of the GoR was to keep it open and review it at a later date.

- AD/EG-72 “Coupled Fluid dynamics and Flight Mechanics of Very Flexible Aircraft Configurations”
  This is a new Exploratory Group set up to deal with the issue of coupled aerodynamics and flight mechanics simulation tools aimed at the analysis of very flexible configurations. With the departure of various individuals, the reorganisation of NLR and difficulties with the release of Airbus IPR, work on this subject was delayed. The IPR issues are now resolved, and it is planned to launch the EG-70 activity prior to Summer Holidays. Harmen van de Ven of NLR will be leading the Group.

- AD/EG- 73” Secondary Inlets and Exhausts”
  A proposal in being prepared by Thomas Berens and will be issued by mid 2016.

MANAGEMENT ISSUES

The GoR-AD has been active in 2015 with two Meetings. The first took place on the 26th to 27th March 2015, hosted by INTA in Madrid. The second meeting was scheduled for Cranfield in the UK, hosted by the ATI on the 1st, 2nd, and 3rd September 2015. Potential attendance was very low due to travel difficulties for some members and the closeness of the 2015 summer holiday season. As a result of this the meeting was cancelled, and rescheduled for CIRA in Naples on 5th and 6th of November 2015.

The presence of Industrial Members and National PoCs at the two GoR meetings was reduced relative to 2014. At both meetings in 2015 the opportunity was taken to allow people to join the meeting by means of WEBEX. Though not totally aligned with the GARTEUR ethos of face to face meetings the use of WEBEX has allowed, more members to take part, with restricted travel budgets for some Research Institutes.

Industrial companies appeared to be a major reason for non-attendance at GoR/AD Meetings. Despite a very successful AG Forum held in FOI in Stockholm in Autumn 2014 it proved to be impossible to arrange a similar event in 2015.

At the end of the 2015 Autumn GoR/AD meeting the new GoR Chair and Vice-Chair took over, with Harmen van de Ven as Chairman for 2016/17 and Fernando Monge as Vice-Chair, and I wish them every success in the future. The preparation of this report is my last function as part of GARTEUR GoR/AD, and it was a great honour to be part of this excellent undertaking, and I cannot think of a better way to celebrate 53 years in the Aerospace Business.

DISSEMINATION OF GARTEUR ACTIVITIES AND RESULTS

In 2015 there was a continued pressure to disseminate the work of the AD/AG work. To this end AG52 published a further book on the result of their activities.

FUTURE PLANS

Compared with 2014 with four active AD/AGs, the status quo was maintained in 2015 with four Active AD/AGs and three AD/EGs. The prospects for 2015 were concerning, with potentially one active EG, AD/EG-72, which with the agreement on the use of the Airbus Flight Dynamics model within the project could result in the launch of an AD/AG during 2016 with the resolution of the Airbus IPR issue.

A proposal for work on thrust vectoring by mean of Fluids control did not gain much favour within the AD membership but is still on the table.

Studies of the application of plasma in Aerodynamics (AD/EG-70) failed to attract sufficient interest amongst the members of the AD. This EG is now inactive although it could be resurrected if sufficient interest is shown in the future.

More importantly the proposal for an AD/EG based on secondary inlets and outlets for ventilation is likely to be launched in 2016.

A potential EG associated with the detection of laminarisation in wind tunnels by various means has been proposed but would require the use of an industrial level wind tunnel with associated high cost.

During the course of 2015 a new list of ideas for research work from industry was issued. This will form the basis of a new initiative in 2016 to establish further AD/EGs.

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

Cat	Topic	2012	2013	2014	2015	2016	2017
AD/AG-51	Lamiminar-Turbulent Transition in Hypersonic flows	🟩	🟩	🟩			
AD/AG-52	Surrogate-based Global optimisation methods in preliminary designs	EG67 →	🟩	🟩	🟩	▩	
AD/AG-53	Receptivity and Transition prediction	EG66 →	🟩	🟩	🟩	🟩	
AD/AG-54	RANS-LES Interfacing Hybrid for Hybrid RANS-LES and embedded LES approaches		EG69 →	🟩	🟩	🟩	
AD/AG-55	Countermeasures Aerodynamics			EG71 →	🟩	🟩	
AD/EG-70	Plasma for Aerodynamics		🟧	🟧			
AD/EG-72	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configs		🟧	🟧	🟧		
AD/EG-73	Secondary Inlets and Exhausts						
		🟩 Active	▩ Extended	🟥 Closed	🟧 Inactive		

MANAGED AND FORESEEN GOR ACTIVITY

First 2016 GoR/AD meeting #96 Meeting was held at ONERA Palaiseau on the 29th February 2016 and 1st March 2016.

GoR/AD meeting #97 will be held, subject to confirmation, at Airbus Bremen on the 6th and & 7th October 2016.

Frank Ogilvie

Chairman (2014-2015)

Group of Responsables Aerodynamics

GOR MEMBERSHIP

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

Current membership of the Group of Responsables Aerodynamics

Chairman			
Mr. Frank Ogilvie	ATI	United Kingdom	frank.ogilvie@ati.org.uk

Vice-Chairman			
Vacant (till mid-2015)			
Mr. Harmen van der Ven (since mid-2015)	NLR	The Netherlands	Harmen.van.der.Ven@nlr.nl

Members			
Mr. Norman Wood	Airbus Ltd	United Kingdom	Norman.Wood@airbus.com
Mr. Bimo Prenata (till June 2015)	NLR	The Netherlands	bimo.pranata@nlr.nl
Mr. Eric Coustols	ONERA	France	Eric.Coustols@onera.fr
Mr. Giuseppe Mingione	CIRA	Italy	g.mingione@cira.it
Mr. Fernando Monge	INTA	Spain	mongef@inta.es
Mr. Henning Rosemann	DLR	Germany	Henning.Rosemann@dlr.de
Mr. Geza Schrauf / Mr. Heribert Bieler	Airbus Operations GmbH	Germany	Geza.Schrauf@airbus.com / Heribert.BIELER@airbus.com
Mr. Per Weinerfelt	SAAB	Sweden	per.weinerfelt@saab.se
Mr. Torsten Berglind	FOI	Sweden	torsten.berglind@foi.se

Industrial Points of Contact			
Mr. Thomas Berens	AIRBUS Defence & Space	Germany	thomas.berens@airbus.com
Mr. Nicola Ceresola	Alenia	Italy	nceresola@alenia.it
Mr. Michel Mallet	Dassault	France	michel.mallet@dassault-aviation.fr
Mr. Didier Pagan	MBDA	France	didier.Pagan@mbda-systems.com
Mr. Luis P. Ruiz-Calavera	AIRBUS Defence & Space	Spain	Luis.Ruiz@airbus.com
Mr. Chris Newbold	QinetiQ	United Kingdom	cmnewbold@qinetiq.com

TABLE OF PARTICIPATING ORGANISATIONS: AD/AGS AND AD/EGS

	AG-51	**AG-52**	**AG-53**	**AG-54**	**AG-55**	**EG-70**	**EG-72**	**EG-73**
Research Establishments								
CIRA	☐	☐	☐	☐				
DLR	☐		☐	☐				
DSTL								
FOI		☐	■	■	■			
INTA		■		☐				
NLR				☐	☐		☐	
ONERA	■	☐	☐	☐		☐		
Industry								
Airbus Military		☐			☐			
Airbus Operations GmbH			☐					
Airbus Operations S.A.S				☐				
Airbus Group Innovations			☐					
Alenia Aeronautics								
CASSIDIAN							☐	☐
Dassault Aviation								
EADS				☐				
LACROIX					☐			
MBDA-F	☐				☐			
MBDA-LFK								
QinetiQ								
SAAB		☐		☐				
Academic Institutions								
Imperial College			☐					
ISL	☐							
KTH			☐					
Southampton Un - ISVR								
TU Munchen				☐				
UAH		☐						
Univ. BwM *(universitat der Bundeswehr Munchen)*	☐							
University of Manchester				☐				
University of Zurich				☐				
UNIS		☐						
Von Karman Institute *(VKI)*	☐							
VUT		☐						

☐ = Member ■ = Chair

TOTAL YEARLY COSTS OF AD/AG RESEARCH PROGRAMMES

GoR	AG	2012		2013		2014		2015		2016		2017 *	
		pm	**k€**	**pm**	**k€**	**pm**	**k€**	**pm**	**k€**	**pm**	**k€**	**pm**	**k€**
	51	13	40	12	40	12	40	0	0	0	0	0	0
	52			20	45	23	63	23	63	23	63	0	0
	53			10	12	13	24	13	24	13	24	0	0
	54					18	100	22	140	22	140	5.5	50
	55							16	24	16	24	16	24
AD	**TOTAL**	**13**	**40**	**42**	**97**	**66**	**227**	**74**	**251**	**74**	**251**	**21.5**	**74**

pm = Person-months k€ = other costs

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

ACTION GROUP REPORTS

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

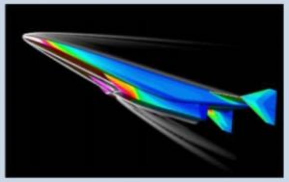
AD-AG51 :
Effect of laminar/turbulent transition in hypersonic flows

Action Group Chairman: Jean Perraud (ONERA)

Vice Chairman: Antoine Durant (MBDA-F)

The Background

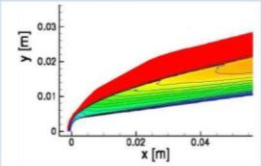
Transition laminar/turbulent:
Thrust-drag balance and air intake adaptation (air breathing hypersonic vehicles)
Heat fluxes (re-entry vehicles)



Different experimental data sources in Europe

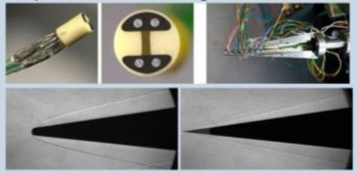
Increasing capability of CFD :
Need of tools/methods to predict laminar/turbulent transition in hypersonic using RANS code

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

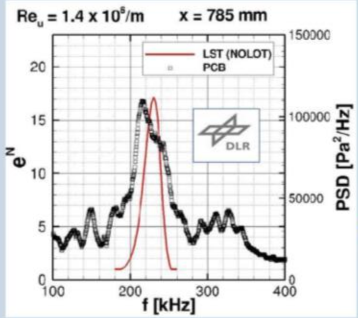


State of the art:
Linear stability theory, Wind tunnel experiments

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

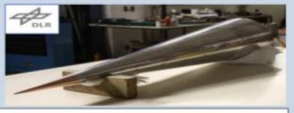


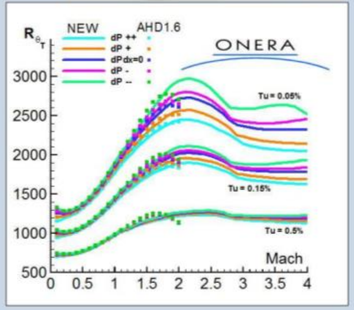
Activities 2013



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

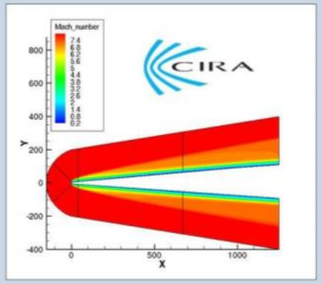
Sharp and blunt cones
Natural transition
Mach=7
Re=3.7 10^6/m





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

WP3 :
First computations on the LEA forebody done at CIRA



Mach=[4-8]
Re=[1.4 – 14] 10^6/m

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

Programme

Objectives of the Action Group AD-AG51:

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

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

Current status :

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

Next Steps :

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

AD/AG-51	**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**

AD/AG-51 was launched in September 2011. This Action Group is dedicated to laminar-turbulent transition prediction and control in hypersonic flows. Seven members are involved, 6 from research establishments (CIRA, DLR, ISL, ONERA, UniBwM and VKI) and 1 from industry (MBDA-F). (VKI is not a member of the GARTEUR organization but its participation was accepted by the GARTEUR Council in January 2011).

The Kick-off meeting took place at ONERA Toulouse on 1st February 2012, and a technical meeting was organised at VKI in November 2012. Due to budget restrictions at ONERA, there was no technical meeting organised in 2013.

The Action Group is split into 3 work packages (WP) relating to natural and triggered transition. First WP deals with experimental database and identification of validation cases, the second WP deals with transition predictions tools, and the third WP covers validation of the transition prediction methods, the effect of wind tunnel noise and transition triggering.

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 7 partners agreed on 4 available 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 natural and triggered transition. Most configurations are academic, e.g. cones or flat plates, with the exception of the LEA forebody proposed by MBDA. Availability of well adapted meshes is to be explored since a proper description of the boundary layer will be necessary.

DLR provided wind tunnel test results on sharp and blunt cones (M=7 and Re=3.7 Millions/m) with heat-flux measurements carried out by using coaxial thermocouples and time resolved surface pressure measurements, compared to stability calculations. A first report was prepared and distributed at the VKI meeting.

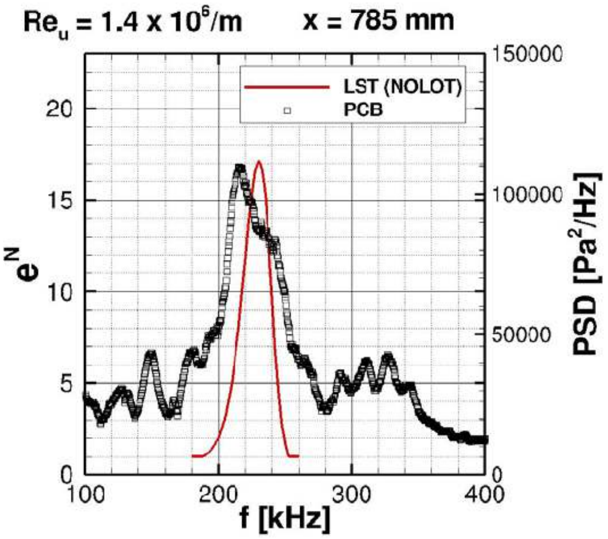


Figure 1 : Wall pressure spectrum compared to linear stability calculation (LST) - DLR HEG Mach 7.5 test of a blunted cone [1]

ISL agreed to provide shock tunnel test results on a sharp cone and on a blunt conical nose (Mach=6; Re = 23.5 10^6/m and 9.6 10^6/m) with visualizations and heat-flux measurements. Corresponding CAD files were uploaded to the ftp server.

MBDA-F provided extracts of wind tunnel test results performed at ITAM (Mach=4 and 8, Re = [1.4 – 7.1] 10^6/m). Measurements include Pitot pressure, Oil flow and Schlieren visualization, and TSP results in the presence of the triggering device. CAD files and meshes of the forebody have been also provided.

The VKI will provide a part of an existing database obtained on a flat plate with isolated roughness. Experiments on a cone started in 2012. This cone is equipped or not with roughness and inserted in the same wind tunnel. Infrared imaging has allowed demonstrating the case of natural and induced transition. Some of the cone experiment will also be shared with the partners. Because other financed projects will be running on the same topic additional run will be possible.

The second work package is dedicated to the extension to hypersonic flows of existing transition criteria and their implementation into CFD codes, starting with the boundary layer code 3C3D and the RANS elsA software. It is planned to study the extension to hypersonics by methods based on linear stability theory (LST), on transport equations models and on the use of transition criterion inserted into RANS codes when possible. Four different LST codes are available, which may run using velocity profiles obtained from RANS codes. LST results and experiments will be used for the validation phase.

Concerning the extension of the longitudinal criterion to Mach 4, pressure gradient effects were taken into account based on about 50 velocity profiles from

Falkner-Skan similarity solutions with several values of the Pohlhausen parameter $\Lambda_2 = \frac{\theta^2}{\nu}\frac{\partial U_e}{\partial x}$.

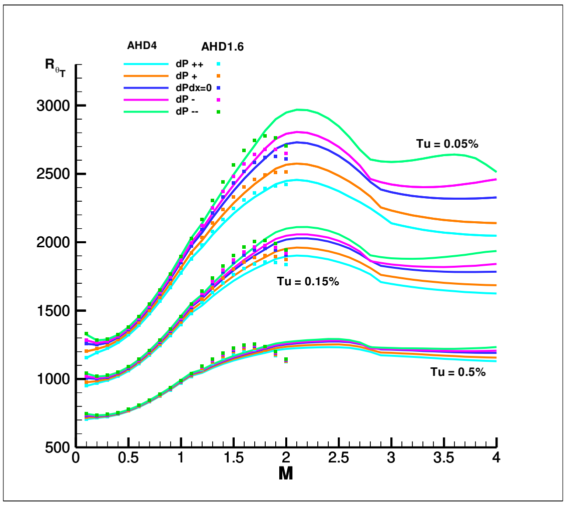


Figure 2 : Application of the new criterion up to Mach 4

A new formulation was determined, for the moment limited to adiabatic walls. This formulation has then been introduced into 3C3D and elsA. In 3C3D, validation is almost completed based on a flat plate with velocity ramps simulating the effects of pressure gradients. A similar validation is underway using elsA. Figure 2 shows the results obtained with 3C3D, compared to what produced the previous compressible model, which was limited to Mach 1.6. Five pressure gradients and three values of the turbulence level are plotted on the figure. A good agreement is indeed observed up to Mach 1.6. A first evaluation of precision using similar profiles showed that the relative error in transition prediction remained, in most cases, below 10% even with a 1% error on the incompressible shape factor estimation (figure 3).

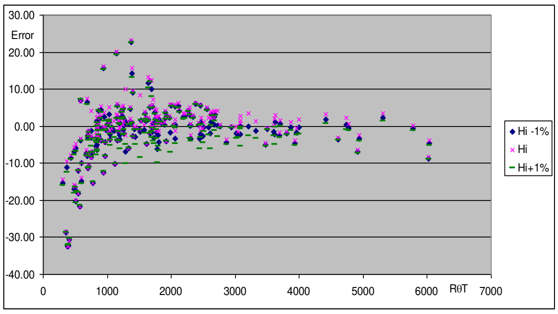


Figure 3 : Precision evaluation using similar profiles 1.1< Me< 4 ; -0.0265< $_2$<0.015 ; .05% < Tu< 1%

Comparisons to exact stability calculations will be necessary to more precisely evaluate the errors in the presence of pressure gradients.

Extension to cold walls will be considered in 2014. A large number of stability calculations have already been made, but time was too short in 2013 to extend the model.

The last work package consists in applying validated methods and the new criteria (when possible) to the configurations provided by the partners. A first computational test (figure 4) was run by CIRA using the LEA geometry.

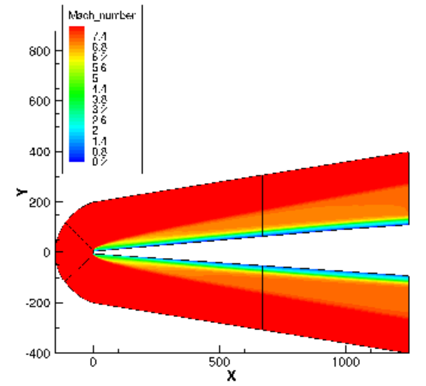


Figure 4 : Mach 8 computation of LEA forebody

Some cross studies between experimental results and numerical approaches will be carried out. The action group may also investigate the effect of wind tunnel facilities on transition, compared to real flight. Last but not least a study of passive triggering devices should also be conducted by CIRA and VKI based on experimental and numerical results.

[1] V. Wartemann, A. Wagner, “AG51 Task 1.1 Data post-processing”, DLR contribution

- **AG membership**

Member	**partner**	**e-mail**
Donato de Rosa	**CIRA**	**d.derosa@cira.it**
Viola Wartemann	**DLR**	**Viola.wartemann@dlr.de**
Dr Patrick Gnemmi	**ISL**	**Patrick.gnemmi@isl.eu**
Antoine Durant	**MBDA**	**antoine.durant@mbda-systems.com**
Jean Perraud	**ONERA**	**jean.perraud@onera.fr**
Prof Ch. Mundt	**UniBwM**	**Christian.mundt@unibw.de**
Dr Patrick Rambaud **Dr Olivier Chazot**	**VKI**	**Rambaud@vki.ac.be** **Chazot@vki.ac.be**

- **Resources**

Resources		Year			
		2012	2013	2014	Total
Person-months	Actual/ Planned	A13 P13	A11.5 P12.5	P12	P41.5
Other costs (in K€)	Actual/ Planned	A40 P40	A40 P40	P40	P120

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

AD/AG-52:
SBGO methods for aerodynamic design

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

Background

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

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

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

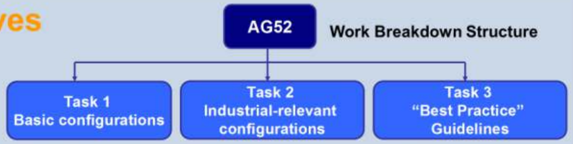
Aerodynamic applications: Aerodynamic shape optimization problems in an early stage. "Best practice" guidelines for the industrial use of SBGO methods

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

Programme/Objectives

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

Project duration: 4 years (2013-2016)



AG52 **Work Breakdown Structure**

Task 1
Basic configurations

To make comparatively studies of partners' simulations to highlight the benefits and drawbacks of different SBGO methods

Task 2
Industrial-relevant configurations

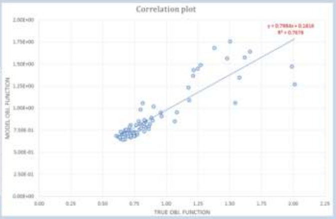
To validate the experience gained from T1 in designing industrial-relevant configurations

Task 3
"Best Practice" Guidelines

To give a clear statement about the possibilities and restrictions in using SBGO methods. To facilitate their **use in aeronautic industries**

Final task 1 results:

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

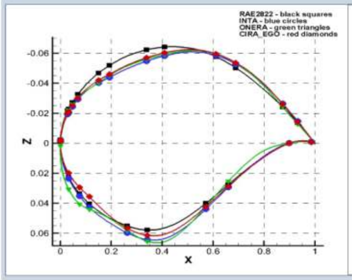


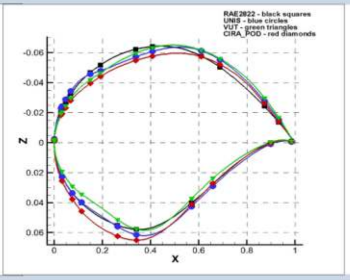
Surrogate models validation. **Error metrics comparison**

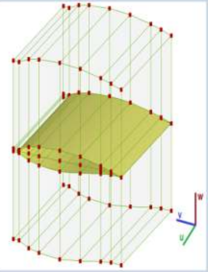
	Mean OF (TAU, MSES, ZEN 3 levels)	Mean OF (only TAU and ZEN fine)
RAE 2822 baseline	1	1
CIRA - POD + GA	0.6223	0.6266
CIRA - EGO + GA	0.6208	0.6236
INTA/UAH – SVM + EA	0.6243	0.6211
ONERA – Kriging + GA	0.6494	0.6498
UNIS – Ensemble + PSO	0.7659	0.7609
VUT – ANN + GA	0.6969	0.7063

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

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







Results

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

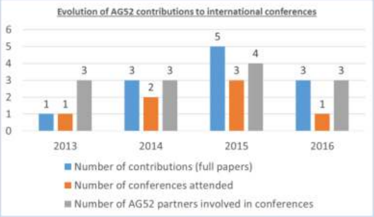
Partial reports delivered:

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

Current Status:

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

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



AG52 dissemination history

AD/AG-52 Surrogate-based global optimization methods in aerodynamic design

Monitoring Responsable: F. Monge
INTA

Chairpersons: E. Andrés
INTA

E. Iuliano
CIRA

• OBJECTIVES

The objective of this Action Group is to investigate and analyze the feasibility and possible contributions of Surrogate-based Global Optimization (SBGO) methods in an early phase of the aerodynamic design, where the design space will be broadly analyzed to get the optimum solution.

• MAIN ACHIEVEMENTS

The AD/AG52 took off on February 2013.

Nine members participate in this Action Group: four from research establishments (INTA, CIRA, FOI, ONERA), three universities (UAH, UNIS, VUT) and two from industry (AIRBUS-Military and SAAB). VUT is not a member of the GARTEUR organization but all partners agreed to welcome the VUT into the team and was accepted by the GARTEUR Council.

The work in AG52 is divided into three tasks. Task 1 and 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3.

Current work focuses on the assessment of different surrogate modeling techniques for fast computation of the fitness function and the evaluation of SBGO strategies for the shape design of the selected configurations.

The specific challenges to be faced in this activity are: dealing with the "curse of dimensionality", off-line and on-line model validation strategies, proper error metrics for comparison, efficient DoE techniques for optimal selection of training points towards validation error mitigation, reduction of the design space, improvement of surrogate accuracy at fixed computational budget, and variable fidelity models.

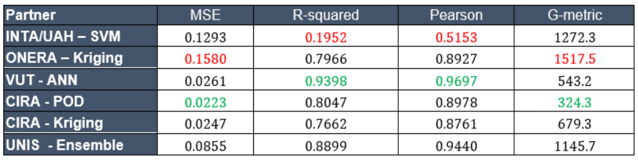
In order to minimize the sources of discrepancies and allow a fair comparison, the geometry parameterization, the computational grids (unstructured and structured) and the surface deformation algorithm are shared in task 1 between all partners. In addition, a cross-analysis on the optimized geometries was performed.

Partial reports delivered:

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

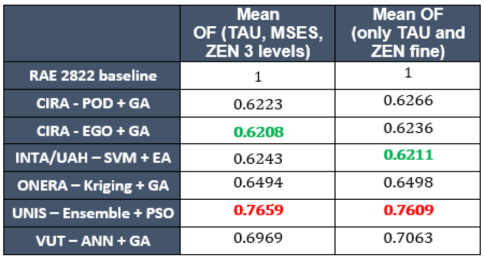
Current Status:

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



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

Figure 1: Surrogate models validation



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

Figure 2: Cross-analysis of the optimized geometries

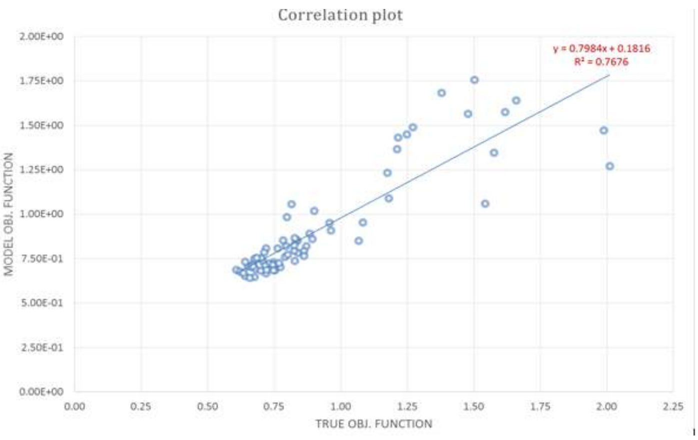


Figure 3: Correlation plot with CIRA-EGO surrogate model

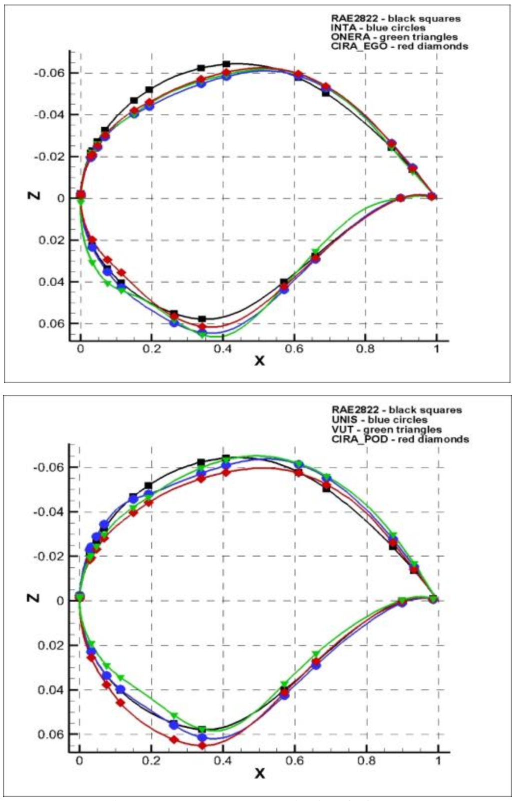
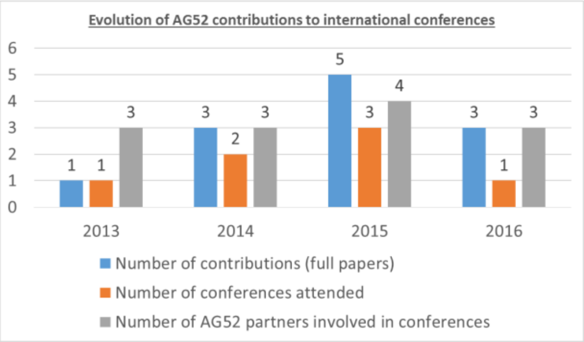


Figure 4: Partners' optimized shapes



	2013	2014	2015	2016
Number of contributions (full papers)	1	3	5	3
Number of conferences attended	1	2	3	1
Number of AG52 partners involved in conferences	3	3	4	3

Figure 5: AG52 dissemination history

- **EXPECTED RESULTS / 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.

- **MANAGEMENT ISSUES**

FOI had to stop its participation in the group due to personnel reasons. SAAB also had limited participation during 2015 due to limitation of resources. Intensive involvement of Emiliano Iuliano (vice-chairman, CIRA) in the management of the Action Group is considered very positive.

- **NEXT MEETINGS**
  - March 2016 (Webex), Oct. 2016 (ONERA)

- **AD/AG-52 MEMBERSHIP**

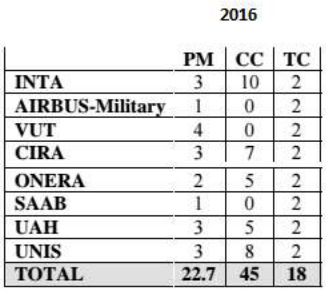
Member	**Partner**	**E-mail**
Esther Andrés **Daniel González**	INTA	eandres@isdefe.es gonzalezjd@inta.es
Emiliano Iuliano **Davide Cinquegrana**	CIRA	e.iuliano@cira.it d.cinquegrana@cira.it
David Funes	AIRBUS-Military	david.funes@military.airbus.com
Olivier Amoignon*	FOI	olivier.amoignon@foi.se
Gerald Carrier **Jacques Peter** **Didier Bally**	ONERA	gerald.carrier@onera.fr jacques.peter@onera.fr Didier.Bailly@onera.fr
Per Weinerfelt	SAAB	per.weinerfelt@saabgroup.com
Leopoldo Carro **Sancho Salcedo**	UAH	leopoldo.carro@uah.es sancho.salcedo@uah.es
Yaochu Jin **John Doherty** **Handing Wang**	UNIS	yaochu.jin@surrey.ac.uk john.doherty@surrey.ac.uk handing.wang@surrey.ac.uk
Petr Dvorak **Ropert Popela**	VUT	dvorak.p@fme.vutbr.cz popela.r@fme.vutbr.cz

* As commented before, Oliver Amoignon left FOI in 2015.

- **RESOURCES**

Resources	***Year***			***Total***
	2013	***2014***	***2015***	
Person-months	P22.7	P22.7	P22.7	P68.1
Other costs (in k€)	P63	P63	P63	P189

The planned resources for 2016 are:



2016

	PM	**CC**	**TC**
INTA	3	10	2
AIRBUS-Military	1	0	2
VUT	4	0	2
CIRA	3	7	2
ONERA	2	5	2
SAAB	1	0	2
UAH	3	5	2
UNIS	3	8	2
TOTAL	**22.7**	**45**	**18**

- **PROGRESS/COMPLETION OF MILESTONES**

Work package / Task	***Actual***
Task 1 – Basic configurations (Surrogate models validation and optimization comparison)	Finished & Partial report
Task 2 – Industrial relevant configurations	May 2016
Task 3 – Best practices & Final AG52 report	Dec 2016

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

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

Background

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

Programme

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

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

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

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

The Outcomes

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

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

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

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

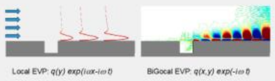
KTH & FOI have completed highly accurate simulations of the leading-edge acoustic receptivity, showing pervious results overestimating the receptivity coefficient. The new results have been verified by comparison with those obtained from compressible computations using a high-order finite-difference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

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

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

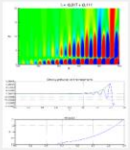
Gap Analysis

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



Local EVP: $q(y)\ exp(i\alpha x\text{-}i\omega t)$ BiGocal EVP: $q(x,y)\ exp(\text{-}i\omega t)$

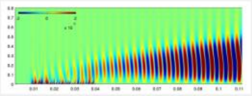
- The linearised Jacobian is extracted from the RANS solution and used as an input for the BiGlobal Solver.
- N-Factors of the eigenmodes are calculated with the e^N theory, analyzing the evolution of the perturbations.



Receptivity model development.

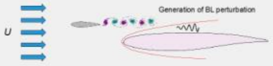
Method:
Linearized Navier-Stokes solver

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

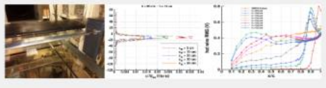


Perturbations generated by randomly distributed surfaces roughness of 5 microns.

Receptivity & transition experiment

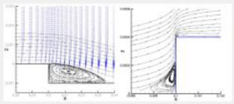


Aim: determine the onset of by-pass transition on a 2D wing due to upstream turbulence increase

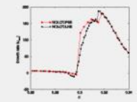


Middle: velocity perturbation behind small wing. Right: Effect of distance from wake on generation and growth of perturbations inside the boundary layer over the ONERA D wing. *h* is distance between the two wings.

Backward/Forward-facing step

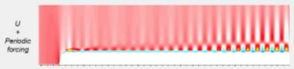


Mean-flow field from CFD.

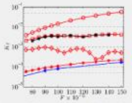


Disturbance growth rate from PSE and LNS for a flow past a backward-facing step (step at x=0.3)

Leading-edge acoustic receptivity



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



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

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

AD/AG-53	**Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations**
Monitoring Responsable:	T. Berglind FOI
Chairman:	A. Hanifi FOI

- **Objectives**

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

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

- **Main activities**

Experiments on effects of free-stream perturbations using the ONERA D profile. The work includes investigations of 2D and 3D flows. The free-stream perturbation will be generated by wake of a moveable body placed upstream of the wing.

Experimental and numerical work concentrated on effects of steps and gaps. The intention is to use a similar configuration as that used in Bippes' experiments.

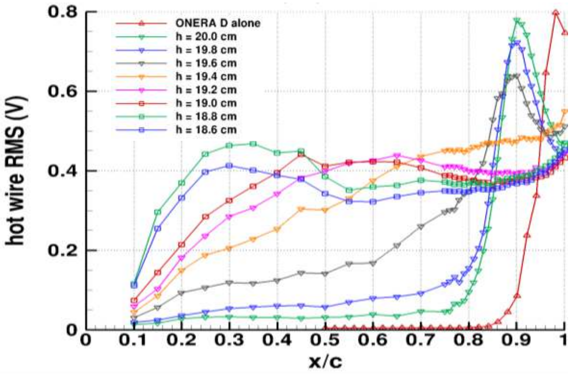
Numerical investigations of acoustic receptivity in 3D boundary layers. Comparison of direct numerical simulations with simpler methods like linearized Navier-Stokes computations and adjoint methods.

- **Expected results/benefits**

Outcome of the suggested activities will improve our understanding of the underlying physical phenomena. The investigations will increase our knowledge about the capability of existing prediction methods through comparison with data form experiments and numerical simulations, and also contribute to improvement of these methods.

- **Main achievements**

The second test campaign of ONERA experiments was performed during November 2015. The aim of these experiments was to proof the occurrence of a by-pass transition on a wing profile when the freestream turbulence level is progressively increased. The turbulent wake of a small wing placed 50 cm upstream of the main wing is used to modulate the turbulence rate outside of the boundary-layer developing past the windward side of the main ONERA D wing set at -2° angle of attack. Hot-wire anemometry was used in order to measure the velocity perturbations in the wake and inside the boundary layer. It was observed that when the small wing is in high position, the transition occurs slightly earlier compared to the case of ONERA D wing alone, but the exponential growth of the perturbations follows a similar path. For lower positions of the small wing, an algebraic growth of the fluctuations can be observed, starting close to the leading edge.



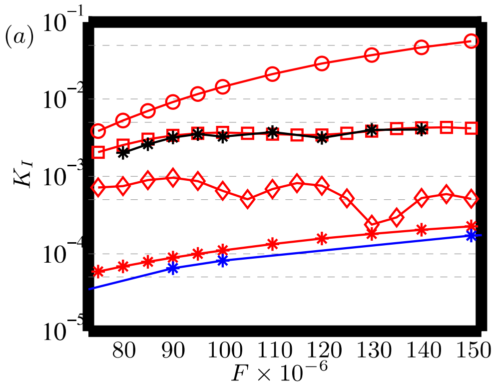
Effect of distance from wake on generation and growth of perturbations inside the boundary layer over the ONERA D wing. h is distance between ONERA D and the small wing.

IC has investigated the instability of flow behind a bump with a freestream Mach number of M=0.87 through numerical simulations. Results indicate effects of upstream propagating acoustic wave. Further, effects of negative bumps, modelled by linearized boundary conditions, are investigated.
The so-called PSE-3D simulations of suction patches have also been performed.
Works on development of methods for nonlinear simulations of Steps and gaps have also been initiated.

AGI has been working on design of ring wing experiments (ALFET project). Here, effects of gap with realistic filler shape on transition will be investigated. The tests include a wide range of depths of filler surface. Wind tunnel tests will be performed during January 2016. It will examine the effect of gap + realistic filler shape on transition for a range of depths of filler surface.

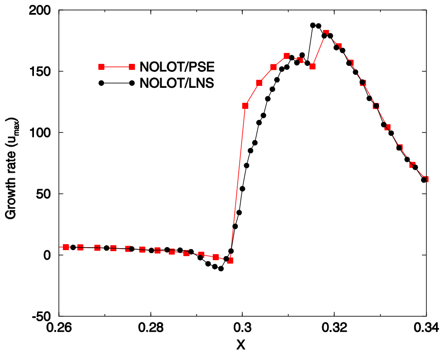
CIRA has been performed receptivity analysis for distributed roughness elements. Activities also include extension of the receptivity code for inclusion of interaction between acoustic waves and surface roughness, using adjoint methods following the approach of Zuccero & Luchini.

KTH & FOI have completed simulations of the leading-edge acoustic receptivity. Results of these simulations give lower values of the receptivity coefficient compare to those reported earlier in the literature. The new results, which are based on the incompressible computations using a spectral element code, have been verified by comparison with those obtained from compressible computations with a high-order finite-difference code. The new results also agree well with the asymptotic theory in limit of infinitely thin flat plate.



Receptivity coefficient at branch I. red asterisk; flat plate incompressible, blue asterisk; Giannetti & Luchini (2006), diamond; 40:1 MSE incompressible, square; 20:1 MSE incompressible, black asterisk; 20:1 MSE compressible and circle; 6:1 MSE incompressible.

DLR has worked on improving in-house numerical tools for linear stability analysis of boundary-layer flows past forward- and backward-facing steps, i.e. cases with localized surface discontinuities. Approaches based on the parabolized stability equations (PSE) are known to work very well for attached boundary layers. However, in regions where strong streamwise flow gradients are to be expected, e.g. in the vicinity of surface discontinuities, the validity of the PSE approximation becomes questionable. Therefore, linearized Navier-Stokes equations (LNS) can now be solved instead in the immediate vicinity of the step while still making use of the superior numerical efficiency of the PSE approach upstream and downstream of the step.



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

- **Management issues**

The AD/AG-53 had is kick-off meeting on Sept 5, 2013 at University of Genova. Latest technical meeting was held on April 28, 2015 in Stockholm.

- **AD/AG-53 membership**

Member	Organisation	e-mail
A. Hanifi	FOI/KTH	ardeshir.hanifi@foi.se
R. Ashworth	Airbus Group Innovations	Richard.Ashworth@eads.com
G. Casalis	ONERA	Gregoire.Casalis@onera.fr
D. de Rosa	CIRA	d.derosa@cira.it
S. Hein	DLR	Stefan.hein@dlr.de
S. Mughal	IC	s.mughal@imperial.ac.uk
G. Schrauf	Airbus	Geza.Schrauf@airbus.com
N. Shahriari	KTH	nima@mech.kth.se

- **Resources**

Resources		Year				Total
		2013	2014	2015	2016	
Person-months	Actual/ Planned	9.75	12.50	12.50	1.75	41.50
Other costs (in K€)	Actual/ Planned	11.50	24.00	24.00	12.00	71.50

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

AD/AG-54:
RANS-LES Coupling in Hybrid RANS-LES and Embedded LES

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

Background

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

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

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

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

Programme/Objectives

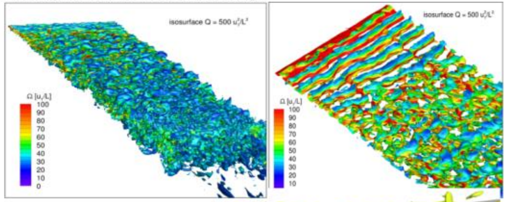
Main objectives: By means of comprehensive and trans-national collaborative effort, to explore and further to develop and improve RANS-LES coupling in the context of embedded LES (ELES) and hybrid RANS-LES methods and, consequently, to address the "grey-area" problem in association with the RANS and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

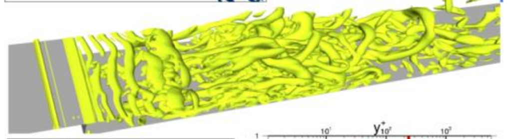
Work plan: The work in AG54 is divided into three tasks. Task 1 and Task 2 deal with non-zonal and zonal hybrid RANS-LES methods, respectively, and an overall assessment of the developed methods is conducted in Task 3.

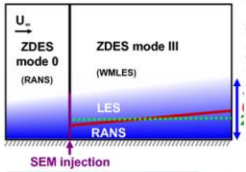
Task 1: Non-zonal modelling methods
(Task Leader: **NLR**)
For models with the location of RANS-LES interface regulated by modelling (not prescribed), typically, for DES-type and other seamless hybrid methods. Two TCs are defined.
TC M1 Spatially developing mixing layer
Initiated from two BLs of U_1 = 41.54 and U_2 = 22.40 m/s, respectively, with Re_θ = 2900 and 1200. Focus on modelling/resolving initial instabilities of the mixing layer.
TC O1 Backward-facing step flow
Incoming BL with U = 50m/s and Re_h = 40000. Focus on modelling/resolving the free shear layer detached from the step (h = step height).

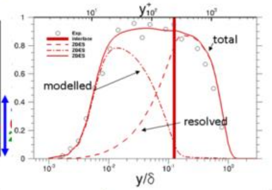
Task 2: Zonal modelling methods
(Task Leader: **UniMan**)
For models with the location of RANS-LES interface prescribed, Including embedded LES. Two TCs are defined.
TC M2 Spatially developing boundary layer
Inflow defined with U = 70m/s and Re_θ = 3040. Focus on turbulence-resolving capabilities on the attached BL after the RANS-LES interface.
TC O2 NASA hump flow
Incoming BL has U = 34.6m/s, Re_c = 936000 (c = hump length). Focus on the turbulence-resolving capabilities on the flow separation over the hump

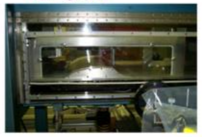
Task 3: Modelling assessment
(Task Leader: **Airbus-Innovations** (EADS-IW))
Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.
TC M3 Co-flow of BL and wake
Re = 2.4x10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.

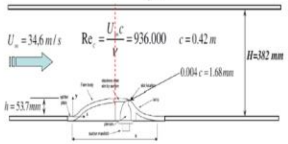


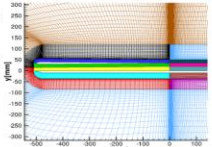


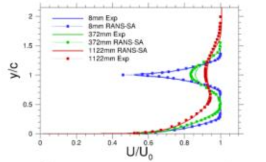












Results

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

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

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

AD/AG-54 RaLESin: RANS-LES Interfacing for hybrid and embedded LES approaches

Monitoring Responsable: T. Berglind
FOI

Chairman: Dr. S.-H. Peng FOI

- **Objectives**

AG54 has been established after the work of EG69. The overall objective of AG54 is, by means of comprehensive and trans-national collaborative effort, to explore and further to develop and improve RANS-LES coupling in the context of embedded LES (ELES) and hybrid RANS-LES methods. More specifically, the major objectives of AG 54 are: (1) To evaluate RANS-LES interfacing methods adopted in existing hybrid RANS-LES modelling approaches; (2) To address the so-called “grey-area” problem in association with RANS-LES interaction, as well as with the RANS and LES modes hybridized; (3) To develop/improve RANS-LES coupling methods for zonal and non-zonal hybrid RANS-LES modelling, as well as for embedded LES methods; (4) To verify and assess the developed methods in turbulence-resolving simulations.

- **Main Achievements**

AG54, consisting of 11 members, including two universities, six research organizations and three industries, had its kickoff meeting in Stockholm on 9 April 2014. The AG work to some extent is a natural continuation of AG49 (completed in March 2013), which has scrutinized a number of selected existing hybrid RANS-LES models. The emphasis in AG54 is placed on improved RANS-LES coupling in hybrid RANS-LES modelling to overcome or alleviate some identified problems, particularly, to address the “grey-area” problem for zonal and non-zonal hybrid models.

The AG work is divided in three technical tasks, based on numerical computations of selected test cases. Task 1 deals with non-zonal hybrid RANS-LES methods (including seamless hybrid models). In Task 2, the RANS-LES coupling for zonal (including wall-modelled LES) and embedded LES is explored. In Tasks 1&2, two test cases are defined, including a mandatory TC and an optional TC. The methods developed in Task 1 ans Task 2 are then assessed in Task 3 in computations of a mandatory test case.

The main activities and achievements can in general be marked on the following three aspects: (a) Evaluation of existing hybrid RANS-LES methods of zonal and non-zonal modelling in computations of test cases; (b) Improved modelling formulation to enhance turbulence-resolving capabilities with special focus on the “grey-area” problem; (c) Definition of all the test cases, and a number of preliminary computations conducted for different test cases.

For non-zonal hybrid modelling in Task 1, the main progress has been reflected in addressing the “grey-area” problem by means of improved modelling formulation, among others, X-LES with stochastic backscatter model, HYB0 and HYB1 with energy backscatter, improved ZDES with vorticity-based length scale, SST-IDDES model with a well-defined hybrid length scale. Figure 1 shows an example of computations for the minxing layer (TC M1) by NLR, where the stochastic backscatter model is shown to improve the prediction over the basline X-LES model. For the same TC, CIRA, DLR, FOI, INTA and ONERA have also started computations exisiting models and/or improved variants.

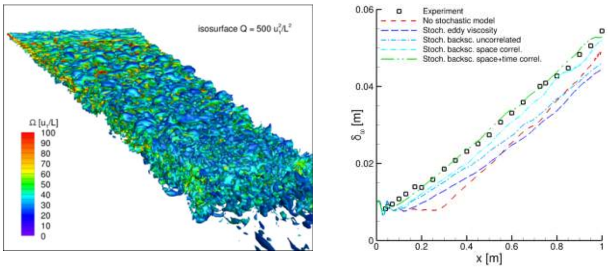


Figure 1: Example of computations by NLR for TC M1 (mixing layer) with an improved non-zonal stcochastic backscatter model. Resolved structures (left); Vorticity thickness (right).

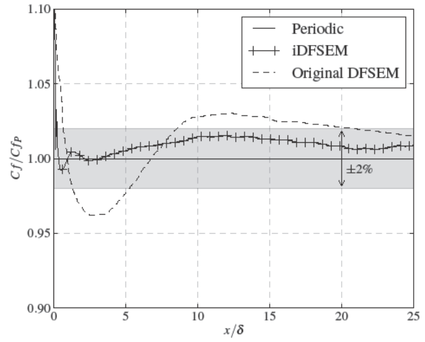


Figure 2: Improved DFSEM (iDFSEM) of UniMan in computations of turbulent channel flow.

For zonal hybrid RANS-LES modelling in Task 2, the work has been progressed with a focus on the method of generating synthetic turbulence for better RANS-LES interface, and on the verification of such methods in computations of TC M2 (Spatially developing turbulent boundary layer). UniMan has further improved their original Divergence-Free Synthetic Eddy Method (DFSEM). An example is shown in Figure 2. The re-establishement of a turbulent channel flow, reflected by the developing wall skin friction, becomes much effective with the support of the iDFSEM for generating synthetic turbulence imposed at the RANS-LES interface, as compared to the original DFSEM.

The use of synthetic turbulence is exampled in Figure 3 with the computation of ONERA for TC M2. The computation was conducted with RANS in the upstream section and WMLES downstream through a RANS-LES interface on which syhthetic turbulence was imposed.

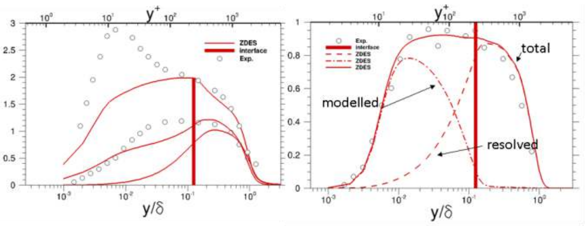


Figure 3: Example of zonal modelling computation of ONERA for TC M2 (Spatially developing boundary layer) with ZDES supported by SEM on the RANS-LES interface.

TC M3 (co-flow of boundary layer and wake) in Task 3 is selected for the assessment of methods developed in Tasks 1 & 2. This TC has been verified by ONERA (TC-M3 coordinator) in RANS computations, as shown in Figure 4. This effort has made this TC well-defined for hybrid RANS-LES computations.

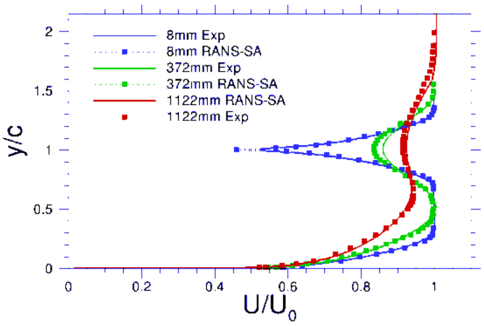


Figure 4: RANS verification of TC M3, serving late-stage hybrid RANS-LES computations with zonal and non-zonal methods.

Besides the mandatory test cases (M1, M2 and M3), the optional TCs (O1 and O2) have also been well defined by TC-coordinators (Saab and TUM, respectively. Some preliminary computations have also been undertaken for the optional TCs.

- **Resources**

Resources		Year				Total
		2014	2015	2016	2017	
Person-months	Actual/ Planned	A18 P18	Axx P22	Axx P22	Axx P5.5	Axx P67.5
Other costs (in K€)	Actual/ Planned	A100 P100	Axxx P138	Axxx P140	Axxx P50	Axxx P428

- **Completion of milestones**

Work package	Planned		Actual
	Initially	Currently (updated)	
Kick-off meeting	9 April. 2014		9 April 2014
Task 1 & Task 2: Specification of TCs	Oct 2014		Oct. 2014
Task 3: TC M3 testing for definition &	Oct. 2014		Oct. 2014
1st progress meeting	Oct. 2014		Oct. 2014
Tasks 1, 2 & 3: Website of AG	Oct. 2014	Feb. 2015	

- **Expected results/benefits**

AG54 aims at a collaborative exploration of hybrid RANS-LES methods. Improved zonal and non-zonal hybrid models (including ELES) are expected with particular focus of addressing the grey-area problem encountered commonly in existing hybrid models. These improved methods will be implemented into the CFD tools of AG members and, consequently, being exploited in other research activities and industrial designs.

- **EG membership**

Member	Organisation	e-mail
P. Catalano	CIRA	p.catalano@cira.it
F. Capizzano	CIRA	f.capizzano@cira.it
T. Knopp	DLR	Tobias.Knopp@dlr.de
A. Probst	DLR	Alex.probst@dlr.de
D. Schwamborn	DLR	Dieter.schwamborn@dlr.de
S.-H. Peng	FOI	Shia-Hui.Peng@foi.se
C. Lozano	INTA	lozanorc@inta.es
J. Kok	NLR	j.kok@nlr.nl
S. Deck	ONERA	sebastien.deck@onera.fr
M. Schneider	EADS-IW	manfred.schneider@eads.net
S. Arvidson	Saab	sebastian.arvidson@saabgroup.com
C. Breitsamter	TUM	Christian.Breitsamter@aer.tum.de
C. Zwerger	TUM	Christian.zwerger@tum.de
A. Revell	UniMan	alistair.revell@machester.ac.uk
A. Skillen	UniMan	Alex.skillen@machester.ac.uk
L. Tourrette	Airbus-FR	Loic.tourrette2airbus.com

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

AD/AG-55: Countermeasure Aerodynamics

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

The Background

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

Lacroix high speed track.

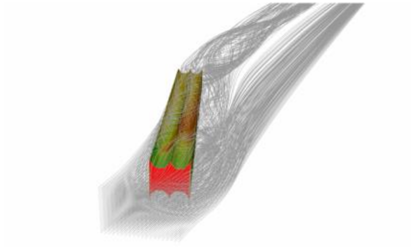
The Programme

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

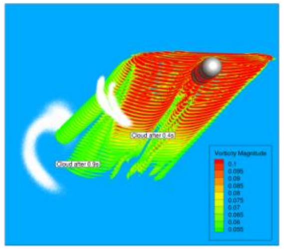
Approach
For WP1 two methods of predicting chaff dispersion, Eulerian and Lagrangian, is be considered. The principle behind the Eulerian method is that chaff is traced as a concentration instead of individual specimen. The aim is to include directional information for both approaches. In addition to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

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

Project duration: January 2015 – December 2017



Visualisation of flow around the flare at 20° incidence.



Simulation of chaff dispensed from a generic helicopter.

The Outcomes

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

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

AD/AG-55 Countermeasure Aerodynamics

Monitoring Responsable:	T. Berglind FOI
Chairman:	T. Berglind FOI

Objectives

In order to increase the defensive capability of aircraft or helicopter, countermeasures are used to decoy enemy tracking systems. Two commonly used countermeasures are chaff and flares.

Chaff is a radar countermeasure consisting of small pieces or threads of metal or metalized glass fibre. The chaff interacts with the electromagnetic radar wave and can thereby decoy or distract enemy radar. Chaff is dispensed in very large numbers from specific dispenser devices, on an aircraft typically located on the fuselage or under the wing.

Flares are used against IR-seeking missiles. They are larger in size, typically a few decimetres in length, and can be dispensed as individual entities even though several flares are often fired in series. Flares can have built in propulsions systems.

The aerodynamic behaviours of these two countermeasures differ significantly. Chaff dispensed from an aircraft propagate through the wake of the aircraft with the motion induced by trailing vortices. When simulating chaff dispersion it is therefore of major importance to obtain an accurate description of flow in the wake.

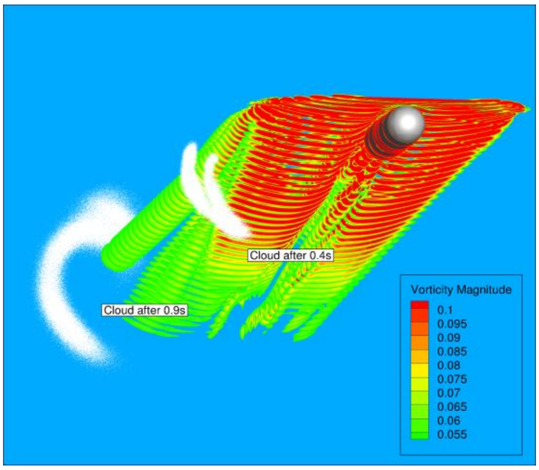


Fig. 1 Simulation of chaff dispensed from a generic helicopter (NLR).

Visualisation of a chaff cloud propagating in the wake of a generic helicopter is shown in figure 1. Flares, on the other hand, are solid bodies for which the burning constantly changes their aerodynamic and mechanic properties. Figure 2 displays computed flow around a flare.

There are two main methods to simulate chaff dispersion an Eulerian approach in which the chaff concentration is represented as a scalar field, and a Lagrangian method in which individual chaff are tracked. Both methods are used in a separate post processing step, once the flow field has been determined. Furthermore, chaff will be modelled as fibres having a spatial extension and direction. The aim is to incorporate directional information in both approaches.

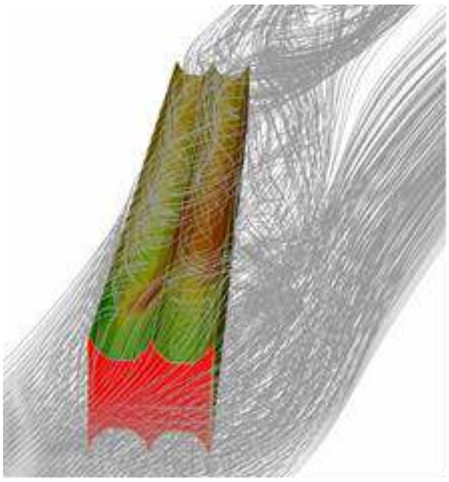


Fig. 2 Visualisation of flow around the flare at 20^o incidence (FOI).

The flare work is focused on predicting flare trajectories. Of special interest is how burning of the IR payload affects the aerodynamic and mechanical properties of a flare. These effects include both exhaust gases as well as deformation of the exterior surface due to the burning process. A special boundary condition will be developed in order to model the flow of exhaust gases from flare. The work package also includes performing experiments on flare trajectories, considering both inert and burning flares, see Fig. 3. CFD will be performed for different levels of flare models. Finally an evaluation of computed trajectories will be done by comparison with experiment.

Main achievements

A meeting was held at MBDA le Plessis in Paris June 16th. All partners attended except Lacroix who participated via phone during the flare part.

In the WP1 dealing with chaff it was decided that the test case should be chaff dispended from a helicopter. NLR delivered a computational grid with 14.6 million nodes around a generic helicopter in the beginning of October.

In a first step the Eulerian and Lagrangian approach is going to be compared. FOI has, during this year, implemented the Lagrangian approach with a diffusivity model.

A significant part of the work in WP2 consists of computations to generate aerodynamic databases for the flare with and without exhaust gases. Lacroix computed maps of the flare profile with the program VULCAD. The work to compute the aerodynamic database was spited between Airbus, FOI and MBDA. Grids were generated around the flare geometry after 0 sec (Airbus), 1 sec (FOI), 2 and 3 secs (MBDA). The database will be used to simulate 6DoF-trajectories for the flare with varying mass and moments of inertia. This database is expected to be completed early next year. Thereafter first trajectory-simulations for the ground test case can start.

Next meeting was planned at NLR Amsterdam the November 25th-27th. Due to delays this meeting was postponed to February 3rd-4th 2016.

Fig. 3 Lacroix high speed track.

- **Management issues**

AD/AG-55 started the January 1st of 2015. Olof Grundestam has left FOI and Torsten Berglind has replaced him as Chairman of AD/AG-55.

- **Expected results/benefits**

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

- **AD/AG-55 membership**

Member	Organisation	e-mail
L. Ruiz	Airbus Military	Luis.Ruiz@military.airbus.com
O. Estibals	Etienne Lacroix	Olivier.Estibals@etienne-lacroix.com
T. Berglind	FOI	Torsten.berglind@foi.se
C. Jeune	MBDA France	Christophe.jeune@mbda-systems.com
H. Van der Ven	NLR	Harmen.van.der.ven@nlr.nl

- **Resources**

Resources		Year			Total
		2015	2016	2017	
Person-months	Actual/ Planned	16 16	16	16	48
Other costs (in K€)	Actual/ Planned	24 24	24	24	72

- **Progress/Completion of milestones**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: Provide helicopter test case + grid + flowfield	Jul. 2015	Oct. 2015	Delivered
Task 2: Use VULCAD to compute flare section and evolution versus time	Jul. 2015	Sep. 2015	Delivered
Task 3: Grid around initial flare geometry	Aug. 2015	Jul. 2009	Delivered
Task 4: Aero data base for flare without exhaust gases	Nov. 2015	Feb. 2016	In progress
Task 5: Comparisons of chaff computations with Eul. and Lagr. Approach	Feb 2016		

Blank page

ANNEX B

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES “AVIATION SECURITY”

The Group of Responsables on Aviation Security was created during the GARTEUR Council meeting in March 2014.

This new GoR is composed of specialists from Research Establishments and Industry who have identified relevant topics to be studied in the Aviation Security area.

GoR AS pursues to do research in the Aviation Security field dealing with both military and civil R&T.

Future GoR AS projects will initiate activities in research fields regarding:

- Cybersecurity in the aviation sector,
- Chemical, Biological and Explosive (CBE) detection,
- Dazzling,
- Malevolent use of RPAS.

Blank page

TABLE OF CONTENTS

AVIATION SECURITY

OVERVIEW

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

Four research themes have been identified inside this GoR:

- **Cybersecurity**: Airspace operators (both commercial and military) wish to make use of new communications capabilities to support their missions, develop new cost efficient operations and maintenance procedures, and offer new revenue producing services. These intentions can only be realised by moving more information on and off the aircraft on a regular basis. The latest aircraft therefore rely on interconnected systems which extend off the aircraft to ground-based systems run by airlines, airports and Aviation Service providers of various types. With the continual and rapid integration of new technologies, the aviation industry keeps expanding, changing, and becoming increasingly connected.
  A forthcoming evolution towards net-centric operations of the Air Transport System will occur in the Air Traffic Management domain. The current Air Traffic Management (ATM) system was designed decades ago and is based on an operational concept and technologies which are currently reaching their limits and which will not be able to cope with the expected increase in traffic demand. The “SESAR” project (Single European Sky Air Traffic Management Research) has been set up as a development program for a new ATM system that should be able to handle a 3-fold increase in capacity, while improving the safety performance by a factor of 10, enabling a 10% reduction in the effect flights have on the environment and reducing the ATM services cost to the airspace users by at least 50%.
  Supporting the SESAR ATM system to reach its goals is a net-centric, System Wide Information Management (SWIM) environment that enables sharing essential information between all the ATM stakeholders. It will support collaborative decision making processes, using efficient end-user applications to exploit the power of shared information and will facilitate greater sharing of ATM system information, such as airport operational status, weather information, flight data, etc. In order to accommodate data sharing, SWIM will require introduction of new communication methods and technologies, including the use of commercial internet based solutions.
  The introduction of new technologies and interconnection of systems also introduce new vulnerabilities. Without the appropriate cyber-security measures in place, the air transport system may be at risk. More attention is therefore due to this complex problem.
- **CBE** (Chemical, Biological and Explosive detection): Both, the criminal and the accidental release of chemical, biological and explosive (CBE) substances represent a threat to civil security, especially at public places like airports. Laser based standoff methods offer promising possibilities for early detection and identification of hazardous CBE substances at a distance. People and luggage can be screened nearly instantaneously in a harmless way without any further disturbance of the passengers and by maintaining their integrity. In case of crisis management discrete and reliable detection methods allow for an immediate initiating of counter measures and thereby reduce the threat for people in general and first responders in particular.
- **Dazzling**: In order to protect pilots from dazzling attack, laser radiation present on an aircraft has to be detected and to be reported to the pilots to make them aware of the threat and to prepare protection measures.
- **Malevolent use of RPAS**: Remotely Piloted Aircraft Systems and/or Unmanned Aerial Systems (RPAS/UAS) are expected to become a reality in the airspace within the coming years thanks to their (imminent) integration into non segregated airspace (thanks, among others, to EU roadmap). This will open the airspace not only to security applications but also to a wide number of particular, private, leisure and commercial ones.

Many small and low cost systems (some hundred Euros) such as autonomous model aircraft or micro/mini RPAS/UAS are currently being flown in cities and/or in open environments and will exponentially thrive within this context.

So more effort in prevention has to be done. Security agencies do not count on required technology or procedures to face such a scenario. Closing the airspace is not a solution, as these devices can be deployed few hundreds of meters away from their possible targets and they fly at very low altitude. Normal radars are not able to detect such small objects. Frequency inhibitors or GPS jamming systems may not be effective enough as RPA navigation systems may be based on ground/face recognition and/or radio silence navigation mode. Only several very costly laser based systems have been developed as countermeasures to cope with similar threats (RPAS/UAS or mortar projectiles). However, these technologies are extremely expensive or their use in the urban environment would be questionable.

GOR ACTIVITIES

The main action in 2015 was to produce a White paper on Aviation Security proposing a research programme in this domain. This white paper was presented to the European commission representatives on October 12 (DG HOME and DG MOVE). The meeting was very interesting and showed that security topics are scattered in several different European initiatives. AS-GoR could be a good place to make links between these different initiatives.
The white paper was also distributed to institutions and industrial companies. It raised a lot of interest and allowed to identify interested industrial partners that are potential IPoC for the GoR.

Two GoR meetings also took place in 2015 in February and October.

Four Exploratory Groups are under consideration inside the GoR:

- AS/EG-1 (Cybersecurity): Towards an Information Security Management System for the aviation sector;
- AS/EG-2 (CBE): Enhancing airport security against CBE threats;
- AS/EG-3 (Dazzling): Detection of threatening laser radiation on aircraft or helicopters for future protection of pilots;
- AS/EG-4 (RPAS): Analysis of new threats posed by malevolent use of Unmanned Aerial Systems (UAS) and/or Remote Piloted Aircraft Systems (RPAS). Threat mapping.

The description of these four Exploratory Groups is given below.

AS/EG-1: TOWARDS AN INFORMATION SECURITY MANAGEMENT SYSTEM FOR THE AVIATION SECTOR

Task 1
The ability to assess, manage, reduce, mitigate and accept risk is paramount for an effective protection of the air transport system against cybersecurity threats and incidents. A “cyber resilient” air transport system will therefore require the establishment, adaption and implementation of a standardized aviation Information Security Management System (ISMS). An ISMS can be defined as a systematic approach to managing sensitive information so that it remains secure. It includes people, processes and IT systems by applying a risk management process. GARTEUR could contribute to the definition of (parts of) such an ISMS for the aviation sector, focusing on understanding risk as first step.

Proposed tasks for GARTEUR include:

- Definition of key assets/systems/services in the Air Transport System to protect;
- Identification of vulnerabilities that can be exploited by cyber threats;
- Definition of aviation specific cyber-threat scenario’s;
- Risk assessment: Specification of tools (such as assessment methodology and metrics) to systematically and dynamically assess the impact of threat scenario’s.

Task 2: Research on aeronautical information systems assurance that would contribute to airworthiness certification
Risks are increased by the increased use of internet technologies and COTS systems both ‘on’ and ‘off’ the aircraft. The rule-making and regulatory bodies are struggling to provide the certification criteria, methods and toolsets which will be required to substantiate the airworthiness assurance, i.e. safety, related to the new cyber security dimension. This applies equally to the manufacture, operation and maintenance of the new aircraft and new ATM systems.

Proposed tasks for GARTEUR include:

- Aviation certification authorities will have to deal with cyber-security in the future. System assurance techniques that usually focus on safety need to be extended/changed in order to deal with cyber-threats.

Expected impact/Justification:

- The introduction of new communication methods and technologies in the air transport system also introduces new cyber security vulnerabilities. These vulnerabilities have the potential to jeopardise civil aviation safety and efficiency and therefore need to be identified and addressed.
- Understanding the (cyber) environment the Air Transport System is operating in, the cyber threat and associated risks is a prerequisite for defining procedures and technological measures to prevent, detect and recover from cyber attacks.

AS/EG-2: ENHANCING AIRPORT SECURITY AGAINST CBE THREATS

Description of the task:

- Fast and safe screening of passengers and luggage at a distance by optical methods;
- Integration in existing security and luggage sections.

Expected impact/Justification:

- Protection of citizens in airports and aircrafts from CBE exposures;
- Filling the gap of B detection;
- No additional time delay for passengers due to the additional inspection;
- Maintenance of the integrity for persons and freight;
- Further application of the system at public events.

AS/EG-3: DETECTION OF THREATENING LASER RADIATION ON AIRCRAFT OR HELICOPTERS FOR FUTURE PROTECTION OF PILOTS

Description:

- Comparison of solutions of detection of the threats: detection from the aircraft or detection from the ground → Assessment → Scenarios and technological impact → Perspectives;
- Localisation of the threat.

Expected impact/Justification:

- Detection is the first step for this topic and is required for protection.
- Civil and military interest.
- Perspectives → Proposals for protection.
- No solution at present.

AS/EG-4: ANALYSIS OF NEW THREATS POSED BY MALEVOLENT USE OF UNMANNED AERIAL SYSTEMS (UAS) AND/OR REMOTE PILOTED AIRCRAFT SYSTEMS (RPAS). THREAT MAPPING.

Description:

The research areas under the scope of this topic will mainly cover the scenario analysis. It is intended to map the different occasions, physical layouts and/or opportunities in which this threat may occur. It is intended to:

a. Identify situations, assets or terrorist objectives vulnerable to this threat:
    - General assets: critical infrastructures, power plants, airports, official buildings, industries;
    - Public mass events;
    - VIP events protection;
    - Mobile targets: airplanes, trains, vessels;

b. Identify the possible innovative means for RPAS/UAS guidance and target tracking: automatic optical reconnaissance systems / GPS / ADS-B / acoustic / Electromagnetic signal recognisers / etc…
c. RPAS high-jacking. Dealing with the very specific topics of GPS jamming and spoofing, D/L security and RPS security. This is related to cybersecurity.

Expected impact/Justification:
- The potential for increasing the authorities' awareness and preparedness to face this new issue, bringing together mutual benefit across industry, academia and end users.
- The value for a future system prototype/ industrial development in terms of product implementation after the project and participation of SMEs.
- The promotion of standardization (hybrid or not) and interoperability features, through the contribution of standardization bodies.
- The capacity to increase social acceptance of the use of RPAS. The proposal will address the Safety of Life of citizens, and will have a positive impact on the perception of threats and the measures taken to address them by authorities.
- The development of solutions at different levels:
    - At technology level, by covering previous technologies for detection and threat assessment and new countermeasures techniques;
    - Operational and procedural level;
    - Potential for policy and standards' recommendations.

Ethical issues arising from the misuse of the developed research should be considered related to its malevolent use with unlawful purposes by criminals and/or for privacy interventions.
End users of the results would be law enforcement authorities and private sector able in prototyping such a pre-commercial systems.

6 years rolling Plan for AS/EGs

No	Theme	Topic	2012	2013	2014	2015	2016	2017
AS/EG-1	Cybersecurity	- Towards an Information Security Management System for the aviation sector			⬜🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	
AS/EG-2	CBE	- Enhancing airport security against CBE threat			⬜🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	
AS/EG-3	Dazzling	- Detection of threatening laser radiation on aircraft or helicopters for future protection of pilots			⬜🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	
AS/EG-4	Malevolent use of RPAS	- Analysis of new threats posed by malevolent use of Unmanned Aerial Systems (UAS) and/or Remote Piloted Aircraft Systems (RPAS) - Threat mapping			⬜🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	

🟩 **Active** 🟥 **Closed**
🟩 **Extended** 🟨 **Inactive**

FUTURE PLANS

A first objective in 2016 is to include industrial partners in the GoR. This addition should help the GoR focus on specific research themes and propose consortia for collaborative research projects.

In 2016 the first meeting will take place in January. The second meeting involving industrial partners will take place in April.

Virginie Wiels
Chairman (2014-2016)
Group of Responsables Aviation Security

GOR MEMBERSHIP

Chairman			
Ms. Virginie Wiels	ONERA	France	Virginie.Wiels@onera.fr

Vice-Chairman			
Mr. Ingmar Ehrenpfordt	DLR	Germany	Ingmar.Ehrenpfordt@dlr.de

Members			
Mr. Bernd Eberle	Fraunhofer	Germany	Bernd.Eberle@iosb.fraunhofer.de
Mr. Anders Eriksson	FOI	Sweden	e.Anders.Eriksson@foi.se
Mr. Francisco Munoz Sanz	INTA	Spain	mugnozsf@inta.es
Ms. Angela Vozella	CIRA	Italy	A.Vozella@cira.it
Mr. René Wiegers	NLR	Netherlands	Rene.Wiegers@nlr.nl

ANNEX C

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.

Blank page

TABLE OF CONTENTS

FLIGHT MECHANICS, SYSTEMS AND INTEGRATION

GoR-FM OVERVIEW

GOR ACTIVITIES

The FM GoR faced a few changes in membership in 2015. Several members are facing significant budget reductions, preventing new ideas to grow and Exploratory Groups to transition to Action Groups. GoR management has been active. Despite, existing EGs did not transition into AGs, and new ideas did not transition into EGs.

Two Exploratory Groups have been identified in 2015, but not active:

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

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

FM/EG-29 showed little progress in 2015. The development of a pilot paper was agreed but not completed in 2015.

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

In 2015, there were no Action Groups active.

MANAGEMENT ISSUES

The GoR met on two occasions during 2015, with good attendance at each meeting. Existing EGs were discussed, as well as ideas for new EGs. Moreover, FM GoR identified and agreed to have a close look at Horizon 2020 and other funding opportunities for (new) activities as defined within FM GoR. Topics from unsuccessful bids are being considered for GARTEUR collaboration (since these are already considered a priority for nations).

Participation in the FM GoR by industry and research organizations was rather stable in 2015. One industry partner had difficulties participating to FM GoR meetings.

FUTURE PLANS

During 2016 the GoR will continue efforts to establish new EGs and transition EGs into AGs.

The FM GoR will continue to explore new ideas and funding mechanisms for the new ideas, within and outside GARTEUR context.

3-5 YEAR ROLLING PLAN

Time-Schedule

FM GoR Research Objectives	Subjects	CAT	2011	2012	2013	2014	2015	2016
B	Towards greater Autonomy in Multiple Unmanned Air Vehicles	FM/AG-18	🟩 🟩	🟩 🟩	🟩 🟩	AG Finished		
A	Flexible Aircraft Modelling Methodologies	FM/AG-19	🟩 🟩	🟩 🟩	🟩	AG Cancelled		
A	Fault Tolerant Integrated Aircraft Management System	PP	▩	No EG, Cancelled				
A	Non-linear control benchmark	EG28		🟨	🟨 🟨	🟨 🟨		🟧
A	Trajectory V&V Methods	EG29			🟧	🟨 🟨		
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 refueling		FP7 Project RECREATE					
C	Pilot Wearable Avionics	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 2015:
- 103rd GoR(FM) meeting at INTA, Madrid, Spain, 9+10 March 2015;
- 104th GoR(FM) meeting at FOI, Stockholm, Sweden, 13 October 2015.

Six national representatives and IPOCs attended each of the meetings during 2015 to monitor the activities of the EGs and to discuss new ideas and pilot papers. The estimated effort associated with these activities amounts to 1 man-month (20 man-days) in total and the associated travel and subsistence costs are roughly 10 k€.

The following meetings are planned for 2016:
- 105th GoR(FM) meeting at NLR, Amsterdam, The Netherlands, 5 April 2016;
- 106th GoR(FM) meeting TBD.

Rob Ruigrok
Chairman (March 2015 - March 2017)
Group of Responsables
Flight Mechanics, Systems and Integration

GOR MEMBERSHIP

2015 membership of the Group of Responsables Flight Mechanics, Systems and Integration

Chairman			
Mr. Rob Ruigrok	NLR	The Netherlands	ruigrok@nlr.nl

Vice-Chairman			
Mr. Martin Hagström	FOI	Sweden	martin.hagstrom@foi.es

Members			
Mr. Leopoldo Verde	CIRA	Italy	l.verde@cira.it
Mr. Emmanuel Cortet	Airbus	France	Emmanuel.CORTET@airbus.com
Mr. Francisco Muñoz Sanz (resigned during 2015)	INTA	Spain	mugnozsf@inta.es
Mr. Bernd Korn	DLR	Germany	Bernd.Korn@dlr.de
Mr. Philippe Mouyon	ONERA	France	philippe.mouyon@onera.fr

Industrial Points of Contact			
Mr. Laurent Goerig	Dassault	France	laurent.goerig@dassault-aviation.com
Mr. Francisco Asensio	Airbus Military	Spain	Francisco.Asensio@military.airbus.com
Mr. Fredrik Karlsson (resigned during 2015)	SAAB	Sweden	Fredrik.Karlsson@saab.se
Mr. Martin Hanel	EADS	Germany	Martin.Hanel@cassidian.com

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action Groups (AG)

None.

Exploratory Groups (EG)

Two Exploratory Groups have been under discussion in 2015:

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

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

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

FUTURE TOPICS

One pilot paper was agreed on: Pilot Wearable Avionics.

TABLE OF ACTION GROUPS AND EXPLORATORY GROUPS

Subjects	ST	2010	2011	2012	2013	2014	2015	2016
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	🟩	🟩	🟩	🟩🟥			
FM/AG-19 Flexible Aircraft Modelling Methodologies	AG	🟩	🟩🟨	🟨	🟨🟥			
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
🟨 Non-active
🟥 Closed

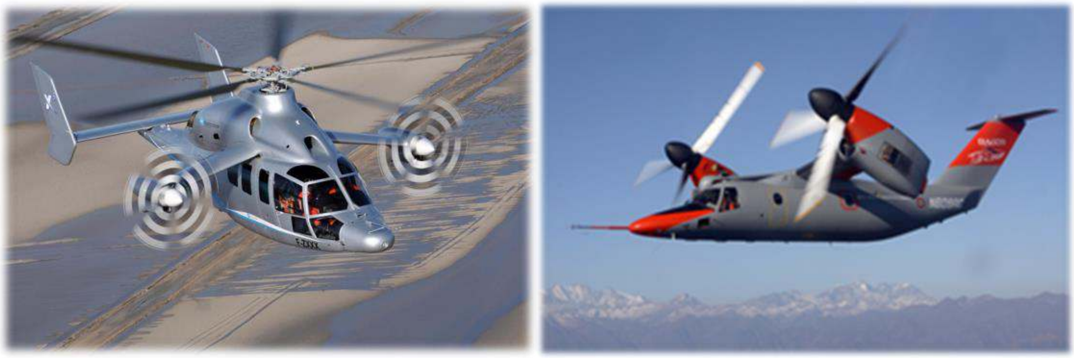
Status December 2015

ACTION GROUP REPORTS

No FM Action Groups were active in 2015.

ANNEX D

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 numerical simulation using 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, aeroelasticity including stability, structural dynamics and vibration, flight mechanics, control and handling qualities, vehicle design synthesis and optimisation, crew station and human factors, internal and external acoustics and environmental impact, flight testing, and simulation techniques and facilities for ground-based testing and simulation specific to rotorcraft.

A characteristic of helicopter 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-HC OVERVIEW

GOR ACTIVITIES

The members of GoR for Helicopters represent the major national research centres and helicopter manufacturers in the European Union involved in civil and military rotorcraft related research. Currently, it is noticeable that the two European helicopter manufacturers 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 ideas which may be mature for collaboration. The GoR also considers other collaborative initiatives within Europe, bringing mutual understanding and co-ordination and hence contributing to best use of scarce resources. For instance, the GoR is maintaining an awareness of the range of EU Technology Programmes.

MANAGEMENT ISSUES

The chairmanship in 2015 was held by Mark White (University of Liverpool). Vice Chairman is Philippe Beaumier (ONERA) who has replaced Blanche Demaret (ONERA) and will take the chairmanship in 2017. Odile Parnet replaced Elio Zoppitelli as the Airbus Helicopters France GoR member in 2015.

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

In the Clean Sky Joint Technology Initiative and specially for the Green Rotorcraft ITD, the GoR members are active. 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:

- 71st GoR Meeting: 11-12 February '15, TuDelft, Delft, The Netherlands
- 72nd GoR Meeting: 27-28 October '15, The University of Liverpool, Liverpool, UK

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 H2020. These meetings were also used to discuss about Clean Sky JTI activities, 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 2015 the activities in the HC-AGs were at a high level. 2015 started with six active Action Groups and one running Exploratory Group resulting; at the end of the year all these Groups remained active.

FUTURE TOPICS

The following topics are being considered for future Exploratory Groups, together with general Safety related problems. The Clean Sky 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. Furthermore, the assessment and validation of CFD methods for the analysis of full rotorcraft configuration is considered a valuable topic for future activities (also with respect to the Clean Sky 2 Fast Rotorcraft IADP Programme activities). With this regards, in fact, there are a number of experimental aerodynamic databases, developed in past EU funded projects that should be still completely exploited.

Topics that are under consideration include:

- Safety (Crash, Hums, Crew Workload, all weather operations);
- Noise external (flight procedures, noise pollution, psycho-acoustic effects) ;
- Low order models for new rotorcraft configurations to examine aerodynamic/rotor interactions;
- Man-machine interface requirements for cockpit operations;
- Sand/dust engine protection.

ACTIVE HC/AGS

HC/AG-19 “Methods for Improvement of Structural Dynamic Finite Element Models Using In-Flight Test Data” was started in May 2010 for a duration of 3 years. This AG was extended up to the end of 2015, and the final report is under preparation.

HC/AG-20 “Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction” started in October 2012. Activities focused on the experimental test activities and comparison and validation of numerical methods proposed by partners.

HC/AG-21 “Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity” has been launched April 2013. Main goal of the project is the development of new simulation assessment criteria for both open loop predictive fidelity and closed-loop perceived fidelity.

HC/AG-22 “Forces on Obstacles in Rotor Wake” was launched in November 2014. The objective is to investigate, both numerically and experimentally, the interactional process between a helicopter rotor wake and the surrounding obstacles and the evaluation of the forces acting on these obstacles.

HC/AG-23 “Wind turbine wake and helicopter operations” was launched in November 2014. The objectives are the analysis of the behaviour of helicopters in a wind turbine wake, the identification of the safety hazards and the definition of measures to mitigate identified safety issues.

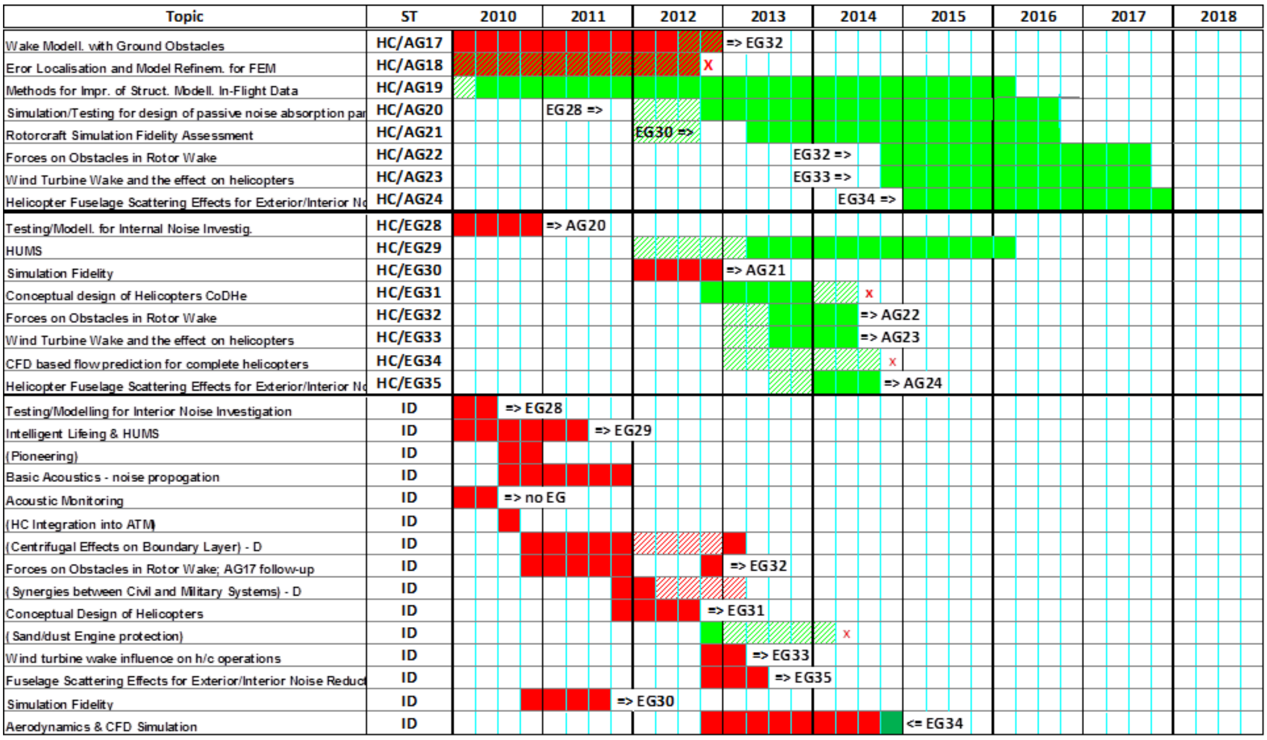
HC/AG-24 “Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction” was launched in January 2015, with an initial plan to run for two years with an option to run for a third year. The main objective is to examine rotor noise propagation in the presence of a fuselage. The activity will establish an experimental acoustic database and prediction design tools for main and tail rotor noise in the influence of a fuselage and will also include main/tail rotor interactions.

RUNNING EXPLORATORY GROUPS

HC/EG-29 “Intelligent Lifeing & HUMS” was launched in 2011, and started in April 2013. The exploratory group is expected to conclude its activities early 2016.

GENERATING NEW TOPICS FOR COMMON STUDIES

The 3–5 year planning will continue to be implemented and was presented in more detail to the Council in the Autumn 2015 meeting in Seville. 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	2010	2011	2012	2013	2014	2015	2016	2017	2018
Wake Modell. with Ground Obstacles	HC/AG17				=> EG32					
Eror Localisation and Model Refinem. for FEM	HC/AG18			X						
Methods for Impr. of Struct. Modell. In-Flight Data	HC/AG19									
Simulation/Testing for design of passive noise absorption par	HC/AG20		EG28 =>							
Rotorcraft Simulation Fidelity Assessment	HC/AG21			EG30 =>						
Forces on Obstacles in Rotor Wake	HC/AG22				EG32 =>					
Wind Turbine Wake and the effect on helicopters	HC/AG23				EG33 =>					
Helicopter Fuselage Scattering Effects for Exterior/Interior No	HC/AG24					EG34 =>				
Testing/Modell. for Internal Noise Investig.	HC/EG28		=> AG20							
HUMS	HC/EG29									
Simulation Fidelity	HC/EG30				=> AG21					
Conceptual design of Helicopters CoDHe	HC/EG31					x				
Forces on Obstacles in Rotor Wake	HC/EG32					=> AG22				
Wind Turbine Wake and the effect on helicopters	HC/EG33					=> AG23				
CFD based flow prediction for complete helicopters	HC/EG34					x				
Helicopter Fuselage Scattering Effects for Exterior/Interior No	HC/EG35					=> AG24				
Testing/Modelling for Interior Noise Investigation	ID	=> EG28								
Intelligent Lifeing & HUMS	ID		=> EG29							
(Pioneering)	ID									
Basic Acoustics - noise propogation	ID									
Acoustic Monitoring	ID	=> no EG								
(HC Integration into ATM)	ID									
(Centrifugal Effects on Boundary Layer) - D	ID									
Forces on Obstacles in Rotor Wake; AG17 follow-up	ID				=> EG32					
(Synergies between Civil and Military Systems) - D	ID									
Conceptual Design of Helicopters	ID			=> EG31						
(Sand/dust Engine protection)	ID					x				
Wind turbine wake influence on h/c operations	ID				=> EG33					
Fuselage Scattering Effects for Exterior/Interior Noise Reduct	ID				=> EG35					
Simulation Fidelity	ID		=> EG30							
Aerodynamics & CFD Simulation	ID						<= EG34			

( ): 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 follow up of the programme, the Clean Sky 2 JTI, started in 2014. The GoR members, are associates (research centres) and leaders (industry) in the CS1 initiative while in CS2 the industrial members are leaders and the research institutions are proposing to become partners.

REPORTS ISSUED

In 2015, no final reports were issued.

FORESEEN GOR ACTIVITY

Two meetings are planned for 2016; the first one on 24-25 February at Airbus Helicopters, Marignane, France and the second one on 21-22 September at DLR Braunschweig, Germany.

Mark White
Chairman (2015-2016)
Group of Responsables Helicopters

GOR MEMBERSHIP

Membership of the Group of Responsables Helicopters (end 2015)

Chairman			
Mark White	Uni of Liverpool	United Kingdom	mdw@liverpool.ac.uk
Vice-Chairman			
Philippe Beaumier	ONERA	France	beaumier@onera.fr
Members			
Odile Parnet	Airbus Helicopters	France	odile.parnet@airbus.com
Antonio Antifora	AgustaWestland	Italy	antonio.antifora@agustawestland.com
Philipp Krämer	Airbus Helicopters	Germany	Philipp.Kraemer@eurocopter.com
Klausdieter Pahlke	DLR	Germany	klausdieter.pahlke@dlr.de
Joost Hakkaart	NLR	The Netherlands	Joost.hakkaart@nlr.nl
Lorenzo Notarnicola	CIRA	Italy	l.notarnicola@cira.it
Observer			
Richard Markiewicz	Dstl	United Kingdom	rhmarkiewicz@mail.dstl.gov.uk

HC-GoR visiting the Virtual Engineering Centre at the University of Liverpool, during the 72nd GoR meeting (27-28 October 2015):
Joost Hakkaart, Lorenzo Notarnicola, Mark White, Blanche Demaret, Philipp Krämer, Klausdieter Pahlke, Philippe Beaumier

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action groups (AG)

The following Action Groups were active throughout 2015:

HC/AG-19	"Methods for Improvement of Structural Dynamic Finite Element Models Using In-Flight Test Data" has been started May 2010 for a 3 years duration. This AG was extended up to the end of 2015, and the final report is under preparation.
HC/AG-20	"Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction" started in October 2012. The activities in 2014 were focused on the experimental test activities and comparison and validation of numerical methods proposed by partners.
HC/AG-21	"Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity" has been launched April 2013. Main goal of the project is the development of new simulation assessment criteria for both open loop predictive fidelity and closed-loop perceived fidelity.
HC/AG-22	"Forces on Obstacles in Rotor Wake" has been launched in November 2014. The objective is to investigate, both numerically and experimentally, the interactional process between a helicopter rotor wake and the surrounding obstacles and the evaluation of the forces acting on these obstacles.
HC/AG-23	"Wind turbine wake and helicopter operations" has been launched in November 2014. The objectives are the analysis of the behaviour of helicopters in a wind turbine wake, the identification of the safety hazards and the definition of measures to mitigate identified safety issues. The University of Glasgow has joined this AG due to the movement of one of the AG members, Professor G Barakos, to that University.
HC/AG-24	"Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction" was launched in January 2015, with an initial plan to run for two years with an option to run for a third year. The main objective is to examine rotor noise propagation in the presence of a fuselage. The activity will establish an experimental acoustic database and prediction design tools for main and tail rotor noise in the influence of a fuselage and will also include main/tail rotor interactions.

Exploratory groups (EG)

HC/EG-29 "Intelligent Lifeing & HUMS" was launched in 2011, and started in April 2013. The exploratory group is expected to conclude its activities early 2016.

TABLE OF PARTICIPATING ORGANISATIONS

	HC/AG and HC/EG numbers						
	AG19	AG20	AG21	AG22	AG23	AG24	EG29
Research Establishments							
ONERA		■	□	□	□	□	□
DLR		□	□	□	□	■	□
CIRA		□		■	□	□	
NLR	■	□	□	□	■	□	□
Dstl							
CNR-INSEAN						□	
Industry							
Airbus Helicopters, France						□	
Airbus Helicopters, Germany						□	□
Finmeccanica Helicopters	□		□				
Thales			□				
Siemens PLM Software	□						
CAE (UK)			□				
ZF Luftfahrttechnik GmbH (D)							□
IMA Dresden (D)							□
MICROFLOWN		□					
Academic Institutes							
University of Liverpool (UK)			■	□	□		
University of Cranfield (UK)							□
Imperial College, London (UK)							
University of Manchester (UK)							
University of Glasgow (UK)				□	□		
University of Bristol (UK)	□						
University of Brunel (UK)	□						
TU Delft (NL)			□	□	□		
University of Twente (NL)							
University of Munich (D)					□		■
University of Roma La Sapienza (IT)	□						
University of Roma 3 (IT)						□	
Politecnico di Milano (IT)		□		□		□	
Politecnico di Torino (IT)							
National Technical Univ. of Athens				□	□		

∟ = Member ■ = Chair

The large number of UK Universities involved in AGs is noticeable.

TOTAL YEARLY COSTS OF HC/AG RESEARCH PROGRAMMES

	2010	2011	2012	2013	2014	2015	2016	Total
Person-month	35	27	14	36.5	34.5	99	65	311
Other costs (k€)	31	30	7	13	38	139	81	339

ACTION GROUP REPORTS

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 Agusta Westland Ltd (with NLR assistance) on 5-7 March 2012.

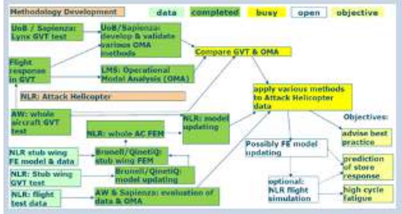
The department of mechanical and aerospace engineering of "La Sapienza" University has a model helicopter at it disposal. Flight tests have been conducted with this helicopter. A finite element model is available. Ground vibration tests have been conducted. The advantage of this helicopter is that it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

The third data set is based on LMS flight test data for Polish Helicopter

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 the related FE models. For the attack helicopter, model mass and construction of the complete helicopter model is finished. The GVT on a Dutch Attack helicopter was 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**

Two sources of flight test data were 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 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. The advantage of this helicopter is that it is always available for additional ground vibration and flight tests.

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 completed 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. The model was tuned with the GVT results.

The available experimental flight test data were processed and transition to hover flight data was performed by AW and provided good results.

Work on methods development at the universities has been completed. Reporting will be completed early 2016.

• 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. There were two technical meetings in 2012 (NLR in Amsterdam and La Sapienza in Rome) and one meeting in 2013. Final meeting planned for end 2014.

• 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

Member	Organisation	e-mail
Giuliano Cappotelli	Sapienza Uni Rome	chiara.grappasonni@uniroma1.it
Johnathan Cooper	Bristol Uni	J.E.Cooper@liverpool.ac.uk
David Ewins	Bristol Uni	d.ewins@bristol.ac.uk
Cristinel Mares	Brunell Uni	Cristinel.Mares@brunel.ac.uk
Simone Manzato	LMS	simone.manzato@lmsintl.com
Hans v Tongeren *c*	NLR	Hans.van.tongeren@nlr.nl
Trevor Walton	Agusta Westland Ltd	Trevor.Walton@agustawestland.com

• Resources

Resources		Year						Total
		08-09	2010	2011	2012	2013	2014	
Person-months	Actual/ Planned	A5 P6	A16 P6	A7 P18	A12 P10	A3 P8	A10	A53 P48
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	2014
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	2014
Task 4: Vibration prediction based on hub load predictions for the flight test conditions	2011	2013	2014
Task 5: Reporting	2011	2013	2016

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

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

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

Background

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

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

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

Programme/Objectives

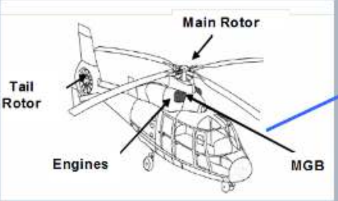
Objectives

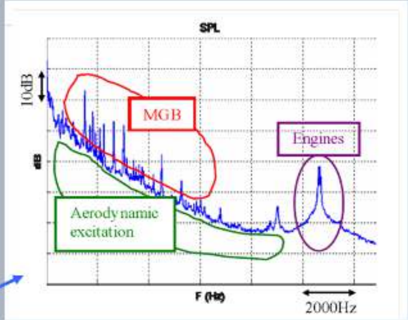
HC/EG-28, about internal noise and associated passive acoustic solutions (soundproofing, e.g. 1cm-thick trim panels designed for optimizing the absorption or the transmission loss), development of a vibro-acoustic model of the cabin (SEA coupled with FEM), human factors (subjective annoyance, speech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

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

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

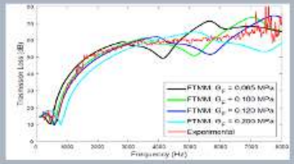
- applying different types of simulation methods to design and optimize composite trim panels according to common acoustic cost functions, and to validate numerical approaches by tests in laboratory
- applying different types of experimental techniques to characterize composite trim panel acoustic radiating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





Results

The AG results in a benchmark of the appropriateness of tools for complex configurations (multiple anisotropic layers with various mechanical characteristics) and applies complementary passive and active concepts for composite trim panels.



Panel 2: Simulations Polimi / expérimentation Onera

Members of the HC/AG-20 group are:

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

GARTEUR Responsable:

P. Beaumier	ONERA

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

HC/AG-20 CABIN INTERNAL NOISE: SIMULATION METHODS AND EXPERIMENTAL METHODS FOR NEW SOLUTIONS FOR INTERNAL

Monitoring Responsable:	P. Beaumier 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.

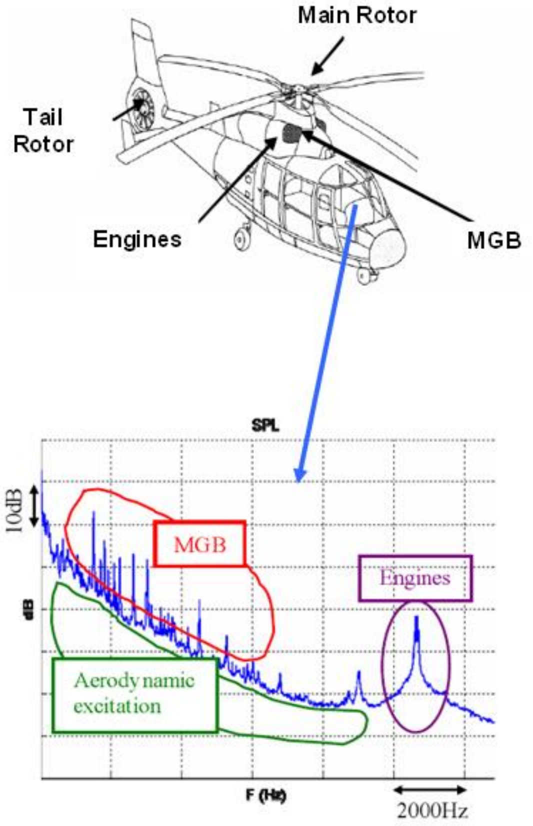
The EG28 conclusions listed the following needs:

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 of AG20 in 2015 explored 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.

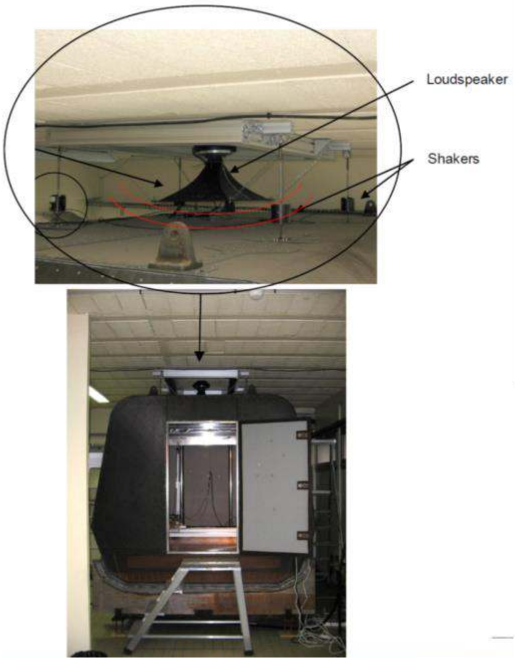


- **Management issues**

In 2015 there was one technical progress web meeting on 15th July.

- **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). A workshop on this AG is planned for ERF 2016.



- **HC/AG-20 membership**

Member	Organisation	e-mail
Andrea Grosso	MICROFLOWN	grosso@microflown.com
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
Gian Luca Ghiringhelli	PoliMI	gianluca.ghiringhelli@polimi.it

- **Resources**

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**

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	
2.3: Analysis and comparison of results	T0+36	2015	

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

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

Background

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

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

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

Programme/Objectives

Objectives

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

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

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

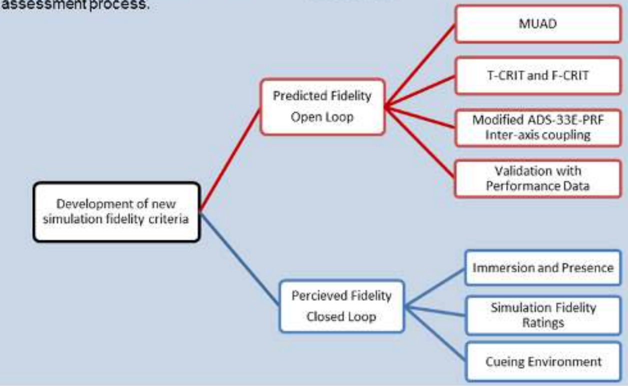
The work programme has two strands:

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

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

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

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



Development of new simulation fidelity criteria

Predicted Fidelity Open Loop
- MUAD
- T-CRIT and F-CRIT
- Modified ADS-33E-PRF Inter-axis coupling
- Validation with Performance Data

Percieved Fidelity Closed Loop
- Immersion and Presence
- Simulation Fidelity Ratings
- Cueing Environment

Results

A series of simulation trials have been completed to look at the effect of motion cueing on pilot's subjective and objective measures of task performance when flying Mission Task Elements (example task shown below)

The test showed that the Simulation Fidelity Rating (SFR) Scale is a useful tool for measuring fidelity in the absence of objective tests. Data analysis is ongoing to attempt to determine a correlation between subjective ratings (SFRs) and objective measures of pilot adaptation e.g. control frequency analysis

Immersion questionnaires have been developed to subjectively assess the fidelity experienced by users are currently being used in simulation fidelity trials..

Precision Hover MTE: Example test course used in the piloted simulation trials

Members of the HC/AG-21 group are:

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

GARTEUR Responsable:

J. Haakkart	NLR

HC/AG-21 "ROTORCRAFT SIMULATION FIDELITY ASSESSMENT: PREDICTED AND PERCEIVED MEASURES OF FIDELITY"

Monitoring Responsable: J. Hakkaart
NLR

Chairman: Dr. M. White
UoL

- **Objectives**

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..

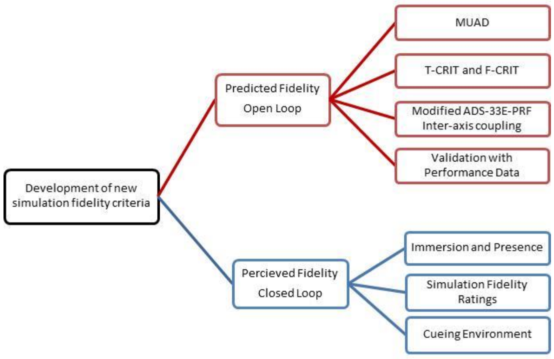
Specific areas of interest for helicopter flight simulation device fidelity include:

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

- **Activities**

The activities in the new AG21 constitute the conclusion of EG30. The work programme has two strands within the AG activity:

1. Predicted Fidelity assessment using off-line flight models with a range of standard control inputs
2. Perceived Fidelity assessment using ground-based pilot-in the-loop simulations at partners' own facilities.



In the predicted fidelity activity, existing models (and flight test data where possible) will be used to provide the framework for the evaluation of the different validation techniques. Activity 2 focussed on perceived fidelity assessment in examining the effect of the cueing and virtual environment on subjective evaluation of fidelity A series of flight simulation trials have been completed to examine the effect of motion cueing on task performance and analysis of the results is ongoing.

- **Management issues**

The Chair was able to organise the kick-off meeting on April 23rd 2013. Staffing issues were a problem in 2015 leading to slight delays in the planned activities. Two meetings were held in 2015; teleconference meeting on a January 29th and a progress meeting on 21-22 July.

- **Results/benefits**

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.

HC/AG-21 membership

Member	Organisation	e-mail
Mark White	UoL	mdw@liv.ac.uk
G. Meyer	UoL	georg@liv.ac.uk
Marilena Pavel	TuD	M.D.Pavel@tudelft.nl
Olaf Stroosma	TuD	O.Stroosma@tudelft.nl
Jasper van der Vorst	NLR	Jasper.van.der.Vorst@nlr.nl
Carsten Seehoff	DLR	Carsten.Seehof@dlr.de
Fabrice Cuzieux	ONERA	Fabrice.Cuzieux@onera.fr
Bruno Berberian	ONERA	Bruno.Berberian@onera.fr
Daniel Spira	CAE	daniel.spira@cae.com
Sylvain Richard	Thales	sylvain.richard@thalesgroup.com
Claudio Emmanuele	Agusta Westland (Training Academy)	Claudio.Emmanuele@agustawestland.com

Resources

Preson month resources were confirmed during the kick-off meeting and have been split tentatively in years. Other costs will be assessed at the next progress meeting.

Resources		Year			Total
		2013	2014	2015	
Person-months	Actual/ Planned	A15.5 P18	A14.5 P30	A15 P18	A45 P66
Other costs (in K€)	Actual/ Planned		A10 P10	A10 P5	A20

Progress/Completion of milestone

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP 1 Simulation Models and Mission Task Elements (MTE) Definition	2013	2014	End of 2014
WP 2 Simulator cueing – motion fidelity metrics	2015	2016	
WP3 Flight Loop Fidelity	2015	2016	
WP 4 Immersion and Presence	2015	2016	
WP 5 Perceived Fidelity Assessment	2015	2016	

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

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

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

Background

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

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

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

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

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

Programme/Objectives

Objectives

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

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

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

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

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

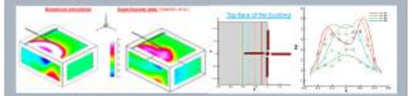
The work programme is structured in four work packages:

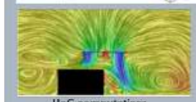
- WP0 – Management & Dissemination: is aimed at the fulfilment of all the obligations concerning the project management and the dissemination of the results;
- WP1 – Preliminary Computations & Code Enhancements: deals with a preparation phase during which partners are involved in literature review and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

Results

The action group started the activities in November 2014.

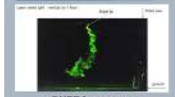
Improvements of the computational codes are on-going at CIRA, DLR and NTUA. Univ. Glasgow has performed first calculations in hover conditions providing an overall good correlation with PoliMi existing database of a rotor hovering in proximity to a cubic obstacle.



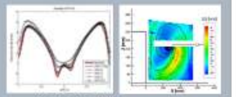


UoG computations

The Univ. Glasgow and ONERA wind tunnel test campaigns have been almost completed. The PoliMi wind tunnel test campaign is on-going, while the CIRA wind tunnel test campaign is in the preparation phase.



ONERA pressure measurements & visualizations



UoG LDA & SPIV measurements

Members of the HC/AG-22 group are:

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

GARTEUR Responsable:

K. Pahlke	DLR

CIRA Centro Italiano Ricerche Aerospaziali

DLR

NLR

ONERA THE FRENCH AEROSPACE LAB

POLITECNICO MILANO

University of Glasgow

HC/AG-22 "FORCES ON OBSTACLES IN ROTOR WAKE"

Monitoring Responsable: K. Pahlke
DLR

Chairman: Mr. A.Visingardi
CIRA

- **Objectives**

Helicopters are largely employed in missions within "confined areas", regions where the flight of the helicopter is limited in some direction by terrain or by the presence of obstructions, natural or manmade. In these conditions the wake generated by the obstacle may result in: (a) high compensatory workload for the pilot and degradation of the handling qualities and performance of the aircraft; (b) unsteady forces on the structure of the surrounding obstacles.

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

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

The principal objective of HC/AG-22 is thus to investigate, both numerically and experimentally:

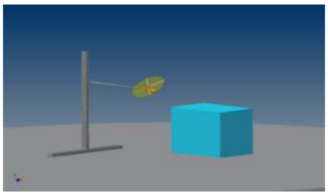
- primarily, the effects of the confined area geometry on a hovering helicopter rotor from the standpoints of both the phenomenological understanding of the interactional process and the evaluation of the forces acting on surrounding obstacles;
- secondly, the downwash and its influence on the forces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

- **Activities**

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

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

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



- **Management issues**

The kick-off meeting was held on November the 7th, 2014. During the meeting the membership, resources and work packages were discussed and confirmed. Two teleconference meetings were held in 2015 on May 29th and December 18th.

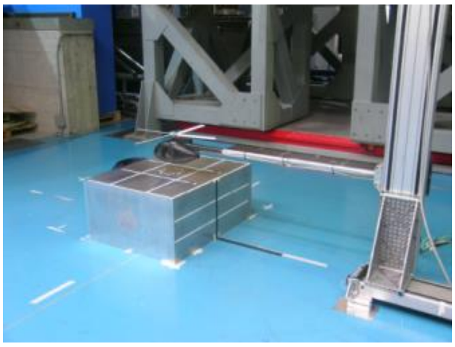
- **Results/benefits**

The action group started the activities in November 2014.

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

In 2015, CIRA, DLR, NLR and NTUA made improvements to their respective computational methodologies. UoG performed first comparisons with the existing database provided by PoliMi. ONERA and UoG performed the respective WT test campaigns. The analysis of the results is on-going. Further measurements will be performed by ONERA.

The PoliMI test campaign is on-going, while the CIRA one is in the preparation phase;



- **HC/AG-22 membership**

Member	Organisation	e-mail
A. Visingardi	CIRA	a.visingardi@cira.it
F. De Gregorio	CIRA	f.degregorio@cira.it
T. Schwarz	DLR	thorsten.schwarz@dlr.de
R. Bakker	NLR	rbakker@nlr.nl
S. Voutsinas	NTUA	spyros@fluid.mech.ntua.gr
B. Rodriguez	ONERA	benoit.rodriguez@onera.fr
G. Gibertini	Politecnico di Milano	giuseppe.gibertini@polimi.it
R. Green	Glasgow Uni.	richard.green@glasgow.ac.uk
G. Barakos	Glasgow Uni.	g.barakos@liverpool.ac.uk

- **Resources**

Resources were confirmed during the kick-off meeting.

Resources		Year			Total 15-17
		2015	2016	2017	
Person-months	Actual/ Planned	A21.7 P14.3	P18.5	P15	P47.8
Other costs (in K€)	Actual/ Planned	A33.1 P19.3	P33	P20	P72.6

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

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

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

Background

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

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

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

Programme/Objectives

Objectives

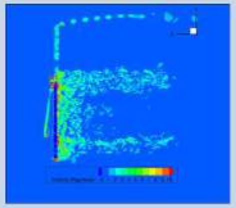
Despite the amount of literature on both wind turbine wakes and helicopter – fixed wing tip vortex encounters, not much research has been done on the interactions of wind turbine wakes and helicopter flight.
The aim of the Action Group is to set up a team of researchers from universities and research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

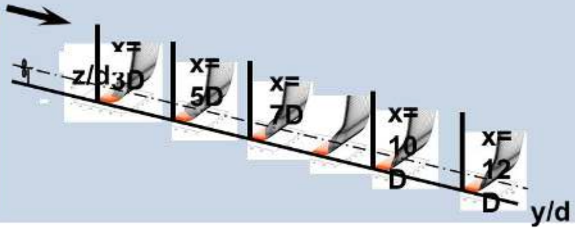
Programme

The programme consists of 5 work packages

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

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





Results

- A reference wind turbine (NREL5), a reference helicopter (BO105, and a set of test cases to be studied have been discussed and a selection has been made. The appropriate databases have been made available to the partners.
- An extensive overview of wind turbine wake characteristics, methods and tools has been produced. Analytical, computational and experimental data has been collected.
- First results of computed wind turbine wake velocity fields using a variety of CFD tools and with different methodologies.
- Preliminary computations of a helicopter - wind turbine encounter a) Interaction of helicopter and wind turbine wake and 2) the resulting track deviations when flying through a wind turbine wake
- Preparations have been made for the implementation of a wind turbine wake and a helicopter in a full-scale simulator. The need to harmonise the helicopter model characteristics will be addressed.
- Study for the definition of objective criteria to assess handling qualities in a wind turbine wake has been conducted.

Members of the HC/AG-23 group are:

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

GARTEUR Responsable:

J. Hakkaart	NLR

UNIVERSITY OF LIVERPOOL
TUDelft Delft University of Technology
TECHNISCHE UNIVERSITÄT MÜNCHEN
NLR
ONERA THE FRENCH AEROSPACE LAB
CIRA
University of Glasgow

HC/AG-23 "WIND TURBINE WAKE AND HELICOPTER OPERATIONS"

Monitoring Responsable: J. Hakkaart
NLR

Chairman: Mr. R. Bakker
NLR

- **Objectives**

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

Ultimately the likelihood of air traffic encounters with wind turbine wakes is increasing, showing the need for a more detailed study on the interactions of rotorcraft and the wind turbine wake.

Despite the amount of literature on both wind turbine wakes and helicopter – fixed wing tip vortex encounters, not much research has been done on the interactions of wind turbine wakes and helicopter flight.

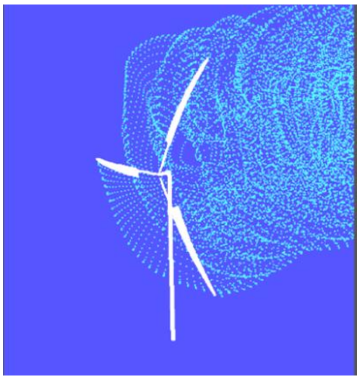
The aim of the Action Group is to set up a team of researchers from universities and research institutes to cooperate and perform the following activities:

- Perform a survey of available experimental and analytical wake data for typical wind turbines. Collect and assemble the data to produce a database of wind turbine wake properties. Identify appropriate wake characteristics with regard to the effect it has on the helicopter flight characteristics
- Define representative test cases for a wind turbine and helicopter combination. Several combinations of small/large helicopter and wind turbines, depending on available experimental data, available helicopter models, pilot-in-the-loop facilities etc. should be considered
- Perform computations and piloted simulator experiments and analyse the effects of wind turbine wake on the stability, handling qualities and safety aspects of a helicopter
- Validate the results of the computational tools and simulator trials with available experimental data.
- The group should provide recommendations for legislation and disseminate the findings to the appropriate authorities and parties concerned.

- **Activities**

The programme consists of 5 work packages

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



- **Management issues**

The kick-off meeting was held on November the 7th, 2014. During the meeting the membership, resources and work packages were discussed and confirmed. Professor Barakos has moved to the University of Glasgow and will continue his CFD contribution there. Dr White at the University of Liverpool will contribute to the flight simulation activities. Two teleconferences were held on 21st May and 9th December.

- **Results/benefits**

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

The first deliverable; a technical report on wind turbine wake characteristics is in progress and the NREL5 model selected as reference wind turbine for the AG23 activities. Initial CFD work and wind tunnel test preparation has commenced. The Bo105 helicopter has been chosen as the reference helicopter and a model validation exercise has been planned.

- **HC/AG-23 membership**

Member	Organisation	e-mail
Richard Bakker	NLR	rbakker@nlr.nl
Paul Lehman	DLR	Paul.Lehmann@dlr.de
Antonio Visingardi	CIRA	a.visingardi@cira.it
Pierre-Marie Basset	ONERA	pierre-marie.basset@onera.fr
Filippo Campagnolo	TUM	filippo.campagnolo@polimi.it
Marilena Pavel	TU-Delft	M.D.Pavel@tudelft.nl
George Barakos	Glasgow Uni	George.Barakos@glasgow.ac.uk
S. Voutsinas	NTUA	spyros@fluid.mech.ntua.gr
Mark White	Liverpool Uni	mdw@liverpool.ac.uk

- **Resources**

Person month resources were confirmed during the kick-off meeting and have been split tentatively in years. Other costs will be assessed at the next progress meeting.

Resources		Year			Total 15-17
		2015	2016	2017	
Person-months	Actual/ Planned	A14 P10	P22	P18	P50
Other costs (in K€)	Actual/ Planned	A1.6	tbd	tbd	

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

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

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

Background

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

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

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

Programme/Objectives

Objectives

The present research work will address noise propagation in presence of the fuselage. The principal objective of HC-AG24 is then to promote activities to:
- establish unique quality database - for unsteady scattered acoustic pressure on the fuselage and in the far field as well as flow field, including flow refraction and convection effect;
- validated prediction design tools for main and tail rotor noise under influence of fuselage - including main/tail rotor interactions;
- proof of rotor noise reduction through adding acoustic absorbing liner on the part of fuselage.

The timescale for the project is two years during which the following topics are to be addressed:
- Investigate the capability and reliability of tools capable of predicting the effects of noise scattering problems;
- Perform computations of numerical benchmark cases and incorporation of the convective flow effects;
- Study the possibility to account for a surface impedance;
- Define representative test cases for generating a data base with a generic configuration, including sound pressure and flow field data

The work programme is structured in three work packages:

➢ WP 1: Simulation on the acoustic scattering effect

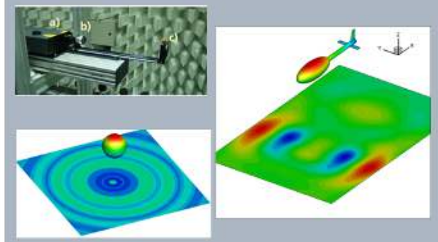
- Code adaptation & prediction
- Code validation & improvement of prediction tools
- Evaluation of noise scattering of various components using validated codes

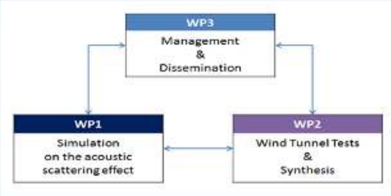
➢ WP 2: Wind Tunnel Tests & Synthesis

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

➢ WP 3: Management & Dissemination

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




WP3
Management & Dissemination

WP1
Simulation on the acoustic scattering effect

WP2
Wind Tunnel Tests & Synthesis

Results

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

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

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

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

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

GARTEUR Responsable:

K. Pahlke	DLR

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

HC/AG-24 “HELICOPTER FUSELAGE SCATTERING EFFECTS FOR EXTERIOR/INTERIOR NOISE REDUCTION”

Monitoring Responsable: **K. Pahlke**
DLR

Chairman: **J Yin**
DLR

- **Objectives**

The present research work will address rotor noise propagation in the presence of a fuselage. The focus is on the development and validation prediction methods. The present research work will also generate a unique experimental database for acoustic scattering using a generic configuration, including sound pressure data in the field as well as clearly prescribed noise sources; such a database is not currently available. The database will be used as a benchmark for code validation.

The effect of acoustic scattering is likely to be more significant for tail rotor noise because the wavelength of the tail rotor harmonics is comparable with or smaller than the characteristic dimension of the fuselage. The noise shielding and refraction effect can significantly alter the tail rotor noise directivity in the far field. Therefore the AG will give more focus on the scattering problem of the tail rotor.

For internal noise studies, the present research will also provide a reliable estimation of the acoustic pressure on the helicopter fuselage. Furthermore passive technology installed on the fuselage for nose reduction will be investigated.

- **Activities**

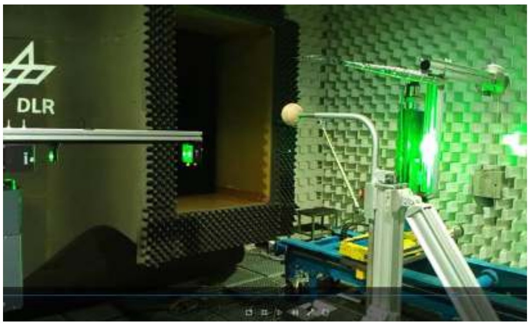
The AG consists of 3 work packages:

1: Simulation of the acoustic scattering effect
2: Wind tunnel tests and synthesis
3: Management and dissemination

To date a code to code comparison regarding a monopole scattering by sphere has been completed and distributed and the specification of the common simulation for NACA 0012 test arrangement has been issued; numerical simulations by all partners is on-going.

- **Management Issues**

The AG in envisage to run for two years with a mid-term review to enable an extension for a third year. The kick-off meeting was held at DLR Braunschweig, Germany in Jan. 2015 and the first technical review meeting was held 15-16-July, 2015, at CIRA, Napoli, Italy.



- **Results/benefits**

From a scientific point of view the main innovation of the AG comprises of:

- Unique quality database for unsteady scattered acoustic pressure measurements on the fuselage and thein the far field as including flow refraction and convection effects
- Validated prediction tools for main rotor nd tail rotor assessment in the presence of a fuselage, including main rotor/tail rotor interactions.
- Proof of rotor noise reduction through adding an acoustic aborning liner on part of the fuselage.

This AG will expand the limits of current noise prediction tools. The tools will enable the development of new helicopter designs which will exploit shielding effects and controlled surface impedance to further reduce noise emissions on the ground, reducing the environmental impact of helicopters.

- **HC/AG-24 membership**

Member	Organisation	e-mail
J. Yin (Chair)	DLR	Jianping.Yin@dlr.de
T. Schwarz	DLR	Thorsten.schwarz@dlr.de
M. Barbarino (Vice-Chair)	CIRA	m.barbarino@cira.it
H. Brouwer	NLR	Harry.Brouwer@nlr.nl
J. Kok	NLR	Johan.Kok@nlr.nl
Y. Delrieux	ONERA	Yves.Delrieux@onera.fr
F. Simon	ONERA	Frank.Simon@onera.fr
G. Reboul	ONERA	Gabriel.reboul@onera.fr
J. Bulte	ONERA	jean.bulte@onera.fr
L. Vigevano	PoliMi	Luigi.vigevano@polimi.it
G. Bernardini	Roma TRE Uni	g.bernardini@uniroma3.it
C.Testa	CNR-INSEAN	claudio.testa@cnr.it

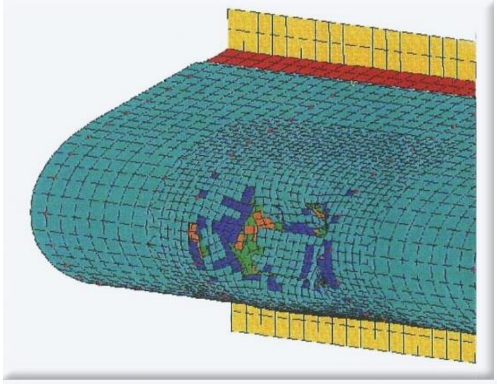
- **Resources**

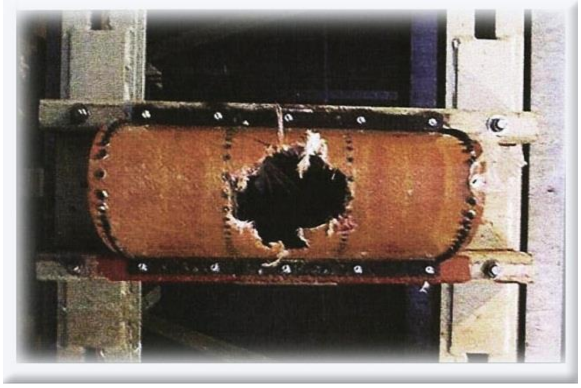
Person month resources were confirmed during the kick-off meeting and have been split tentatively in years. Other costs will be assessed at the next progress meeting.

Resources		Year			Total 15-17
		2015	2016	2017	
Person-months	Actual/ Planned	P30	P25	P22	P77
Other costs (in K€)	Actual/ Planned	P66	P48	P34	P148

ANNEX E

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 be included in improved theoretical models. Finally, the theoretical results must be verified and validated by comparison with results from suitable experiments or trials.

E-2

Blank page

TABLE OF CONTENTS

STRUCTURES AND MATERIALS

GoR-SM OVERVIEW

GOR ACTIVITIES

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

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

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.

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.

Bonded and bolted joints are among the most important structural elements in aircraft structures. Improper design of bonded and bolted joints may lead to structural problems or conservative design leading to overweight structures and high life-cycle cost. There is a need is to further develop the numerical methods to predict failure and damage in bolted and bonded joints. Experimental work to support the numerical methods and to improve measurement methods is also needed. This is addressed in a new Exploratory Group within GoR SM.

Additive Manufacturing (AM) with metals is an emerging technology that finds more and more applications in different markets such as orthopaedic implants, dentistry and high-end industry. There is also a lot of interest coming from the Aerospace industry. Metal AM technology can provide great advantages with respect to conventional metal working techniques, such as significantly lower waste of materials, a larger freedom of design, high potential for weight reduction and the possibility to integrate of functionality. Specific design guide lines must be taken into account and currently available CAD design tools are considered inadequate for designing for AM. Currently it still is difficult for AM technologies to compete with traditional techniques on reliability and reproducibility because the quality of final products depends very strongly on material and process parameters. Metal AM material qualification and process certification methods are not available yet. Qualification and Certification is essential for high demanding applications for example in aerospace. The goal of the new Exploratory Group is to build up knowledge, skills and corresponding demonstrator products in the field of metal AM processes and materials in order to support the manufacturing industry and increase its competitiveness.

Although the specific topics vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas on future activities. 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 2014, a new Exploratory Group has started. There are still two final reports missing from previous Action Groups.

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

Activity	2008		2009		2010		2011		2012		2013		2014		2015		2016	
AG30: High velocity impact	🟧	🟧	🟧	🟥	🟥	🟥									▲			
AG33: RTM material properties during curing			🟧	🟧	🟧	🟧									▲			
AG34: Damage repair in composite and metal structure	🟥	🟥	🟧	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
AG35: Fatigue and damage tolerance assessment of hybrid structure	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
EG39: Design for high velocity impact on realistic structure							🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	**→**	**A**	**G**	**36**
EG41: Sizing of aircraft structures subjected to dynamic loading											🟩	🟩	🟩	🟩				
EG42: Bonded and bolted joints												🟩	🟩	🟩	🟩	🟩	🟩	🟩
EG43: Additive Layer Manufacturing															🟩	🟩	🟩	🟩

▲Report issued

MANAGED AND FORESEEN GOR ACTIVITY

In 2015, the GoR(SM) held two meetings:

- 71st meeting: 2015, March 3rd-4th at QinetiQ, Farnborough, United Kingdom;
- 72nd meeting: 2015, October 8th-9th at INTA, Madrid, Spain.

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 2016, GoR meetings are planned as follows:

- 73rd meeting: 2016, March 1st-2nd at DLR, Stade, Germany;
- 74th meeting: 2016, September 19th-20th, Netherlands.

Dr. Jean-Pierre Grisval
Chairman (2014-2015)
Group of Responsables
Structures and Materials

GOR MEMBERSHIP

Current membership of the Group of Responsables Structures and Materials

Chairman			
Dr. Jean-Pierre Grisval	ONERA	France	jean-pierre.grisval@onera.fr

Vice-Chairman			
Dr-Ing. Peter Wierach	DLR	Germany	peter.wierach@dlr.de

Members			
Dr. Domenico Tescione	CIRA	Italy	u.mercurio@cira.it
Dr. Aniello Riccio*	UNINA	Italy	aniello.riccio@unina2.it
Dr. Henri de Vries	NLR	The Netherlands	henri.de.vries@nlr.nl
Mr. Javier Sanmilan	INTA	Spain	marotosj@inta.es
Dr. Tomas Ireman	SAAB	Sweden	tomas.ireman@saabgroup.com
Dr. Joakim Schön	FOI	Sweden	joakim.schon@foi.se

Industrial Points of Contact			
Dr. Caroline Petiot	Airbus AGI	France	caroline.petiot@eads.net
Dr. Walter Zink	Airbus	Germany	walter.zink@airbus.com
Dr. Roland Lang	Airbus DS	Germany	roland.lang@airbus.com
Dr. Massimo Riccio	Alenia	Italy	massimo.riccio@alenia.it
Dr. Luc Hootsmans	Fokker	The Netherlands	luc.hootsmans@fokker.com
Mr. Angel Barrio Cárdaba	Airbus DS	Spain	angel.barrio@casa.eads.net
Dr. Hans Ansell	SAAB	Sweden	hans.ansell@saabgroup.com
Dr. Renaud Gutkin	Swerea Sicomp	Sweden	soren.nilsson@swerea.se
Dr. Andy Foreman	Qinetiq	United Kingdom	adforema@qinetiq.com

* : Associated member

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action Groups (AG)

The following Action Groups were active during 2015:

- SM/AG-34: Damage repair in composite and metal structures. This AG is a result from EG-40.
- SM/AG-35: Fatigue and Damage Tolerance Assessment of Hybrid Structures. This AG is a result from EG-38.

Two reports were finalised with the following Actions Groups:

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

Exploratory Groups (EG)

The following Exploratory Groups were active during 2015:

- SM/EG-39: Design for high velocity impact on realistic structures. This EG could become an AG with a new coordinator.
- SM/EG-42: Bonded and bolted joints. This EG started in the Fall of 2013. This EG could continue with a new coordinator.
- SM/EG-43: Development of additive layer manufacturing for aerospace applications. This EG was formally started at the GoR Fall 2014 meeting and the first EG-43 meeting was held on 10th April 2015.

Future topics

The following topics for future Exploratory Groups are discussed:

- Multi-functional Material;
- Multi-scale dynamics of joints: modelling and testing;
- New Methodologies for thermal-mechanical design of supersonic and hypersonic vehicles;
- Composite Fire Behaviour;
- Structural Uncertainties;
- Aeroelasticity and aero-servo-elasticity.

TABLE OF PARTICIPATING ORGANISATIONS

● = Member **■ = Chair**

SM/AG number	**34**	**35**

Research Establishments

DLR		●
CIRA	●	
NLR	●	■
INTA	●	
FOI	●	●
CNR	●	

Industry

QinetiQ	●	
SAAB	●	●
SICOMP		
ALENIA	●	
FOKKER		●

Academic Institutes

ICL	●	
LTU	●	
NTNU	●	
SUN	■	

TOTAL YEARLY COSTS OF SM/AG RESEARCH PROGRAMMES

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Man-month	**108**	**102,5**	**50**	**6**	**7**	**60,5**	**61**	**61**
Other costs (k€)	**117**	**128**	**40**	**10**	**2**	**65**	**61**	**61**

ACTION GROUP REPORTS

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

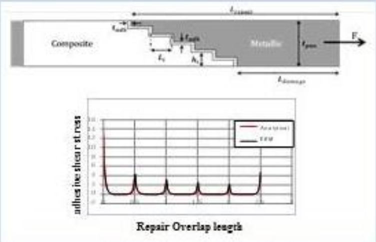
WP 5 EFFECTIVE REPAIR METHODS

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.



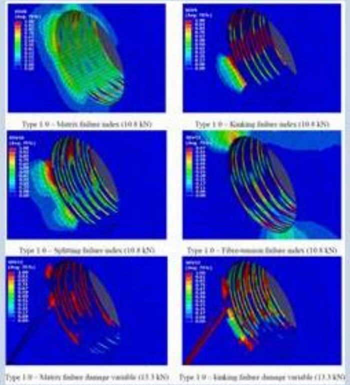
Development of an Analytical tool for Repair Design

Expected Results

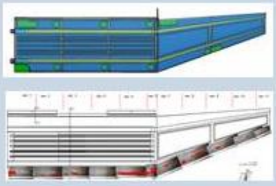
The effective outcomes can be summarized in:

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

A number of benchmarks have been selected for models validation.



Numerical Analysis - progressive Damage in composite Joint



Repair of an UAV wing

CIRA, Seconda Università degli Studi di Napoli SUN, AleniaAermacchi Una Società Finmeccanica, 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

SM/AG-34 DAMAGE REPAIR WITH COMPOSITES

Monitoring Responsable: D. Tescione
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 tests

- *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.*

- **Main achievements**

Tasks accomplished in 2014

- The Second technical meeting has been held in Sorrento (IT) on 23 April 2013. The most of the partners attended the meeting.
- Some partners gave presentations on the AG-34 work at the conference.
- The Third meeting has been held on 24 October 2013 at INTA.
- In 2014 and 2015 no meeting has been planned, however many partners have continued to work on the project's topic. The fourth meeting will be held during 2016.

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**

Member	Organisation	e-mail
Aniello Riccio (chairman)	SUN	aniello.riccio@unina2.it
Iñaki Armendariz Benítez (Vice Chairman)	INTA	armendarizbi@inta.es
Andrea Sellitto	SUN	Andrea.sellitto@unina2.it
Dimitra Ramantani	SICOMP	dimitra.ramantani@swerea.se
David Mattsson	SICOMP	David.mattsson@swerea.se
Ralf Creemers	NLR	ralf.creemers@nlr.nl
Joakim Schon	FOI	snj@foi.se
Domenico Tescione (AG Monitoring Responsible)	CIRA	u.mercurio@cira.it
Fluvio Romano	CIRA	f.romano@cira.it
Paul Robinson	IMPERIAL COLLEGE	p.robinson@imperial.ac.uk
Benedetto Gambino	ALENIA	benedetto.gambino@alenia.it
Charlotte Meeks	QINETIQ	cbmeeks@qinetiq.com
Mauro Zarrelli	CNR	m.zarrelli@imcb.cnr.it ; mauro.zarrelli@imcb.cnr.it
Janis Varna	LULEA UNIVERSITY of TECHNOLOGY	janis.varna@ltu.se
Marcus Henriksson	Saab	marcus.henriksson@saabgroup.com
Andreas Echtermeyer	NTNU	andreas.echtermeyer@ntnu.no
Giovanni Perillo	NTNU	giovanni.perillo@ntnu.no

- **Resources**

Resources		Year					Total 12-15
		2012	2013	2014	2015		
Person-months	Act./ Plan.	-	50/36	50/30			
Other costs (in K€)	Act./ Plan.	-	49/32	20/0			

- **Progress/Completion of milestone**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1 Report	Oct 2014	Oct 2014	
WP2 Report	Apr 2016	Apr 2016	
WP3 Report	Apr 2016	Apr 2016	
WP4 Report	Apr 2016	Apr 2016	
WP5 Report	Oct 2016	Oct 2016	
Final Report	Oct 2016	Oct 2016	

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

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

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

Background

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.

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

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

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

Task 3;

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

SM/AG-35 FATIGUE AND DAMAGE TOLERANCE ASSESSMENT OF HYBRID STRUCTURES

Monitoring Responsable: H.P.J. de Vries
NLR

Chairman: R.P.G. Veul (till 31-08-2013)
NLR
J. Laméris (from 1-09-2013)
NLR

- **Objectives**

The main objectives are listed below:

- Validation of the basic assumptions for any applied spectrum manipulation techniques;
- Examination of the capabilities and benefits of a probabilistic approach;
- Determination of the optimum way to account for thermal loads in a non-thermo test set-up;
- leading to a joint 'best practice' approach for testing of hybrid airframe structural components.

- **Main achievements**

Task 1: Determination of a test spectrum

A conceptual definition of a specimen geometry was proposed by Fokker/NLR in order to be able to observe the behaviour of the test specimen with respect to the various (conflicting) requirements associated with a hybrid (metal-CFRP) fatigue test. Further detailing of the test specimen needs to be done. Some joint tests have been conducted in order to be able to define the test specimens.

A proposal for a load spectrum to which the benchmark test specimen will be subjected was made.

Task 2: Probabilistic approach

Work has been performed by DLR on probabilistic methods but could not be presented at the progress meeting due to different reasons.

Task 3: Environmental influences

A test setup has been developed by FOI that simulates thermal stresses in a hybrid bolted joint designed to fail in bearing. The setup applies biaxial loading to fasteners in a double lap bolted joint at 90^{o}C. Specimens were tested both quasi-statically loaded and fatigue loaded and with biaxial loading and without biaxial loading. For biaxially loaded joints an effective bearing stress can be calculated from Pythagoras theorem. When the effective bearing stress is used for comparison on quasi-static loaded joints, both the damage initiation and bearing failure occurs at similar stress levels for biaxially loaded joints and joints that are not biaxially loaded. When the effective bearing stress is used for comparison on fatigue loaded joints the fatigue life for not biaxially loaded joints is slightly shorter than for biaxially loaded joints. This indicates that the effective bearing stress is a conservative method to predict fatigue life for biaxially loaded joints and thermally loaded hybrid joints.

Saab presented results of FEM simulations of some of the FOI performed static and fatigue tests on bolted specimens under biaxial and thermal loads using ABACUS. A second presentation described research on the development of a fatigue model for bearing failure under variable bi-axial loading at elevated temperature.

- **Management issues**

The fourth progress meeting was held on September 22nd, 2015 at the Saab facilities in Linkoping in Sweden. Unfortunately due to different reasons no results from DLR could be presented.

- **Expected results/benefits**

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

- **SM/AG-35 membership**

Member	Organisation	e-mail
Dr.-Ing Joachim Hausmann till 1/9/14	DLR	joachim.hausmann@dlr.de
Dr. Jan Haubrich From 1/9/14	DLR	Jan.haubrich@dlr.de
Dr. Anders Blom	FOI	anders.blom@foi.se
Dr. Joakim Schön	FOI	joakim.schon@foi.se
Tim Janssen	Fokker Aerostructures	tim.janssen@fokker.com
Frank Grooteman	NLR	frank.grooteman@nlr.nl
Dr. Jaap Laméris	NLR	jaap.lameris@nlr.nl
Hans van Tongeren	NLR	hans.van.tongeren@nlr.nl
Rudy Veul	NLR	rudy.veul@nlr.nl
Hans Ansell	SAAB	hans.ansell@saabgroup.com
Zlatan Kapidzic	SAAB	zlatan.kapidzic@saabgroup.com

Dr.Ing Joachim Hausmann is now working at the IVW GmbH, Kaiserslautern and has obtained consent to be part of the AG.

- **Planned Resources**

Resources		Year				Total 12-15
		2012	2013	2014	2015	
Person-months	Act./ Plan.	1/1	10.5/11	11/11	/10	/33
Other costs (in K€)	Act./ Plan.	1/2	16/30	41/41.5	/35	/108.5

- **Progress / Completion of milestone**

Work task	Planned		Actual
	Initially (end of...)	Currently (updated)	
Task 1	April 2015	Dec 2016	Dec 2016
Task 2	June 2015	Dec 2016	Dec 2016
Task 3	June 2015	Dec 2016	Dec 2016
Report	October 2015	December 2016	December 2016

EXPLORATORY GROUP REPORTS

SM/EG-39 DESIGN FOR HIGH VELOCITY IMPACT ON REALISTIC STRUCTURES

Monitoring Responsable:	A. Riccio SUN
Chairman:	M. Willows 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 39 has been put on hold until IC secure the necessary funding to manage the project.

- **EG membership**

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

SM/EG-42 BONDED AND BOLTED JOINTS

Monitoring Responsable:	TBD
Chairman:	J. Schön FOI

- **Objectives**

The objective is to further develop the numerical methods to predict failure and damage in bolted and bonded joints. To do experimental work to support the numerical methods and to improve measurement methods. To study both metallic and composite joints.

- **Benefits**

Although, aircraft structures are becoming larger there are still a larger number of joints, both bolted and bonded, needed to join them together. If it would be possible to numerically predict damage and failure load for joints the cost of designing joints would be reduced substantially. Even if it would only be possible to interpolate between experimental data it would be useful. When calculating the undamaged stress state in a joint there is no major differences between metallic and composite joints. Therefore, both metallic and composite joints can be considered. Hybrid joints, composite and metallic parts joined together, are considered in AG35 and will not be part of this EG.

- **Progress**

EG was initiated by FOI and was formally started at the GoR fall meeting 2013.
Due to budget cuts, FOI won't be able to manage or even participate in the AG.
Based on the member feedback a reorientation of the EG with a focus on bonded joints is discussed.
DLR will check possibilities to manage the EG.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
DLR	Germany	TBD

SM/EG-43 DEVELOPMENT OF ALM TECHNOLOGIES FOR AEROSPACE APPLICATIONS

Monitoring Responsable: H.P.J. de Vries
NLR

Chairman: L. ‘t Hoen
NLR

- **Objectives**

The goal of the proposed research programme is to build up knowledge, skills and corresponding demonstrator products in the field of metal AM processes and materials in order to support the manufacturing industry and increase its competitiveness. This program offers the opportunity for the industrial participants to counteract the shortage of metal AM knowledge and skills and to develop new market opportunities.

- **Benefits**

With Additive Manufacturing (AM) products are constructed in layers from a 3D CAD file. Other commonly used terms for this technology are: 3D Printing, Rapid Manufacturing, Solid Free Form fabrication, digital or direct manufacturing and e-manufacturing. This research program will mainly focus on AM techniques of metal objects.

Three-dimensional solid objects are produced from a digital model by successive application of layers of material. Two fundamentally different techniques can be distinguished:

1. Powder bed method: A product is constructed in layers into a powder bed. The powder is locally melted with a laser or electron beam.
2. Deposition method: Material is continuously fed in the form of powder, wire or strip and melted with a laser or electron beam. The deposition method is faster compared to the powder bed method and it is also suitable for making repairs. It is suitable for making larger parts. The accuracy is lower so that post machining is required.

Additive Manufacturing (AM) with metals is an emerging technology that finds more and more applications in different markets such as orthopaedic implants, dentistry and high-end industry. There is also a lot of interest coming from the Aerospace industry.

Metal AM technology can provide great advantages with respect to conventional metal working techniques, such as significantly lower waste of materials, a larger freedom of design, high potential for weight reduction and the possibility to integrate of functionality.

There are still significant hurdles for successful commercialisation of metal AM. Specific design guide lines must be taken into account and currently available CAD design tools are considered inadequate for designing for AM. Currently it still is difficult for AM technologies to compete with traditional techniques on reliability and reproducibility because the quality of final products depends very strongly on material and process parameters. Metal AM material qualification and process certification methods are not available yet. Qualification and Certification is essential for high demanding applications for example in aerospace.

- **Progress**

The EG was formally started at the GoR fall (2014) meeting. In the past months more interested members have been found. A first meeting to set-up the project was held in April 2015.
Now a project plan is being written.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
CIRA	Italy	R. Borelli
GKN	United Kingdom	A. Bates
DLR	Germany	J. Haubrich
NLR	Netherlands	L. ‘t Hoen
ONERA	France	M. Thomas
Airbus	United Kingdom	M. Muir