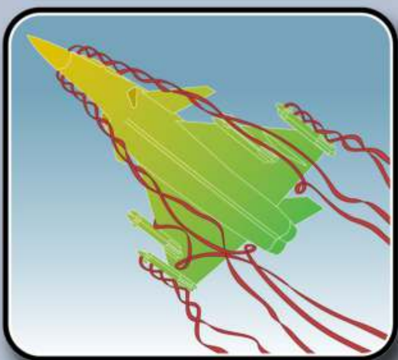
GARTEUR

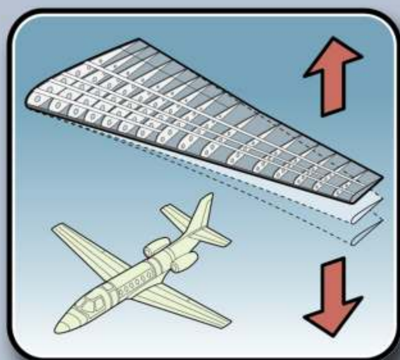
GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

Document X/D 50

GARTEUR
Annexes to the
Annual Report 2014





June 2015

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GARTEUR X/D 50

Annexes to the GARTEUR Annual Report 2014 (X/D 49)

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

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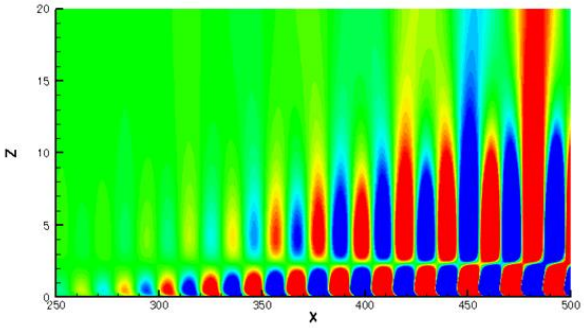
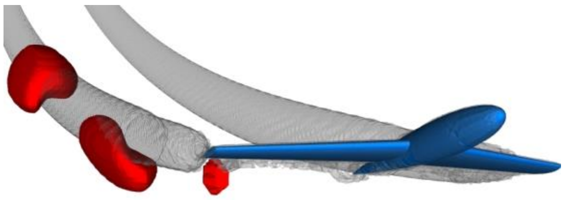
ANNEX A

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AERODYNAMICS"





Remit

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

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

- Aerodynamics;
- Aero-thermodynamics;
- Aero-acoustics;
- Aero-elasticity;
- Aerodynamic Shape optimum;
- Aerodynamics coupled to Flight Mechanics;
- Aerodynamics Systems integration.

In general terms the work consists of both computational and experiment aspects 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 proposals or compliment concurrent EU program content. Also the content of GoR AD can be cross sectorial in covering both Civil and Military interests.

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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" 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.

Four Action Groups have been active in 2014.

- 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 will consist of both wind tunnel tests and CFD prediction. Work will concentrate on the Mach number range of 4 to 10 at atmospheric condition appropriate for 30 km altitude, and will use 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 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 will be tested against reference geometries allowing cost / accuracy between different approaches to be made, a major output of the work will be best practice guidelines for industrial use of SBGO methods in shape optimisation. The work was started in February 2013 and expected to be completed by December 2016, an extension of the programme from the original finish date having been agreed. 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 is to understand the effects of surface irregularities and disturbances in the oncoming flow on transition in three dimensional boundary layers, the evaluation of transition control techniques. The work will cover both experiment and 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". The main objective of this project is to explore, further develop and improve RANS-LES coupling in the context of embedded LES (ELES) and hybrid RANS-LES method thus enabling the "Grey Area" problem. 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 is in effect a follow Action Group from AD/EG-71 and was given the go ahead in October 2014. 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 of burning flares, and is focused on improved understanding together with the aerodynamic effect of the combustion on the flares aerodynamic characteristics. 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 is Dr. O. Grundestam (FOI) and the Monitoring Responsible is Torsten Berglind (FOI).

AD/EG-72 is a new Exploratory Group set up to deal with the issue of Coupled aerodynamics and Flight mechanics simulation of very flexible configurations. Bimo Prenanta (NLR) will be chairing the group and the Monitoring Responsible was to have been Koen de Cock. At the end of April 2014 it was announced that Koen was leaving NLR and the industry. At the time of writing no information on a replacement was forthcoming. The teams are proposing to use XRF1, an Airbus owned reference model and some pre-existing aerodynamic data, however they were negotiating with Airbus for the release of an appropriate related flight dynamics model. The negotiations were continuing at the turn of the year.

MANAGEMENT ISSUES

The author took over the Chairmanship, with the assistance of Chris Newbold (QinetiQ), of the GoR at the 2014 Spring Meeting of the GoR-AD with Koen de Cock as Deputy Chairman. Shortly after the meeting it became known that Koen was leaving both NLR and the industry, and within a month Chris Newbold had also left the ATI and GARTEUR. I asked the GoR AD members for a volunteer to replace Koen in particular without result. With ever increasing work load it has been very difficult for the author to pay the amount of attention that leading the GoR needs. At the next meeting scheduled for September 2015 the priority for the GoR will be to put in place the transfer of the Chairmanship, and appointing a Deputy Chair-person, and to ensure that the information for the annual report arrives in good time for the 2015 Annual report.

A cause for concern is the slow reduction in the industrial partners leaving GARTEUR for a number of reasons amongst which is the lack of funding and manpower for low TRL work due to the pressure to find resources to support Clean Sky 1 and 2 demonstrators. Norman Wood and Geza Schrauf have not attended meetings in 2014 due to this pressure. In fairness to Geza he has provided a replacement in the form of Heribert Bieler.

It should be noted that recent reductions in finance for GARTEUR activities across all the involved parties, have contributed to numbers of people being unable to travel to GoR meetings. Despite reservations, use has been made of WEBEX Tele conferencing to enable members unable to travel to take part in the meetings. It is likely that for the near future the use of these forms of taking part in GARTEUR activity will continue, and grow.

At the first GoR-AD meeting in 2013 a suggesting was made by Norman Wood of Airbus to hold an Annual Aerodynamics Forum, similar to the forums which NATO/STO organise. Some discussion took place and recognising that the ethos of GARTEUR was to ensure that within a group people should meet face to face as a group at least twice a year, it was agreed to try out the idea. The 2014 September Meeting of the GoR-AD at FOI was chosen for the event. To minimise travel the forum would be held concurrently with the GoR autumn meeting. It was agreed that the meeting would span three days. The first would be set aside for meeting of the individual AGs. The second day would start with the forum and presentation of the work of 4 AGs, leading up until to lunch time. The start of the GoR meeting would be after lunch, and would continue on the morning of the third day.

The forum and GoR meeting were hosted by FOI and were generally acknowledged as being a great success. The GoR-AD will repeat this event at their meeting at Cranfield in October 2015.

At the end of 2013 the GoR –AD put forward three candidates for the GARTEUR Award of Excellence: the AD/AG-46 “Highly integrated subsonic intakes”, organised by Thomas Berens, was chosen followed closely by AD/AG-45 and AG/AD-50, following a vote by members. Thomas gave a presentation of his AIAA Paper at the autumn Council meeting when he was presented with his Award of Excellence.

DISSEMINATION OF GARTEUR ACTIVITIES AND RESULTS

The Special GARTEUR Paper session was held at the AIAA Science and Technology Forum and Exposition in January 2014 which is organised by Thomas Berens. The first paper in this session was an introduction to GARTEUR given by Hervé Consigny from ONERA. Of the six papers delivered at this session two were GARTEUR papers showing research done in AD/AG-43 and in AD/AG-46. AD/AG-52 presented a paper and organised a special session at ECCOMAS 2014.

FUTURE PLANS

Compared with 2013 with nine active AD/AGs and four active AD/EGs, 2014 saw only four Active AD/AGs, and three AD/EGs of which only one was active, AD/EG-71 which was launched into AD/AG-55. The prospects for 2015 are 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 2015.

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 2015.

More importantly the proposal for an AD/EG based on secondary inlets and outlets for ventilation is likely to be launched in 2015.

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 wind tunnel.

During the course of 2014 a new list of ideas for research work from industry was issued. This will form the basis of a new initiative in 2015 to establish further AD/EGs.

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

No	Topic	2011	2012	2013	2014	2015	2016
AD/AG-45	Application of CFD to predict high G Wing Loads						
AD/AG-46	Highly Integrated Subsonic Air Intakes						
AD/AG-47	Coupling of CFD with Flight Mechanics						
AD/AG-48	Lateral Jet Interactions at Supersonic Speeds				Final report finalised in 2015		
AD/AG-49	Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications						
AD/AG-50	Effect of wind tunnel shear layers on aeroacoustic tests						
AD/AG-51	Laminar-Turbulent Transition in hypersonic flows	EG65 =>					
AD/AG-52	Surrogate-based global optimization methods in Preliminary Aerodynamic Design		EG67 =>				
AD/AG-53	Receptivity & Transition Prediction: Effects of surface irregularity and inflow perturbations		EG66 =>				
AD/AG-54	RANS-LES Interfacing for hybrid and embedded LES approaches			EG69 =>			
AD/AG-55	Countermeasure Aerodynamics				EG71 =>		

AD/EG-70	Plasma for Aerodynamics						
AD/EG-72	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configs						

Active
Extended
Closed
Inactive

MANAGED AND FORESEEN GOR ACTIVITY

In 2014 the first meeting will take place at CIRA in Italy, on February 26th-27th, 2015. The second meeting will be held October 22nd-23rd at ATI in Cranfield.

Frank Ogilvie

Chairman (2014-2015)

Group of Responsables Aerodynamics

GOR MEMBERSHIP

The Membership of the GoR-AD in 2014 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			

Members			
Mr. Norman Wood	Airbus Operations Ltd	United Kingdom	Norman.Wood@airbus.com
Mr. Bimo Prenata	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	Airbus Operations GmbH	Germany	geza.schrauf@airbus.com
Mr. Per Weinerfelt	SAAB	Sweden	ernst.totland@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.fr
Mr. Luis P. Ruiz-Calavera	AIRBUS Defence & Space	Spain	Luis.Ruiz@airbus.com
Vacant	QinetiQ	United Kingdom	

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

	AG-46	AG-48	AG-51	AG-52	AG-53	AG-54	AG-55	EG-70	EG-72
Research Establishments									
CIRA			☐	☐	☐	☐			
DLR	☐	☐	☐		☐	☐			
DSTL									
FOI	☐	☐		☐	■	■	■		
INTA				■		☐			
NLR							☐		■
ONERA	☐	☐	■	☐	☐	☐		■	
Industry									
Airbus military	☐			☐			☐		
Airbus Operations GmbH					☐				
Airbus Operations Ltd									
Airbus Operations S.A.S.									
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						☐			
UNIS									
Von Karman Institute *(VKI)*			☐						
VUT				☐					

☐= Member ■= Chair

AD/EG-70 and -72 membership not yet finalised

TOTAL YEARLY COSTS OF AD/AG RESEARCH PROGRAMMES

GoR	AG	2011		2012		2013		2014		2015		2016*	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	44					1	0						
	45	5	10	5	5	1	0						
	46	10	0	3	0	3	3	0	0				
	47	10		10		1	0	0	0				
	48	11	7	3	6	6	8	1	0				
	49	20	170	15	100	7	70						
	50	16	60	8	0	10	20						
	51			13	40	12	40	12	40				
	52					20	45	23	63	23	63	23	63
	53					10	12	13	24	13	24		
	54							18	100	22	140		
	55									0	0		
AD	**TOTAL**	**72**	**247**	**57**	**151**	**71**	**198**	**67**	**227**	**58**	**227**	**23**	**63**

pm = Person-months
k€ = other costs

* NOTE: Several Action Groups are planned to end during 2015, while others are in preparation to be started during 2015 and 2016. Hence it is not meaningful at this stage to estimate resources for 2016.

ACTION GROUP REPORTS

GARTEUR — GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

AD/AG-46: Highly Integrated Subsonic Air Intakes

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

Background

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

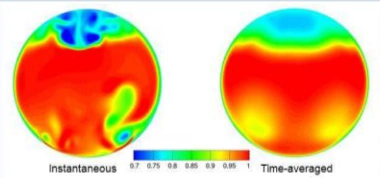
Application of modern hybrid CFD methods: Detached Eddy Simulation (DES) of internal flow field with separation, code validation

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

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

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

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



DES S-A Computation: Total Pressure Ratio Distribution in the AIP
Case 3 Sharp Intake Cowl, M_∞ = 0.80, MF = 3.97 kg/s

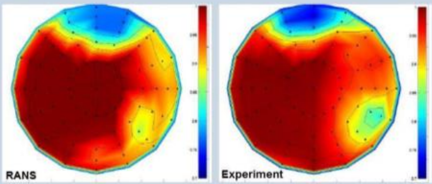
Programme/Objectives

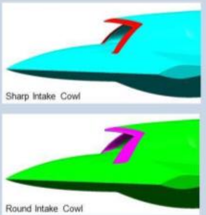
Main objectives of AD/AG-46: (1) to investigate the capability of modern CFD methods (Detached Eddy Simulation DES) to analyze unsteady flow phenomena of highly integrated subsonic air intakes, (2) to support innovative design for advanced subsonic aerial vehicles, and (3) to assess the flow behavior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

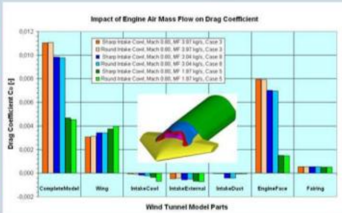
Focus: Numerical simulations of unsteady internal flow in a subsonic air intake highly integrated into the airframe of a UAV applying different standard CFD methods and DES, comparison with experimental data. Parametric studies of innovative intake design features accompanied by basic wind tunnel investigations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

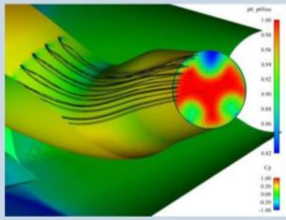
Partners: CASSIDIAN, ONERA, FOI, AIRBUS Military, DLR, SAAB, MBDA, Alenia, Dassault-Aviation

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









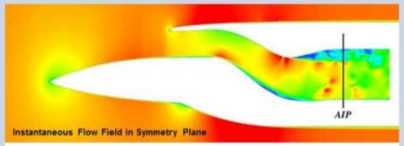
- Assessment of dynamic distortion coefficients at aerodynamic interface plane and comparison with test data
- Simulations for internal flow control by employing numerical models for vortex generators and micro-jets
- Computational investigation on intake lip shaping impacting intake performance and aerodynamic drag

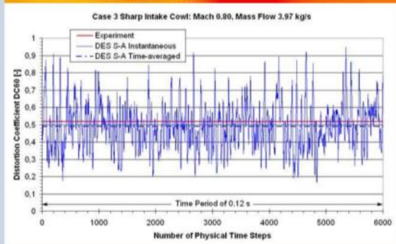
CASSIDIAN, FOI, DLR, SAAB, ONERA, AIRBUS MILITARY, MBDA, AleniaAeronautica, DASSAULT AVIATION

Results

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

- The basis for time-accurate predictions of intake performance parameters such as dynamic intake distortion will be enhanced in order to prepare the groundwork for engine/intake compatibility prediction with improved accuracy levels.
- To accompany the design process of highly integrated subsonic air intakes, efficient hybrid CFD methods are a vital means for improving performance prediction capabilities as well as for reducing system development time and cost. Expenses for wind tunnel experiments could be minimized by increasing numerical support.





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

- Fundamental experimental studies of decisive intake design parameters will advance the knowledge innovative configurations of compact air induction systems require.
- Numerical investigations on intake cowl shaping will provide interesting insight into the impact of this important design parameter on internal flow, intake performance, and aerodynamic drag.

AD/AG-46	HIGHLY INTEGRATED SUBSONIC AIR INTAKES
Monitoring Responsable:	Dr. T. Berens AIRBUS Defence & Space (formerly CASSIDIAN)
Chairman:	Dr. T. Berens AIRBUS Defence & Space

- **Objectives**

The objectives of Action Group AD/AG-46 are aimed at the investigation of the capability of modern CFD methods (Detached Eddy Simulation DES) to analyze unsteady flow phenomena of subsonic air intakes and to support innovative design for highly integrated intakes of advanced aerial vehicles.
The computational prediction of the instantaneous total pressure distribution in the engine face as the basic parameter for the assessment of dynamic intake distortion and engine/intake compatibility is most challenging.
The flow behavior at the intake cowl due to complex multi-disciplinary lip shaping and the impact of the design on intake internal flow and aerodynamic drag represent other vital topics regarding this area of research. Flow control by applying vortex generators and micro-jets in serpentine ducts plays a major role in enhancing performance.
Computational flow simulations within these fields of interest and their accuracy levels will be compared with experimental data.
A parametric study of innovative intake design features accompanied by basic experimental investigations will address fundamental design issues and should contribute to a better understanding of flow phenomena occurring in highly integrated air intakes.
As results best practice advice for innovative intake design and for the application of modern hybrid numerical simulation methods is expected.

- **Main achievements**

Thirteen tasks were defined to achieve the objectives of the Action Group and were completed in 2013. The geometry and the experimental data of a UAV (EIKON), which was designed and wind tunnel tested at FOI, served as a basis for the numerical simulations of unsteady internal flow in subsonic air intakes.
RANS, URANS, and DES computations were performed with the EIKON configuration for a variety of test cases, and the results were compared with experimental data. Investigations of a potential influence of not considering the wind tunnel walls in the CFD calculations on the computational results confirmed no impact. Fig. 1 displays instantaneous and time-averaged total pressure ratio distributions from DES results in the AIP for Test Case 7. The unsteady character of the intake flow field is clearly revealed.

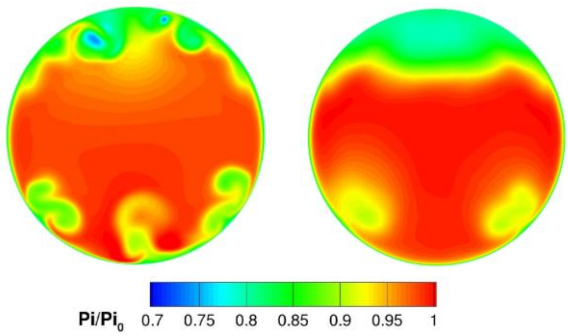


Fig. 1 Instantaneous (left) and time-averaged (right) total pressure ratio distributions in the AIP for Test Case 7 (Mach 0.6, mass flow 3.98 kg/s) from DES computations by AIRBUS Defence & Space (formerly CASSIDIAN)

A numerical study on intake lip shaping was finished comprising an alternative round cowl design and the comparison of CFD results with data obtained for the original sharp lip geometry.
Internal flow control was investigated by the application of vortex generators and micro-jets in the S-duct using new numerical models.
The experimental parametric studies with a high aspect ratio diverterless S-duct intake model (Fig. 2) in the cryogenic blowdown wind tunnel DNW-KRG in Göttingen could be concluded.

Fig. 2 Intake wind tunnel model with flat plate for parametric study in the DNW-KRG, Göttingen (top: 3D view, bottom left: side view, bottom right: view from the exit of the intake duct towards the measuring rake)

Numerical simulations of boundary layer diversion were conducted in order to address intake performance effects due to ingestion.
The results of AD/AG-46 are documented in five conference papers, which were presented at the AIAA Science and Technology Forum and Exposition being held from 13-17 January 2014, in National Harbor; Maryland, USA:

"Numerical and Experimental Investigations on Highly Integrated Subsonic Air Intakes" by Berens, T. M., Delot, A.-L., Tormalm, M. H., Ruiz-Calavera, L.-P., Funes-Sebastian, D.-E., Rein, M., Säterskog, M., Ceresola, N., and Zurawski, L., AIAA 2014-0722

"DES Computations for a Subsonic UAV Configuration with a Highly Integrated S-Shaped Intake Duct" by Delot, A.-L., Berens, T. M., Tormalm, M. H., Säterskog, M., and Ceresola, N., AIAA 2014-0723

"Flow Control Using Vortex Generators or Micro-Jets Applied in a UCAV Intake" by Tormalm, M. H., AIAA 2014-0724

"Numerical Simulations of Wind Tunnel Effects on Intake Flow of a UAV Configuration" by Funes-Sebastian, D.-E. and Ruiz-Calavera, L.-P., AIAA 2014-0372

"Experimental and Numerical Investigations on the Influence of Ingesting Boundary Layers into a Diverterless S-Duct Intake" by Rein, M., Koch, S., and Ruetten, M., AIAA 2014-0373

The reporting was concluded in January 2014 with the final AD/AG-46 report.

- **Management issues**

Originally it was planned to finish AD/AG-46 in 2010. Labor intensive tasks, however, especially Tasks 6, 9, 10, and 12 as well as problems related to the generation of various computational grids for the UAV configuration required more time and resources than anticipated. In addition, severe resources and budget cuts in 2010, 2011, and 2012 led to further difficulties delaying the work plan considerably and extending the time schedule for the finalization of AD/AG-46 to 2013 with minimal funding. A large amount of the work was performed through personal commitment and private efforts. The final meeting was held on March 6th, 2013, at CASSIDIAN in Manching.

- **Expected results/benefits**

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

- **AD/AG-46 membership**

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- **Resources**

Resources		Year						Total 08-13
		2008	2009	2010	2011	2012	2013	
Person-months	Actual/ Planned	A21 P21	A27 P27	A12 P18	A10 P15	A3 P12	A3 P9	A76 P102
Other costs (in K€)	Actual/ Planned	A7 P7	A7 P7	A0 P7	A0 P0	A0 P7	A3 P7	A17 P35

- **Progress/Completion of milestones**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: Output Definition	June 2008	Dec. 2009	Dec. 2009
Task 2: Data Post-Processing Procedures	Sep. 2008	Oct. 2008	Oct. 2008
Task 3: Provision of Experimental Data UAV	June 2008	June 2009	June 2009
Task 4: Provision of Geometry UAV Config.	Mar 2008	June 2008	June 2008
Task 5: CFD grid Generation UAV Config.	Sep. 2008	May 2010	June 2011
Task 6: CFD Computations	June 2010	June 2013	Nov. 2013
Task 7: Comparison of CFD and Test Results	Aug. 2010	Oct. 2013	Nov. 2013
Task 8: WT and Model Geometry Effects	Mar. 2009	Sep. 2009	Sep.2009
Task 9: Numerical Study on Intake Lip Shaping	June 2010	May 2013	Nov. 2013
Task 10: Boundary Layer Diversion versus Ingestion	Aug. 2010	July 2013	Oct. 2013
Task 11: Intake Internal Flow Control	June 2010	May 2013	July 2013
Task 12: Experimental Parametric Study of Intake Design	June 2010	Apr. 2013	Nov. 2013
Task 13: Reporting	Dec. 2010	Feb. 2014	Jan. 2014

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

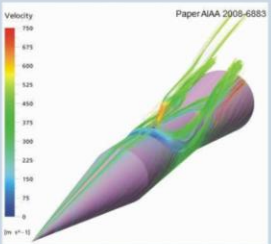
Action Group Chairman: Dr Patrick Gnemmi, ISL (patrick.gnemmi@isl.eu)

Background

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

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

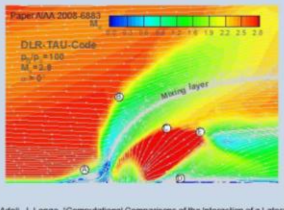
Challenge: defining the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet



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

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

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



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

Programme/Objectives

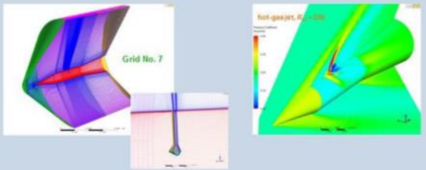
Main objectives of AD/AG48: (1) to accurately predict by CFD the steady-state aerodynamics of the interaction of a hot multi-species gas jet with the cross-flow of a supersonic missile at acceptable computational costs; (2) to deeply analyze the effect of the hot-gas jet from numerical simulations; (3)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

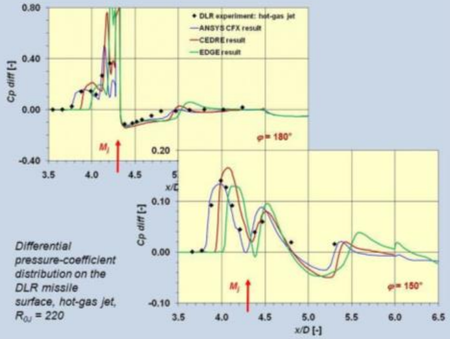
Focus: (1) numerical simulation validations of the interaction of cold-air and hot-gas jets with the cross-flow of supersonic missiles using different Reynolds-Averaged Navier-Stokes (RANS) codes and experimental data from DLR Cologne and ONERA/MBDA-France; (2) numerical simulations for the replacement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

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

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

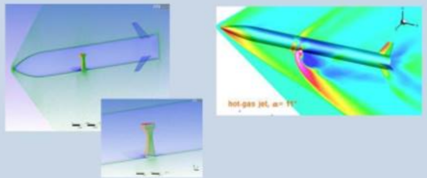
DLR Cologne configurations:
- supersonic flow at Mach 3.00, $\alpha = 0°$
- cold-air and hot-gas jets
- ejection pressure ratio of 130 and 220

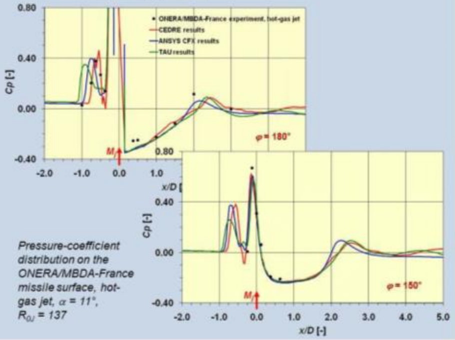




Differential pressure-coefficient distribution on the DLR missile surface, hot-gas jet, $R_{0J} = 220$

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



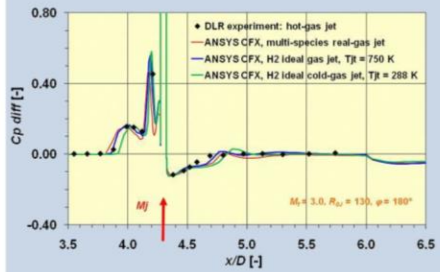


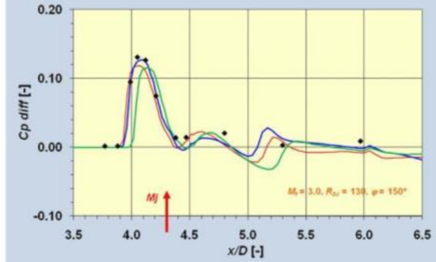
Pressure-coefficient distribution on the ONERA/MBDA-France missile surface, hot-gas jet, $\alpha = 11°$, $R_{0J} = 137$

Results

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

Most appropriate similarity parameters for wind-tunnel tests using cold-gas jets
- steady-state numerical simulations used to try to reproduce the effects of a hot-gas jet by the use of a cold-gas jet
- numerous numerical simulations in progress which must be analyzed





DLR FOI ISL MBDA MISSILE SYSTEMS ONERA THE FRENCH AEROSPACE LAB

AD/AG-48 LATERAL JET INTERACTIONS AT SUPERSONIC SPEEDS

Monitoring Responsable: E. Coustols ONERA

Chairman: Dr. P. Gnemmi ISL

- **Objectives**

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

- **Main achievements**

The AD/AG-48 exists since October 1st, 2008. Different meetings took place at ONERA in October 2008, at MBDA-LFK in April 2009, at DLR Cologne in March 2010, at MBDA-France in August 2010, at ISL in October 2011 and at ONERA in April 2012.
The bibliography on similarity parameters studies has been detailed (task 1). The provision of the geometry and of the experimental data of DLR Cologne (task 2) and ONERA/MBDA-France configurations (task 4) and the provision of the corresponding grids (tasks 3 and 5 respectively) have been achieved. The reports of tasks 1, 2 and 3 have been uploaded on the NLR website (AirTn server) and distributed.
One objective was dedicated to the validation of the numerical simulation for each configuration: 4 DLR cases (task 6) and 4 ONERA/MBDA-France cases (task 7). The goal is considered to be reached in spite of some discrepancies between the used codes. A paper has been presented at the 47th International Symposium of Applied Aerodynamics on March 26-28, 2012 in Paris and the improved version will be published soon in the International Journal of Engineering Systems, Modelling and Simulation.

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

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

Table 1: Computed aerodynamic coefficients for DLR cases

ANSYS-CFX, Edge and CEDRE provide very coherent results: discrepancies are less than 8% for the drag coefficient C_X, 15% for the normal-force coefficient C_N and 18% for the pitching-moment coefficient *Cm(G)* determined at the gravity centre *G*.
For ONERA/MBDA-France cases, computations were carried out for the Mach number of 2.01, for angles of attack of 0 and 11°, for cold-air and hot-gas jets having ejection ratios R_{0J} of 81 and 137, respectively. The pressure coefficient distribution obtained by the codes on the ONERA/MBDA-France missile model was compared to the measurements (poster).
Table 2 compares the computed and measured aerodynamic coefficients. ANSYS-CFX, CEDRE and TAU provide coherent normal-force coefficients and coherent pitching-moment coefficients for the angle of attack of zero: the discrepancies are less than 10% for the normal-force coefficient (except TAU) and are less than 30% for the pitching-moment coefficient. The codes also provide coherent normal-force coefficients for the angle of attack of 11°, but the pitching-moment coefficients have large discrepancies. These differences are significant despite the good distribution of the calculated surface pressure compared to the measured one. This could be due to the influence of the interaction of the jet wake on the fins, but there is no measurement that can confirm that.

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

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

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

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

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

The final objective of the study deals with investigations on similarity parameters which allow the hot-gas jet to be replaced by a cold-gas one in ground-test facilities. This cold-gas jet should reproduce the effects of the hot-gas jet in wind-tunnel or shock-tunnel experiments. The previous DLR and ONERA/MBDA-France hot-gas jet configurations serve as reference cases and many numerical simulations were achieved. Other computations are in progress for DLR cases (task 8) and for ONERA/MBDA-France cases (task 9). The finalisation of AD/AG-48 is shifted to the beginning of 2014.

- **Management issues**

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

- **Expected results/benefits**

The first expected benefit which is the assembly of a bibliography on similarity parameters is available now.
The development of a calibration of the CFD codes based on experimental data using both cold and hot multi-species gases is done. The analysis of the main differences resulting from the use of cold and hot multi-species gases is also done and the group concentrates his efforts now on new numerical simulations for the final benefit of the study.

Finally, the definition of the most appropriate similarity parameters based on these new CFD results is in progress.

- **AD/AG-48 membership**

Member	Organisation	e-mail
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S. Wallin	FOI	stefan.wallin@foi.se
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C. Nottin	MBDA-F	christophe.nottin@mbda-systems.com
M. Leplat	ONERA	michel.leplat@onera.fr

- **Resources**

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

- **Progress/Completion of milestone**

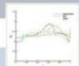
Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: Bibliography	Dec. 2008	Dec. 2010	Finished Reported
Task 2: Experimental data of DLR configuration	Nov. 2008	Jan. 2009	Finished Reported
Task 3: CFD grid for DLR configuration	Dec. 2008	Jul. 2009	Finished Reported
Task 4: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

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

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



Background

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

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

The work in AG49 has focused on an exploration of modelling capabilities in resolving some underlying flow physics in typical aerodynamic applications, e.g., free shear layer, confluence of BLs and wakes, flow separation, recirculation and reattachment. Several selected hybrid RANS-LES methods are scrutinized and evaluated. Some further modelling improvements are also reported.

Fundamental aspects: Examination of hybrid RANS.LES models, modelling evaluation and improvement, modelling-related numerical issues.

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

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

Programme/Objectives

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

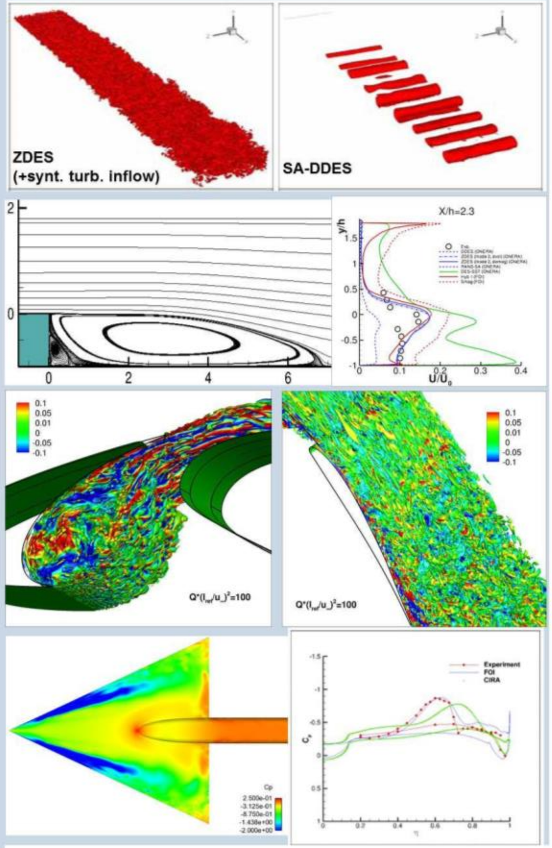
Work plan: The work in AG49 is divided into three tasks. Task 1 and Task 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3. AG49 was completed in April 2013.

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

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

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

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



Results

- Exploration and further improvment of modelling and turbulence-resolving capabilities based on a number of test-case computations using different hybrid RANS-LES models
- Assessment of hybrid RANS-LES methods in terms of their respective advantages and disadvantages, by means of cross comparisons of partners' computations.

Summary:

- Asessment made for a number of hybrid RANS-LES models through test-case computations, and further improvement on XLES with stochastic forcing and/or based on EARSM; HYB0 with energy backscatter in the LES mode, improved ZDES with vorticity-based length scale in the LES mode.
- All AG members have computed the test cases planned and contributed to the cross plotting of the results for computed TCs.
- Partners have used the following hybrid models: *SA-DES / DDES and IDDES, SST-DES / DDES, zonal SA-DDES, zonal RANS-LES/DNS, HYB1, HYB0, X-LES, ZDES and their variants.*
- Cross plots have been conducted for all TCs in comparison with available experimental data, and reported in the final summary report.
- Comparative studies have been conducted for modelling evaluation.
- The impacts of other significant factors have been explored, typically, incoming BL, numericla dissipation, grid resolution and domain size etc..
- Experience gained and lessons learned from the work conducted are summarized
- A new EG (EG69) has been set up in 2013 by the AG49 members, plus several new EG members. A new AG is planned to launch in 2014 to address RANS-LES couplng for zonal and embedd LES methods.

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

AD/AG-49	**HYBRID RANS-LES METHODS FOR AERODYNAMIC APPLICATIONS**	
Monitoring Responsable:		T. Berglind FOI
Chairman:		Dr. S.-H. Peng FOI

- **Objectives**

The overall objective of AG49 is to scrutinize, improve and assess some selected hybrid RANS-LES approaches in simulations of aerodynamic flows and, ultimately, to provide "best-practice" guidelines for industrial use relevant to aeronautic applications.

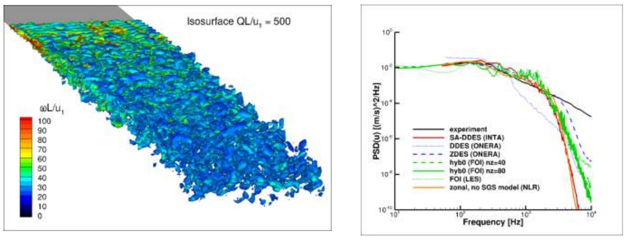
Along with further modelling improvement, an emphasis has been placed on a comprehensive exploration of turbulence-resolving capabilities in computations of four different Test Cases (TC), using hybrid RANS-LES methods. By means of cross comparisons, the *pros and cons* of these modelling approaches, as well as related numerical aspects, have been investigated in comparison with available experimental data.

- **Main Achievements**

In 2013, AG49 had the final project meeting in FOI (Stockholm, 7 March), at which the AG members had presented a summary of the work conducted in AG49. The planned computations for the test cases have been completed by all AG members and were summarized in cross plotting. The layout of the final summary report was discussed, and a draft of the summary report has been ready.

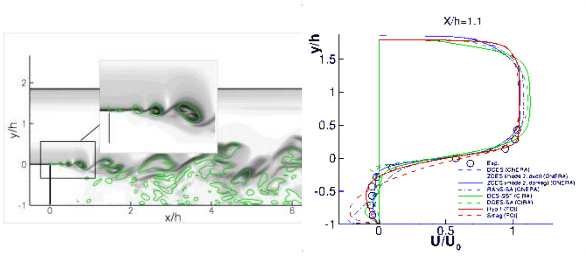
As a continuation of AG4, a new EG (EG69) has also had its kick-off on 8 March 2013 after the AG49 final meeting. Along with the AG49 members, several new members have participated in EG69.

In **Task 1**, computations of two fundamental TCs, mixing layer (TC 1.1) and backward-facing step (BFS, TC 1.2), have been carried out, upon which some modelling improvement and investigation of related numerical issues have been undertaken. In computation of the mixing layer (***TC 1.1***) by FOI, INTA, NLR and ONERA, it is shown that existing conventional hybrid RANS-LES models (including DES and DDES) are not able to capture the initial development of mixing-layer instabilities. Improvement of different degrees has been shown in predictions by NLR using stochastic X-LES, by ONERA using synthetic turbulent inflow conditions with ZDES and, to a less extent, by FOI using the HYB0 model with an energy-backscatter LES mode. NLR's computations show further that reduced dissipative sources may play a significant role for improved predictions; the same is true with improved modelling as done by FOI, NLR and ONERA.



TC 1.1: Mixing layer. Resolved structures (left); PSD of stream-wise velocity fluctuations (right).

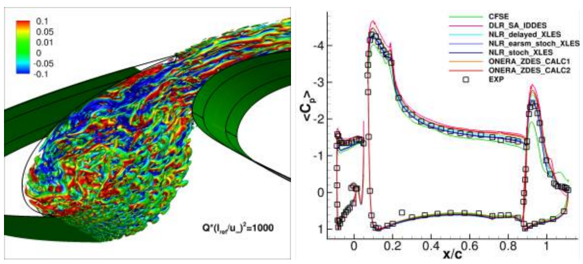
The BFS flow (***TC 1.2***) has been computed by CIRA, FOI and ONERA, using LES, HYB1, SST-DES, ZDES and WMLES methods. The computations in Task 1 have enabled to conduct modelling validation against available experimental data. The two TCs in this task have shown that it is significant to correctly model/resolve the upcoming boundary layer in the simulation of downstream flow properties.



TC1.2: BFS. Resolved shear-layer motion (left) and mean velocity profile at x/h =1.1.

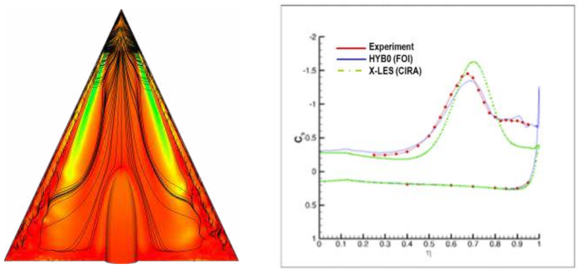
In **Task 2,** DLR, FOI, NLR and ONERA have conducted computations on the F15 high-lift configuration (***TC 2.1***) using SA-DES, SA-DDES, SA-IDDES, HYB0, X-LES (based on k-ω and EARSM) and ZDES, with a large set of results available for cross comparisons and modelling assessment. It has shown that grid resolution and the span-wise extension of computational domain gives an important impact on the prediction.

In general, the DDES-type model, in spite of its advantage as a remedy to the original DES model, leaves very severe "grey-area" problem in the free shear layer and its performance for the high-lift flow is similar to the SA RANS model.



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

For ***TC 2.2*** (VFE-2 Delta wing), computations are being performed by CIRA and FOI using X-LES and HYB0, respectively, in comparison with the experiment conducted by TUM-AER. The surface pressure is well predicted, but the pressure fluctuations are over-estimated.



TC 2.2 Round LE Delta Wing. Surface pattern visualization (left) and Cp distribution (right).

In summary, a large set of results have been produced on all the test cases using a number of different hybrid RANS-LES methods, by which the modelling approaches have been scrutinized. Improved modelling has been reported, and some modelling-related numerical issues have also been addressed.
The AG49 work has contributed to a systematic assessment of some typical hybrid RANS-LES methods by means of collaborative analysis of four typical test cases. The work has highlighted the advantages and disadvantages of selected approaches in turbulence-resolving simulations of aerodynamic flows. These have been reported in the final summary report. The lessons learned and the experience gained have also been summarized. The project has been undertaken in line with its plan and overall objectives.

- **Resources**

Resources		Year					Total
		2009	2010	2011	2012	2013	
Person-months	Actual/ Planned	A3 P4	A21 P20	A20 P16	A15 P15	A7 P7	A66 P62
Other costs (in K€)	Actual/ Planned	A20 P30	A175 P171	A170 P166	A100 P100	A70 P70	A535 P537

- **Completion of milestones**

Work package	Planned		Actual
	Initially	Currently (updated)	
Kick-off meeting	25 Sept. 2009		25 Sept. 2009
Specification of all TCs	Oct 2009		Oct. 2009
Experimental data of TCs 1.1, 1.2 and 2.1	Feb. 2010		Feb. 2010
Grids and preliminary computations of all TCs	April 2010		April 2010
TC 2.2 experimental data	April 2010	Feb. 2012	Jan. 2012
M6 AG meeting	April 2010		April 2010
1st set of results of all TCs	Oct. 2010		Oct. 2010
M12 AG meeting	Oct. 2010		Oct. 2010
Improved computations of TC1.1 and TC 2.1	Dec. 2010		Dec. 2010
M18 AG meeting	April 2011		April 2011
First cross comparisons for TC 1.1 and TC 1.2	Oct. 2011		Oct. 2011
M24 meeting	Oct. 2011		Oct. 2011
Further cross comparison of TC 1.1, 1.2 & 2.1	April 2012		April 2012
M30 meeting	April 2012		April 2012
M36 meeting	Mar. 2013		Mar. 2013
Final report	Sept. 2013		Nov. 2014

- **Benefits**

The project has provided a summary of the computations and the lessons learned and experience gained in the project work. Consequently, the CFD tools used by AG members will be improved. The results will facilitate "*correct and effective*" use of hybrid RANS-LES methods in aeronautical applications. With all AG49 members included, moreover, a new EG (AD/EG-69) has been established. A draft of the description of technical work for the new AG after EG69 has been prepared. The new AG was launched in April 2014.

- **AG membership**

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

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

Action Group Chairman: Dr Pieter Sijtsma, NLR (Pieter.Sijtsma@nlr.nl)

The Background

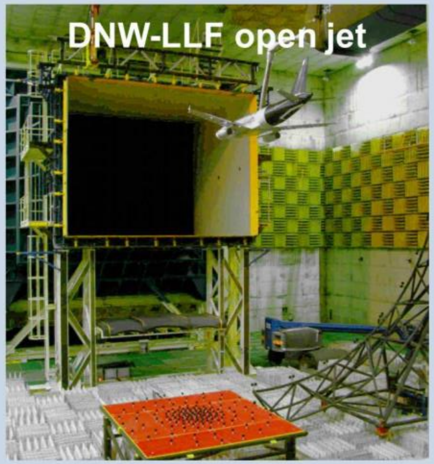
Aeroacoustic wind tunnel tests are typically conducted in open jets
Sound propagates through shear layer

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

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

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

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



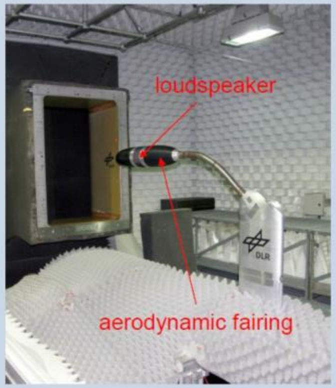
The Programme

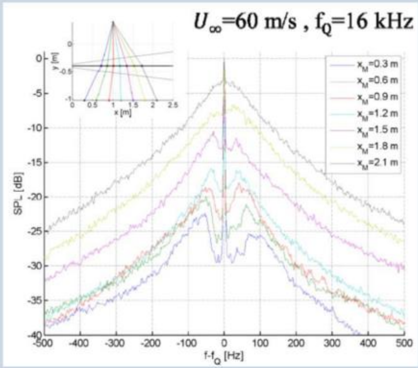
Objectives of AD/AG-50
- To improve the understanding of shear layer effects;
- To quantify the magnitude of shear layer effects, including the dependence on different parameters;
- To develop procedures to correct for shear layer effects;
- To investigate the possibilities to reduce shear layer effects.

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

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

Project duration: 1 January 2010 – 30 April 2013



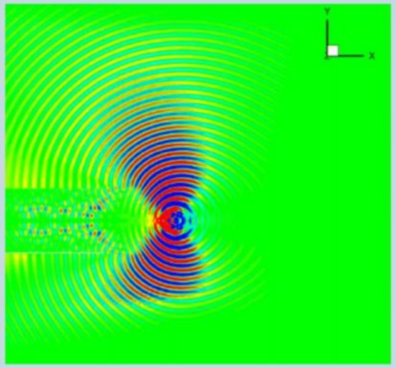


The Outcomes

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

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

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



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

AD/AG-50	**EFFECT OF WIND TUNNEL SHEAR LAYERS ON AEROACOUSTIC TESTS**	
Monitoring Responsable:		K. de Cock NLR
Chairman:		P. Sijtsma NLR

- **Objectives**

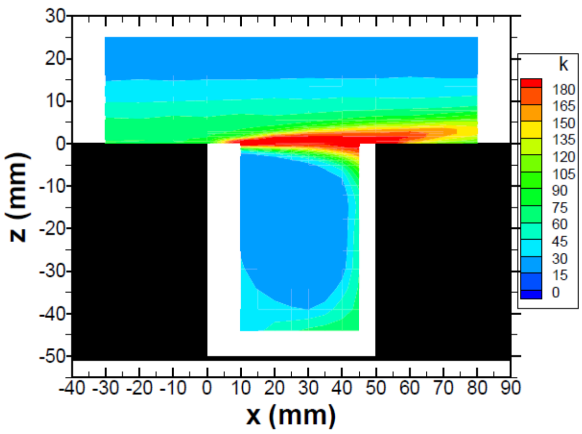
AD/AG-50 investigated the effects of open jet shear layers on acoustic wind tunnel measurements. Aeroacoustic wind tunnel tests are generally conducted in open jet wind tunnels (see picture below). The sound from the model has to pass through the open jet shear layer, which causes refraction, spectral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

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

- **Main achievements**

AD/AG-50 started in January 2010 for a duration of 3 years. At the beginning of the project a deliverable scheme was defined and agreed by the partners. Progress meetings were held every 6 months, hosted by several partners. On request of the majority of the partners, there has been a 3 months extension until April 2013.

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



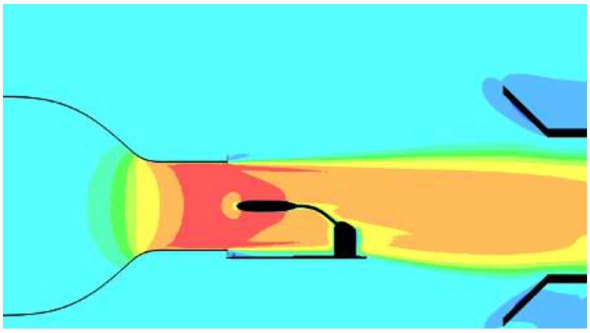
DLR and NLR carried out acoustic and aerodynamic measurements in the open jets of the DNW-PLST, NLR-KAT and DLR-AWB wind tunnels, to characterize spectral broadening as a function of wind speed, frequency, geometry and shear layer thickness. The test conditions for the different facilities were complementary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

effects were also investigated. The use of porous Kevlar material proved to be beneficial.

In addition to the DLR/NLR experiments, ISVR analysed spectral broadening using an existing high quality database from QinetiQ's round jet facility. Herewith, the transition from "weak" to "strong" haystacking, and also the simultaneous angular and frequency scattering was demonstrated for the first time.

The first part of the computational work consisted of a comparison between existing correction methods for shear layer refraction from different partners. NLR and ONERA performed analytical calculations for a limited number of academic benchmark cases using their ray-acoustics based correction methods for shear layers of zero thickness. For the same benchmark cases CIRA calculated the results with their Finite Element Method. The agreement between the three partners was good, showing that the ray acoustics assumption is generally valid for calculating sound refraction by a shear layer.

The second part of the computational work package consisted of advanced numerical calculations of (1) a parallel flow, (2) a diverging mixing layer, and (3) the complete AWB wind tunnel set-up (see picture below). CIRA have provided benchmark results for cases 1 and 2. Using a full 3D Euler method in perturbative form, ONERA compared their results to the CIRA benchmarks, showing good agreement. Finally, DLR performed CFD calculations of the AWB jet with their RANS code, the results of which can be used as input for future CAA calculations.



- **Management issues**

Stefan Oerlemans has been the AD/AG-50 chairman until April 2012, when he left NLR. He was replaced by Pieter Sijtsma (NLR).

- **Results/benefits**

This project yielded better understanding of shear layer effects, improved correction procedures and improved shear layer characteristics. Tools have been developed to improve the quality of aeroacoustic wind tunnel testing substantially. Work performed within the Action Group has led to the following publications:

- D. Casalino (CIRA), "Finite element solutions of a third-order wave equation for sound propagation in sheared flows", AIAA Paper-2010-3762, 2010.
- S. Kröber et al. (DLR), "The current understanding of the spectral broadening effect by turbulent shear layers", AIA-DAGA 2013 Conference on Acoustics, 18-21 March 2013, Merano, Italy.
- S. Kröber et al. (DLR), "Experimental investigation of spectral broadening of sound waves by wind tunnel shear layers", 19th AIAA/CEAS Aeroacoustics Conference, 27-29 May 2013, Berlin, Germany.

More conference papers and/or journal articles are expected.

- **AD/AG-50 membership**

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- **Resources**

Resources		Year				Total
		2010	2011	2012	2013	
Person-months	Actual/ Planned	16/ 21	16/ 20	8/ 17	10	50/ 58
Other costs (in K€)	Actual/ Planned	60/ 80	60/ 80	0/ 20	20	140/ 180

- **Completion**

The final meeting took place in Amsterdam on the 10th of April, 2013 and the final report was delivered December 2013.

GARTEUR — GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

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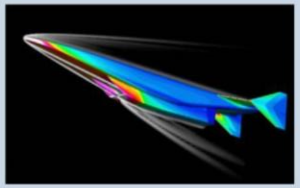
AD-AG51 : Effect of laminar/turbulent transition in hypersonic flows

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

The Background

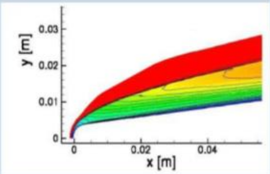
Transition laminar/turbulent:
Thrust-drag balance and air intake adaptation (air breathing hypersonic vehicles)
Heat fluxes (re-entry vehicles)



Different experimental data sources in Europe

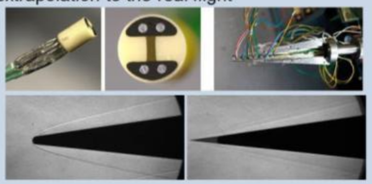
Increasing capability of CFD :
Need of tools/methods to predict laminar/turbulent transition in hypersonic using RANS code

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

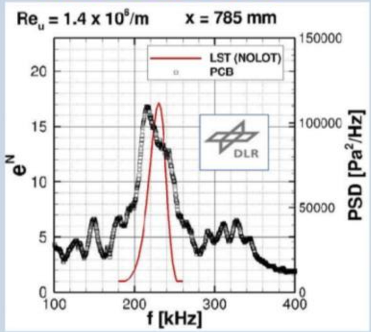


State of the art:
Linear stability theory, Wind tunnel experiments

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

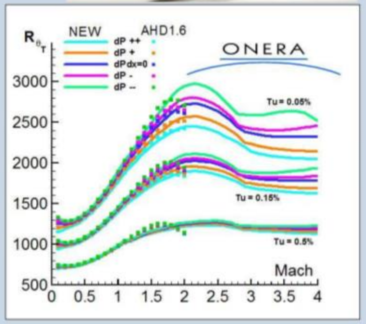


Activities 2013



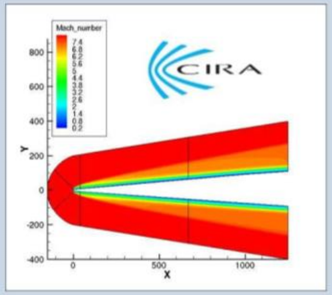
WP1 :
Experimental data described in a draft report, to be completed.
Part of the data bank available at ONERA ftp site.
Figure :
Linear stability calculation compared to experimental wall pressure spectra measured using miniature PCB pressure sensor.

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.

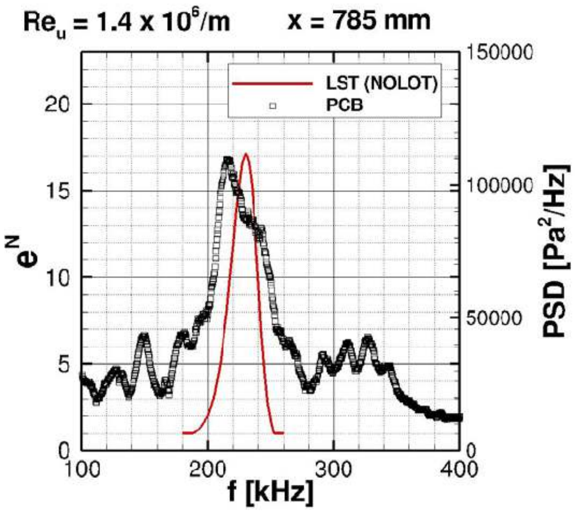


Figure 1 : Wall pressure spectrum compared to linear stability calculation (LST) - DLR HEG Mach 7.5 test of a blunted cone [1]

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 $\Lambda_2 = \frac{\theta^2}{\nu}\frac{\partial U_e}{\partial x}$.

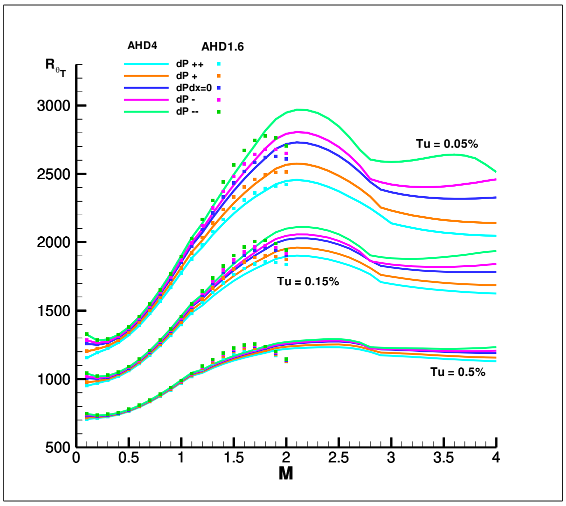


Figure 2 : Application of the new criterion up to Mach 4

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).

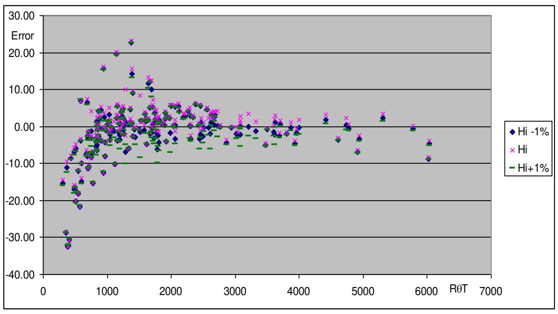


Figure 3 : Precision evaluation using similar profiles $1.1 < Me < 4$; $-0.0265 < {}_2 < 0.015$; $.05\% < Tu < 1\%$

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.

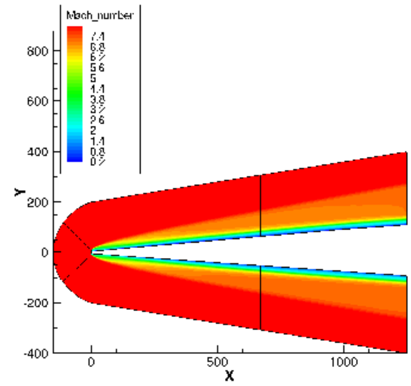


Figure 4 : Mach 8 computation of LEA forebody

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**

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- **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
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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: 3 years (2013-2015)

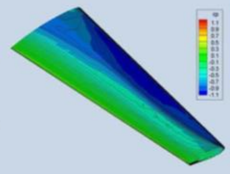
AG52 Work Breakdown Structure

- **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**

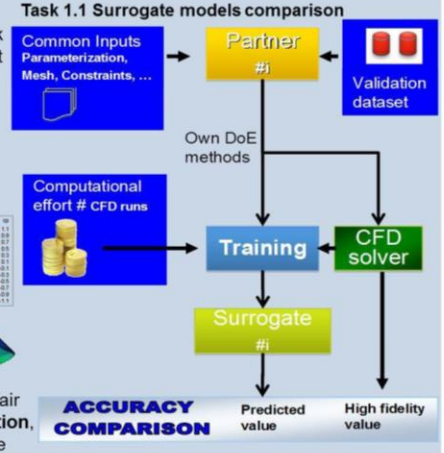
Work plan: The work in AG52 is divided into three tasks. Task 1 and 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3.

Two test cases are defined in Task 1:
TC 1.1 RAE2822 airfoil
Design points: DP1 M=0.734, Re=6.5x106, AoA=2.65º.
DP2 M=0.754, Re=6.2x10^6, AoA=2.65º
Objetive: maximize C_L/C_D

TC 1.2 DPW-W1 wing
Design points: DP1: M=0.76, C_L=0.5, Re=5x10^6, DP2: M=0.78, C_L=0.5, Re=5x10^6, DP3: M=0.20 and C_L^{max} (optima) >= C_L^{max} (original). Objective: Minimize C_D with constant C_L

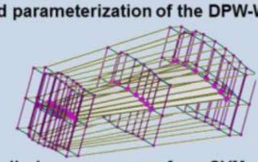


Task 1.1 Surrogate models comparison

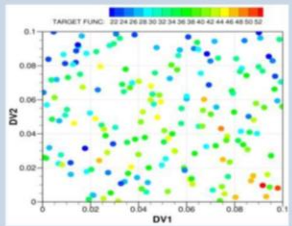


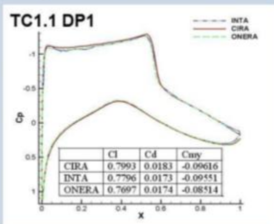
In order to minimize the sources of discrepancies and allow a fair comparison between surrogates, the **geometry parameterization**, the **computational grids** (unstructured and structured) and the **surface deformation algorithm** are **shared** between all partners.

Shared parameterization of the DPW-W1 wing



A CFD cross-analysis of the initial configurations has been performed to quantify differences of using different solvers..





Preliminary measures for a SVM surrogate

Cd		Cl	
MAE	MSE	MAE	MSE
1.4001e-04	3.7997e-08	5.8423e-04	6.2314e-07
1.3642e-03	3.3071e-06	4.8181e-03	4.1851e-05
1.2694e-03	2.7198e-06	4.1788e-03	3.0904e-05

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)

Current Status:
- **Common data** (parameterization, grids and surface mesh deformation) for all TCs of Task1 are **available** for surrogate model validation and optimization comparison.
- A website has been created for dissemination: www.ag52.blogspot.com
- Participation and organization of Special Sessions at **EUROGEN 2013** and **ECCOMAS CFD 2014**.
- A **CFD cross-analysis** to identify the error sources of using different CFD solvers has been performed.
- Preliminary results on surrogate validation (task 1.1) have been shown by some of the partners

Next steps:
- All AG members have started the integration of the common tools into their optimization frameworks and are **currently extracting the surrogate validation data**.
- **Comparative studies will be conducted** for surrogate models evaluation, and proper error measurement, **following the PR03 document**.
- Results on surrogate models comparison will be shown in next meeting.

Next meeting: February 2014, INTA

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

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 analyse 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 analysed to get the optimum solution.

- **MAIN ACHIEVEMENTS**

The AD/AG-52 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 were accepted by the GARTEUR council.
The work in AG-52 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.
Two test cases are defined in Task 1:
<u>TC 1.1 RAE2822 air foil:</u>
DP1: M=0.734, Re=$6.5x10^6$, AoA=2.65º.
DP2:M=0.754, Re=$6.2x10^6$, AoA=2.65º.
Objective: maximize C_L/C_D subject to certain aerodynamic and geometric constraints.

<u>TC 1.2 DPW-W1 wing</u>
DP1: M=0.76, C_L=0.5, Re=$5x10^6$
DP2: M=0.78, C_L=0.5, Re=$5x10^6$
DP3: M=0.20 & C_L^{max}(optima)>=C_L^{max} (original).
Objective: Minimize C_D with constant C_L subject to certain aerodynamic and geometric constraints.
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 between surrogates, the geometry parameterization, the computational grids (unstructured and structured) and the surface deformation algorithm are shared between all partners. The selected set of surrogate techniques for task 1.1 are in the table.

Partner	SVMs	POD	Kriging	GE Kriging	RBF	Ensemble
INTA	TC1.2					
CIRA		TC1.1	TC1.1			
FOI					TC1.2	
ONERA		TC1.1	TC1.2	TC1.2		
UAH	TC1.2					
UNIS						TC1.1
VUT			TC1.1		TC1.1	

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)

Current Status:
- **Common data** (parameterization, grids and surface mesh deformation) for all TCs of Task1 are **available** for surrogate model validation and optimization comparison:
  - Common **meshes** (CIRA, INTA and ONERA) for all the test cases
  - Geometry **parameterization** (INTA) for all the defined test cases
  - Surface deformation **tool** (INTA) and volume mesh deformation tool executable (FOI)
  - NURBS parameterization **parser** (INTA)
  - **Tutorials** for the common tools (INTA)
- Participation and organization of Special Sessions at **EUROGEN 2013** and **ECCOMAS CFD 2014**.
- A **website** has been created for dissemination: **www.ag52.blogspot.com**
- A **CFD cross-analysis** to identify the error sources of using different CFD solvers has been performed.
- Preliminary results on validation (task 1.1) were shown by some of the partners

Next steps: All AG members have started the integration of the common tools into their optimization frameworks and are **currently extracting the surrogate validation data**.

- **Comparative studies will be conducted** for surrogate models evaluation, and proper error measurement, **following the PR03 document**.
- Results on surrogate models comparison will be shown in next meeting (February 2014).

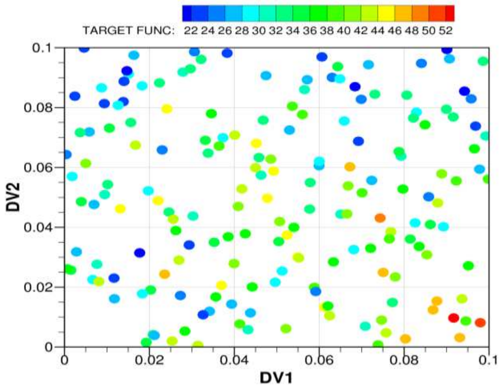


Figure 1: Sampled target response (aerodynamic efficiency) as a function of two design variables

- **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. It is also foreseen that the AG will lead to publications, either as conference or journal articles.

- **MANAGEMENT ISSUES**

A face-to-face meeting was expected to take place in October at CIRA, but it had to be cancelled due to limited attendance. In its place, a review teleconference was allocated.
The integration of common tools is still on-going due to format compatibility issues with partners’ tools (few delay on the schedule –> expected to be recovered when solved).
Intensive involvement of Emiliano Iuliano (vice-chairman, CIRA) in the management of the Action Group is considered very positive.

- **MEETINGS**

The Kick-off meeting took place at INTA Madrid on 12nd and 13rd of February 2013.

- Review teleconf. number 1 was held on 11th of April 2013.
- Review teleconf. number 2 took place on 31st of May 2013.
- Review teleconf. number 3 was held on 8th of November 2013.
- Review teleconf. number 4 will be on 28th of January 2013.

Next face-to-face meeting will take place on the 19th and 20th of February 2014 at INTA.

- **AD/AG-52 MEMBERSHIP**

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- **RESOURCES**

Resources		*Year*			*Total*
		2013	*2014*	*2015*	
Person-months	**Actual / Planned**	A20 P22.7	P22.7	P22.7	P68.1
Other costs (in k€)	**Actual / Planned**	P45 P63	P63	P63	P189

- **PROGRESS/COMPLETION OF MILESTONES**

Work package / Task	Planned		Actual
	Initially (end of….)	Currently (updated)	
Task 1 – DPW-W1 definition and common geometry parameterization	March 2013		March 2013
Task 1 – RAE2822 definition and common geometry parameterization	March 2013	May 2013	May 2013
Task 1 – Shared unstructured grids	April 2013		April 2013
Task 1 – Shared structured grids	April 2013	Sept 2013	Sept 2013
Task 1 – Common tools	May 2013		May 2013
Task 1 – Report on strategy for surrogate models comparison	Sept 2013	Dec 2013	Dec 2013
Task 1 – Surrogate validation results	Nov 2013	Feb 2014	

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: Dr Ardeshir Hanifi, FOI (ardeshir.hanifi@foi.se)

The Background

Environmental issues

Future demands on huge reduction of CO_2 and NO_X have caused an increased interest for laminar aircraft. Design of such devices and specifications of the manufacturing tolerances require a reliable and accurate prediction of transition.

Receptivity process

In the last fifty years the initial linear amplification and the nonlinear stage of growth of these perturbations can now be accurately estimated. However, accurate initial conditions for the amplified waves need to be provided in order to correctly predict the onset of transition.

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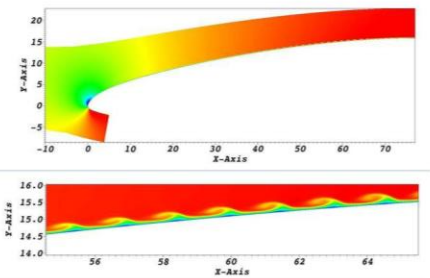


Direct numerical simulation around NLF (2)-0415. Lower figure is a close up of CF vortices in side the boundary layer caused by DRE.

The 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:

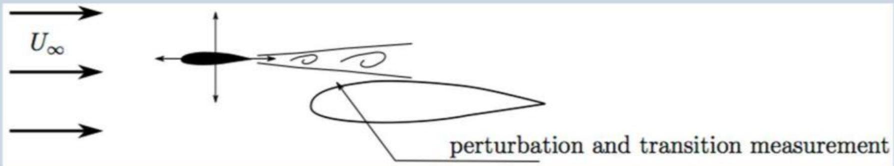
- Acoustic receptivity in 3D boundary-layer flows
- Receptivity to free-stream perturbations
- Effects of steps and gaps on boundary-layer perturbations

Experiments on effects of free-stream perturbations using the ONERA D profile. 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.

Partners

FOI, KTH, CIRA, DLR, Imperial College, Airbus

Project duration: September 2013 – September 2016



Schematic view of the experimental set-up in the ONERA Juju wind tunnel.

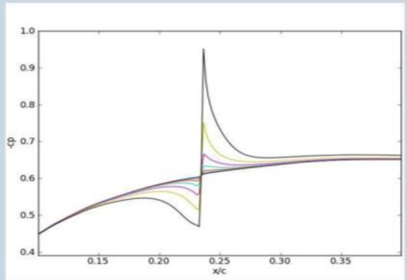
The Outcomes

Expected results/benefits

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

Main achievements

So far the activities are in starting phase or planning stage. IC & EADS have performed flow computations have for a range of step gap deformations at 23% chord on an underlying 2d symmetric aerofoil configuration (M2355).
FOI & KTH have implemented a projection method for extraction of amplitude of boundary-layer instability waves (TS and CF) from the unsteady flow filed. This is a necessary step for computation of acoustic receptivity coefficient from the DNS data.



Pressure and maximum N factor for increasing step height (cubic filler profile).

FOI KTH ROYAL INSTITUTE OF TECHNOLOGY CIRA DLR Imperial College London AIRBUS AN EADS COMPANY

AD/AG-53 RECEPTIVITY AND TRANSITION PREDICTION: EFFECTS OF SURFACE IRREGULARITY AND INFLOW PERTURBATIONS

Monitoring Responsable: T. Berglind
FOI

Chairman: Dr. 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.

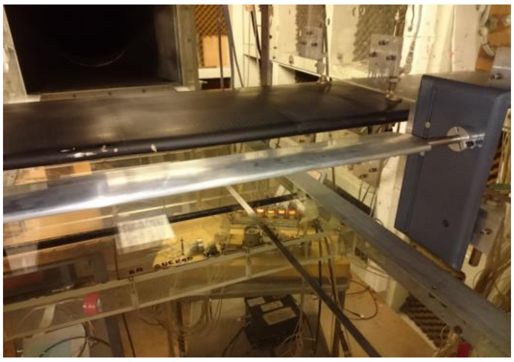
Numerical investigations of acoustic receptivity in 3D boundary layers. Comparison of direct numerical simulations with simpler methods like linearized Navier-Stokes computations and adjoint methods.

- **Expected results/benefits**

Understanding of capability of existing prediction methods through comparison with experimental and DNS data, and improvement of these methods.

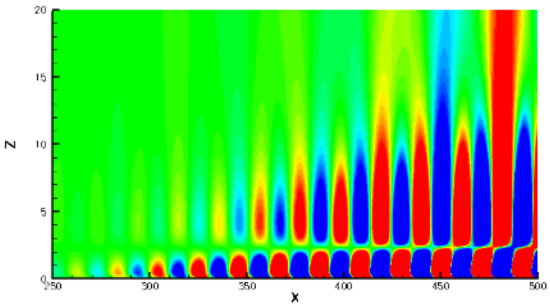
- **Main achievements**

The set up for ONERA experiments has been manufactured and installed in DMAE wind tunnel. The first test campaign was performed during October-November 2014. The pressure distribution on the main wing for several angles of attack was measured. The location of the natural transition on the main wing was detected with hot wire probe. A comparison with the predicted transition location (2D parabolas method) showed a good agreement.



Model installed in ONERA DMAE wind tunnel.

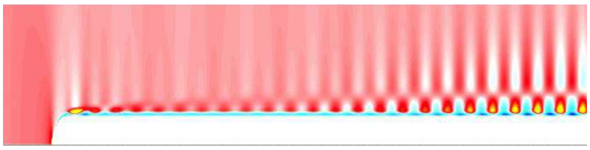
IC & EADS have developed a BiGlobal eigenvalue solver to study the perturbation generated by steps and gaps. Analyses have been performed for performed for mean flow given by RANS simulations (linearized Jacobian). N-factors of these eigenmodes have been calculated in order to analyse the evolution of the perturbations. Further, the linearized NS solver has been used to compute the perturbation field generated by randomly distributed surface roughness.



BiGlobal mode for perturbation generated by a gap. computed based on RANS solutions

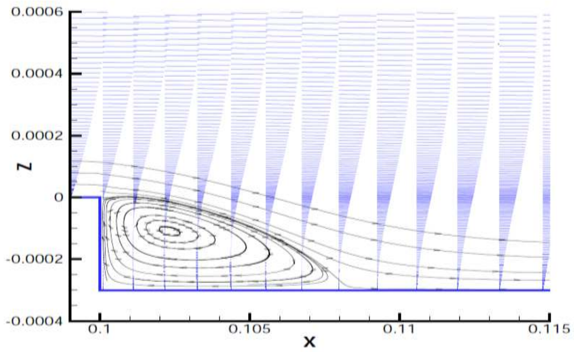
CIRA has been extending its receptivity code code to account for interaction of acoustic waves with surface roughness using adjoint methods following the approach of Zuccero & Luchini.

FOI & KTH have performed direct numerical simulations of acoustic receptivity of a flat plate with modified super-elliptic leading edge. Simulations of large roughness elements in a three-dimensional boundary layer have also been performed in order to analyse the global stability of the flow behind such elements. The idea is relate the critical size of roughness elements to global instability of flow behind it.



Direct numerical simulations of flow past a flat plate with modified super ellipse leading edge (instantaneous streamwise velocity is visualized).

DLR has performed flow computations of forward- and backward-facing steps. The obtained flow fields have been used to perform stability analysis in order to find the amplification of perturbations generated by such surface irregularities.



Flow simulations of flow past backward-facing step.

- **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 March 24, 2014 in Amalfi.

An overview of on-going activities was presented by A. Hanifi at the annual GARTEUR meeting on Sept. 24, 2014 at FOI.

- **AD/AG-53 membership**

Member	Organisation	e-mail
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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

GARTEUR 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.

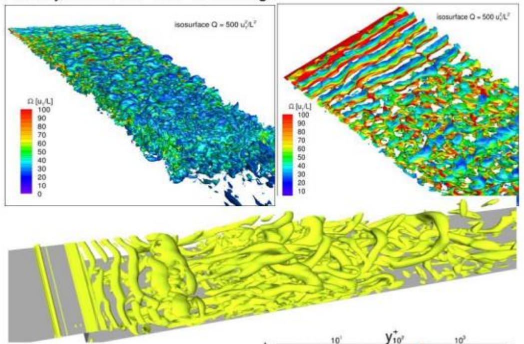
TC M2 Spatially developing boundary layer
Inflow defined with U = 70m/s and Re_θ = 3040. Focus on turbulence-resolving capabilities on the attached BL after the RANS-LES interface.

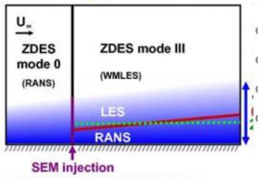
TC O2 NASA hump flow
Incoming BL has U = 34.6m/s, Re_c = 936000 (c = hump length). Focus on the turbulence-resolving capabilities on the flow separation over the hump.

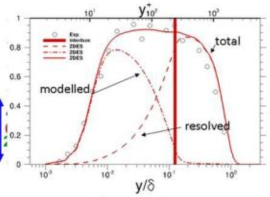
Task 3: Modelling assessment

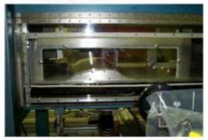
(Task Leader: **Airbus-Innovations** (EADS-IW))
Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.

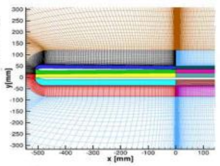
TC M3 Co-flow of BL and wake
Re = 2.4×10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.

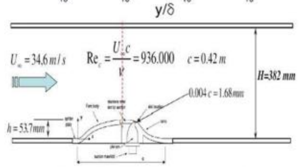


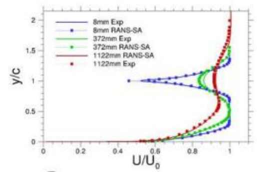












Results

- **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.

AIRBUS AIRBUS GROUP CIRA DLR FOI INTA NLR SAAB MANCHESTER 1824 The University of Manchester ONERA THE FRENCH AEROSPACE LAB TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

AD/AG-54	**RaLESin: RANS-LES INTERFACING FOR HYBRID AND EMBEDDED LES APPROACHESS**
Monitoring Responsable:	T. Berglind FOI
Chairman:	Dr.. S.-H. Peng FOI

- **Objectives**

AG-54 has been established after the work of EG-69. The overall objective of AG-54 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 activities**

AG-54, 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 AG-54 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 and 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 mixing layer (TC M1) by NLR, where the stochastic backscatter model is shown to improve the prediction over the baseline X-LES model. For the same TC, CIRA, DLR, FOI, INTA and ONERA have also started computations existing models and/or improved variants.

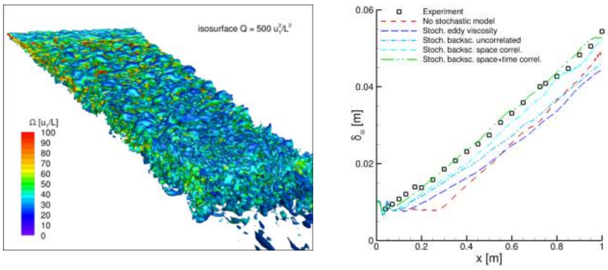


Figure 1: Example of computations by NLR for TC M1 (mixing layer) with an improved non-zonal stochastic backscatter model. Resolved structures (left); Vorticity thickness (right).

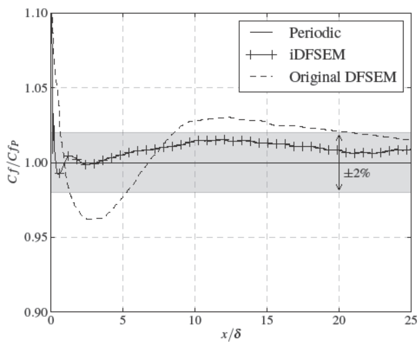


Figure 2: Improved DFSEM (iDFSEM) of UniMan in computations of turbulent channel flow.

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 synthetic turbulence was imposed.

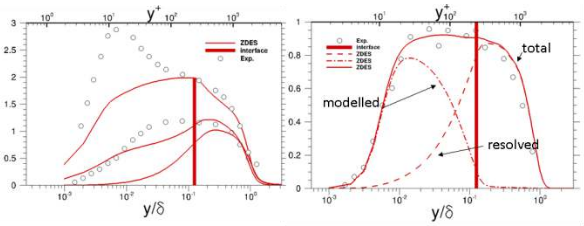


Figure 3: Example of zonal modelling computation of ONERA for TC M2 (Spatially developing boundary layer) with ZDES supported by SEM on the RANS-LES interface.

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.

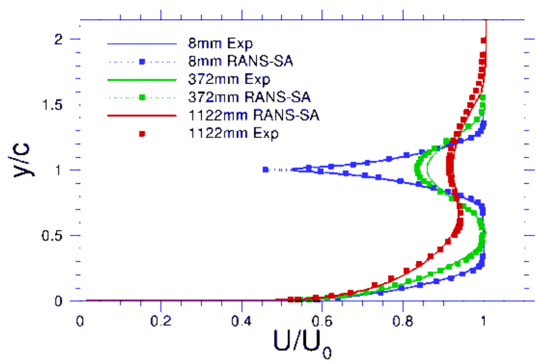


Figure 4: RANS verification of TC M3, serving late-stage hybrid RANS-LES computations with zonal and non-zonal methods.

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 & computation	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**

AG-54 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.

- **AD/AG-54 membership**

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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: Dr Olof Grundestam, FOI
(olof.grundestam@foi.se)

The Background

In order to increase the defensive capability of aircraft, 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, typically located on the fuselage or under the wing of an aircraft. Chaff can also be applied in naval warfare against anti-ship missiles.
Flares are used against IR-seeking missiles. They are much larger in size (typically a few decimetres in length) and are considered 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 hence of major importance to obtain an accurate description of the flow in the wake. Flares, on the other hand, are solid bodies and from this point of view, more conventional methods can be used to evaluate the aerodynamic properties.

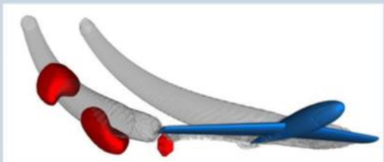
The Programme

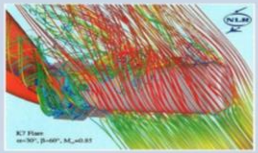
Objectives of AD/AG-55
The main objectives of the proposed activities are to obtain increased understanding and improved modelling tools for chaff dispersion and flare trajectory simulation. The project consists of two work packages: WP1 for chaff and WP2 for flares.The main focus of WP1 is to include directional information of the chaff. For this purpose chaff will assumed to have the shape of finite cylinders (or fibres). For WP2, the primary concern is how the burning of the flare IR payload affects the aerodynamic properties.

Approach
The proposed work is divided into chaff and flare parts. For chaff dispersion, two methods (Eulerian and Lagrangian) will be considered. The principle behind the Eularian method is that chaff is traced as a concentration instead of individual specimen (Lagrangian). The aim is include directional information for both approaches. In addition to this, parametric studies (chaff dispenser position, concentration and distribution) will be performed.
For flares, the primary focus is the aerodynamic properties and how they are affected by the burning of the IR payload. Numerical studies will include inert and reacting flares. For the latter case, a special boundary condition will be developed in order to model the release of heat and exhaust gases from flare. The final goal is to be able to incorporate all essential physical aspects of the process, hopefully also the 2-way fluid-flare coupling.

Partners
Airbus Military, Etienne Lacroix, FOI, MBDA, NLR

Project duration: Oktober 2014 – December 2017





The Outcomes

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

Main achievements
AD/AG-55 was approved by the GARTEUR board at the beginning of October 2014. and since several partners have not yet commenced their activities, no goals have been achieved so far.

FOI · AIRBUS MILITARY · LACROIX Protection Superiority · MBDA MISSILE SYSTEMS · NLR

AD/AG-55 COUNTERMEASURE AERODYNAMICS

Monitoring Responsable: T. Berglind
FOI

Chairman: Dr. O. Grundestam
FOI

- **Background**

In order to increase the defensive capability of aircraft, 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 are dispensed in very large numbers from specific dispenser devices, typically located on the fuselage or under the wing of an aircraft. Chaff can also be applied in naval warfare against anti-ship missiles.
Flares are used against IR-seeking missiles. They are much larger in size (typically a few decimetres in length) and are can be dispensed 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 hence of major importance to obtain an accurate description of the flow in the wake. A visualisation of a chaff cloud propagating in the wake of a simple configuration is shown in the figure 1. Flares, on the other hand, are solid bodies and from this point of view, more conventional methods can be used to evaluate the aerodynamic properties. Figure 2 displays the computed flow around a flare (work by NLR).

- **Proposed work**

The proposed work have been divided into two workpackages, one concerning chaff and one for flares.

The chaff workpackage is aimed at using two different methods to simulate chaff dispersion: An Eulerian approach in which the chaff concentration is represented as a scalar field (depicted in figure 1), and a Lagrangian method in which individual chaff are tracked. Both methods are intended to be 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.

The chaff workpackage (WP1) constitutes five subtasks:

1. Generation of computational grid and steady flow computation (see figure 2).
2. Eularian method for chaff
3. Lagrangian method for chaff
4. Parametric studies
5. Analysis and evaluation

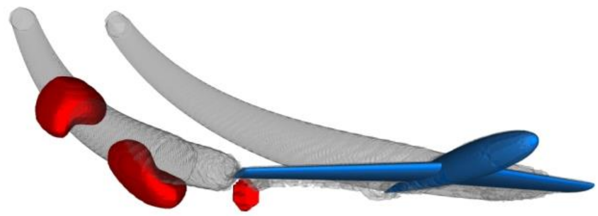


Figure 1: Simulation of chaff concentration transport.

Figure 2: Q-criterion isosurface of chaff test-case geometry (VFE2), preliminary result..

The flare work is focused on improved understanding and modelling of flare trajectories. Of special interest is how the burning of the IR payload affect the aerodynamic properties of a flare. These effects can include both exhaust gases (heat and mass flux) as well as deformation of the exterior surface due to the burning process. The WP also includes performing experiments on chaff trajectories, considering both inert and burning chaff. CFD will be performed for different levels of boundary condition – flight dynamics synthesis.
The flare workpackage is divided into the following subtasks:

1. Experimental database
2. Computational grid and CFD of inert flare
3. Development of mass and heat flux boundary condition
4. Computations using special boundary condition
5. Synthesis

The two workpackages are distinct and without any particular overlap.

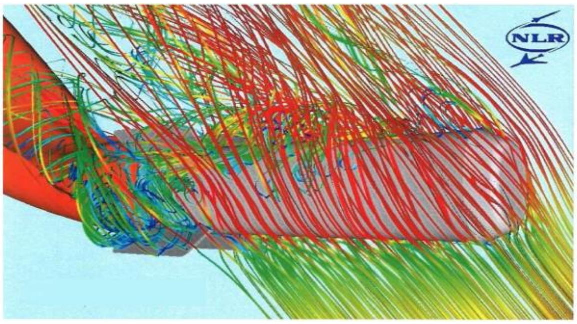


Figure 3: Visualisation of flow around a flare.

- **Achievements**

AD/AG-55 was approved by the GARTEUR board at the beginning of October 2014. And since several partners have not yet commenced their part of the work, no goals have been achieved so far.

- **Expected results**

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**

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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 of 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.

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AVIATION SECURITY

Figure 1: The ICT Environment for Aviation

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

Two meetings took place in 2014: February 27th in Brussels, Belgium and September 11th in Palaiseau, France.

Four Exploratory Groups have been created in 2014:

- 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 in the pages hereafter.

6 YEARS ROLLING PLAN FOR EGS AND AGS

6 years rolling Plan for AS/EGs

No	Theme	Topic	2011	2012	2013	2014	2015	2016
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 2015 is to produce a White paper to describe GARTEUR position on Aviation Security. AS GoR will also go on exploring each of the themes, contact potential new participants in research laboratories as well as in industry and study funding opportunities.

In 2015 the first meeting will take place on February 12th. The second meeting will be held in September.

Virginie Wiels
Chairman (2014-2015)
Group of Responsables Aviation Security

GOR MEMBERSHIP

Current membership of the Group of Responsables Aviation Security

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

Members			
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Ms Angela Vozella	CIRA	Italy	A.Vozella@cira.it
Mr. René Wiegers	NLR	Netherlands	Rene.Wiegers@nlr.nl

EXPLORATORY GROUP REPORTS

AS/EG-1	TOWARDS AN INFORMATION SECURITY MANAGEMENT SYSTEM FOR THE AVIATION SECTOR
Monitoring Responsable / Chairman	René Wiegers (NLR)

- **Theme: Cybersecurity**

- **Description of the EG**

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 scenarios.

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-1 membership**

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José Luis Huertas	INTA	huertasjl@inta.es
Angela Vozella	CIRA	A.Vozella@cira.fr

Members from other organisations might also be involved in this EG.

AS/EG-2 ENHANCING AIRPORT SECURITY AGAINST CBE THREATS

Monitoring Responsable / Chairman Dr. Handke (DLR)

- **Theme: CBE (Chemical, Biological and Explosive) Detection**

- **Description of the EG**

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 aircraft 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-2 membership**

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Juergen Handke	**DLR**	Juergen.Handke@dlr.de
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Alexandre Bresson	ONERA	alexandre.bresson@onera.fr

Members from the Spanish Minitry of Defence or from other organisations might also be involved in this EG.

AS/EG-3	**DETECTION OF THREATENING LASER RADIATION ON AIRCRAFT OR HELICOPTERS FOR FUTURE PROTECTION OF PILOTS**
Monitoring Responsable / Chairman	Bernd Eberle (Fraunhofer)

- **Theme: Dazzling**

- **Description of the EG**

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-3 membership**

Member	Organization	e-mail
Bernd Eberle	**Fraunhofer**	bernd.eberle@iosb.fraunhofer.de
Hans-Albert Eckel	DLR	Hans-Albert.Eckel@dlr.de
Pierre Bourdon	ONERA	pierre.bourdon@onera.fr

Members from SAGEM, Airbus EADS, DIEHL, OTAN/STO or other organisations might be involved in this EG in the future.

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.	
Monitoring / Chairman	**Responsable**	Francisco Muñoz Sanz (INTA)

- **Theme: Malevolent use of RPAS**

- **Description of the EG**

The research areas under the scope of this topic will mainly cover the scenario analysis. It is intended to map the different occasions, physical lay outs 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.

- **AS/EG-4 membership**

Member	Organization	e-mail
Francisco Muñoz Sanz	INTA	mugnozsf@inta.es
Joerg Dittrich	DLR	joerg.dittrich@dlr.de
Claude Le Tallec	ONERA	Claude.LeTallec@onera.fr

Members from other organisations might be involved in this EG in the future.

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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.

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FLIGHT MECHANICS, SYSTEMS AND INTEGRATION

GoR-FM OVERVIEW

GOR ACTIVITIES

The FM GoR faced a few changes in membership in 2014. 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 alive in 2014:
- 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 2014. The development of a pilot paper was agreed.

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 2014, there were no Action Groups active.

MANAGEMENT ISSUES

The GoR met on two occasions during 2014, 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).

Existing participation in the FM GoR by industry and research organizations was secured in 2014.

FUTURE PLANS

During 2015 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	2010	2011	2012	2013	2014	2015
B	Towards greater Autonomy in Multiple Unmanned Air Vehicles	FM/AG-18					AG Finished	
A	Flexible Aircraft Modelling Methodologies	FM/AG-19					Cancelled	
A	Fault Tolerant Integrated Aircraft Management System	PP		On halt				
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 2014:

- 101st GoR(FM) meeting at ONERA, Toulouse, France, 26th of February 2014;
- 102nd GoR(FM) meeting at CIRA, Capua, Italy, 5th of November 2014.

Nine national representatives and IPOCs attended each of the meetings during 2014 to monitor the activities of the EGs and to discuss new ideas and pilot papers. The estimated effort associated with these activities amounts to 2,5 man-months (50 man-days) in total and the associated travel and subsistence costs are roughly 20 k€.
The following meetings are planned for 2015:

- 103rd GoR(FM) meeting at INTA, Madrid, Spain, 10th March 2015;
- 104th GoR(FM) meeting at FOI, Sweden, in September 2015.

Francisco Muñoz Sanz
Chairman (October 2013 – March 2015)
Group of Responsables
Flight Mechanics, Systems and Integration

GOR MEMBERSHIP

2014 membership of the Group of Responsables Flight Mechanics, Systems and Integration

Chairman			
Mr. Francisco Muñoz Sanz	INTA	Spain	mugnozsf@inta.es

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

Members			
Mr. Antonio Vitale	CIRA	Italy	a.vitale@cira.it
Mr. Daniel Cazy (until mid 2014)	Airbus	France	daniel.cazy@airbus.com
Mr. Emmanuel Cortet (from mid 2014)	Airbus	France	Emmanuel.CORTET@airbus.com
Mr. Martin Hagström	FOI	Sweden	martin.hagstrom@foi.es
Mr. Bernd Korn	DLR	Germany	Bernd.Korn@dlr.de
Mr. Philippe Mouyon	ONERA	France	philippe.mouyon@onera.fr

Industrial Points of Contact			
Mr. Francisco Asensio	Airbus Military	Spain	Francisco.Asensio@military.airbus.com
Mr. Laurent Goerig	Dassault	France	laurent.goerig@dassault-aviation.com
Mr. Fredrik Karlsson	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 alive in 2014:

- 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 2014. The development of a pilot paper was agreed.

FUTURE TOPICS

One pilot paper was agreed on: Pilot Wearable Avionics.

TABLE OF ACTION GROUPS AND EXPLORATORY GROUPS

Subjects	ST	2009	2010	2011	2012	2013	2014	2015
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	EG 26 =>						
FM/AG-19 Flexible Aircraft Modelling Methodologies	AG	EG 27 =>						
FM/EG-26 Machine Based Reasoning for Multiple UAVs	EG		=> AG 18					
FM/EG-27 Flexible Aircraft Modelling Methodologies	EG		=> AG 19					
FM/EG-28 Non-linear flexible aircraft benchmark for flight control methods assessment	EG							
FM/EG-29 Safety assessment of flight collision avoidance systems with formal V&V, simulation and proofs	EG							

Active Closed Status December 2014

ACTION GROUP REPORTS

No FM Action Groups were active in 2014.

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

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

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

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

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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 innovations which may be mature for collaboration. The GoR also considers other collaborative initiatives within Europe, bringing mutual understanding and co-ordination and hence contributing to best use of scarce resources. For instance, the GoR is maintaining an awareness of the range of EU Technology Programmes.

MANAGEMENT ISSUES

The chairmanship in 2014 was held by Lorenzo Notarnicola (CIRA). Vice Chairman is Mark White (University of Liverpool) who will take the chairmanship 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:

- 69th GoR Meeting: 11-12 February '14, CIRA, Capua, Italy
- 70th GoR Meeting: 9-10 September '14, ONERA, Salon-de-Provence, France

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 2014 the activities in the HC-AGs was at a fairly good level. The 2014 started with three active Action Groups and six Exploratory Groups resulting, at the end of the year, in five running AGs and one EGs.

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.

These topics can be:

- Conceptual Design of Helicopters
- CFD based flow prediction for complete helicopters
- Performance, fuel efficiency
- Safety (Crash, Hums, Crew Workload, all weather operations)
- Noise external (passive, active rotors, flight procedures, atmospheric effects, shielding)
- Noise internal (Comfort, Costs, Weight ➔ fuel consumption)
- Vibrations having impact on: Comfort, Costs (maintenance)
- Predictive method & Tools
- Synergies between Civil and Military 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” has been started May 2010 for a 3 years duration. This AG was extended up to the end of 2014, 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 was 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.

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 2015.

HC/EG-31 "PreFCS - Conceptual Design of Helicopters", launched early 2013. The group, due to a lack of resources, was inactive during 2014 and it was finally closed. The addressed general topic, still considered of interest will be retained for future activities.

HC/EG-32 "Forces on Obstacles in Rotor Wake" was launched in April 2013. During 2014 the exploratory group successfully concluded its activities and proposed the launch of the action group HC/AG22.

HC/EG-33 "Wind turbine wakes and the effect on helicopters" was launched in April 2013. During 2014 the exploratory group successfully concluded its activities and proposed the launch of the action group HC/AG23.

HC/EG-34 CFD based flow prediction for complete helicopters was launched in Feb. '13. The group, due to a lack of resources, was inactive during 2014 and it was finally closed. The addressed topic, still considered of interest, will be retained for future activities.

HC/EG-35 "Helicopter Fuselage Scattering (installation) Effects for Exterior/Interior Noise Reduction" was lauched in September 2013. During 2014 the exploratory group successfully concluded its activities and proposed the launch of an action group, likely to start early 2015.

GENERATING NEW TOPICS FOR COMMON STUDIES

The 3–5 year planning will continue to be implemented and was presented in more details to the Council in the Autumn 2014 meeting in Venice. 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 p	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				EG32 =>					
Helicopter Fuselage Scattering Effects for Exterior/Interior N	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 N	HC/EG35					=> AG24				
Testing/Modelling for Interior Noise Investigation	ID	=> EG28								
Intelligent Lifeing & HUMS	ID		=> EG29							
(Pioneering)	ID									
Basic Acoustics	ID									
Acoustic Monitoring	ID	=> no EG								
(HC Integration into ATM)	ID									
(Centrifugal Effects on Boundary Layer)	ID									
Forces on Obstacles in Rotor Wake; AG17 follow-up	ID				=> EG32					
(Synergies between Civil and Military Systems)	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 Redu	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 became partners.

REPORTS ISSUED

In 2014, no final reports were issued.

FORESEEN GOR ACTIVITY

Two meetings are planned in 2015; the first one on 11-12 Feb 2015 at TUDelft, Delft, The Netherlands and the second one on October in UK.

Lorenzo Notarnicola
Chairman (2013-2014)
Group of Responsables Helicopters

GOR MEMBERSHIP

Membership of the Group of Responsables Helicopters (end 2014)

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

HC-GoR visiting ONERA, Salon-de-Provence, during the 70th GoR meeting (9-10 September 2014):
Joost Hakkaart, Blanche Demaret, Mark White, Klausdieter Pahlke, Lorenzo Notarnicola, Elio Zoppitelli.

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action groups (AG)

The following Action Groups were active throughout 2014:

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 2014, 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.

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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.

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 2015.

HC/EG-31 "PreFCS - Conceptual Design of Helicopters", launched early 2013. The group, due to a lack of resources, was inactive during 2014 and it was finally closed. The addressed general topic, still considered of interest will be retained for future activities.

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HC/EG-35 "Helicopter Fuselage Scattering (installation) Effects for Exterior/Interior Noise Reduction" was lauched in September 2013. During 2014 the exploratory group successfully concluded its activities and proposed the launch of an action group, likely to start early 2015.

TABLE OF PARTICIPATING ORGANISATIONS

	HC/AG and HC/EG numbers										
	AG19	AG20	AG21	AG22	AG23	EG29	EG31	EG32	EG33	EG34	EG35
Research Establishments											
ONERA		■	□	□	□	□	□	□	□	□	□
DLR		□	□	□	□	□	□	□	□	■	■
CIRA		□		■	□		□	■	□	□	□
NLR	■	□	□	□	■	□	□	□	■	□	□
Dstl											
Industry											
EC											□
ECD						□					
AgustaWestland	□		□				□				
Thales			□								
LMS (Belgium)	□										
CAE (UK)			□								
ZF Luftfahrttechnik GmbH (D)						□					
IMA Dresden (D)						□					
SMEs											
ESI											
ALTAIR											
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)	□										
University Loughborough (UK)											
TU Delft (NL)			□	□	□		□		□		
University of Twente (NL)											
University of Munich (D)						■					
University of Lille (Fr)											
University of Roma La Sapienza (IT)	□										
University of Roma 3 (IT)							□				
Politecnico di Milano (IT)		□		□	□		■	□	□		□
Politecnico di Torino (IT)							□				
University of Stuttgart (D)								□			
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	44	44	69	40	273
Other costs (k€)	31	30	7	30	38	48	33	217

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

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

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

Results

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

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

Members of the HC/AG-19 group are:

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

GARTEUR Responsable:
Joost Hakkaart NLR

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 2015.

- **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
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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 P42
Other costs (in K€)	Actual/ Planned		A4 P4	A10 P10	A5 P5	P3		A19 P22

- **Progress/Completion of milestone**

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
Task 1: model updating based on ground vibration tests	2009	2013	2013
Task 2: Prediction of configuration changes on FRF behaviour	2011	2013	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	2014

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.

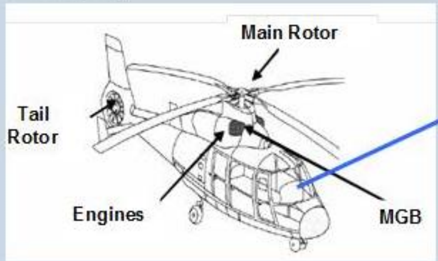
It appears that conventional passive systems (trim panels, passive anti-resonance isolation systems as well as classical vibration absorbers and pendulum absorbers) are still the main way to control the acoustic of the cabin whereas active systems (active vibration and noise control) are not completely 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

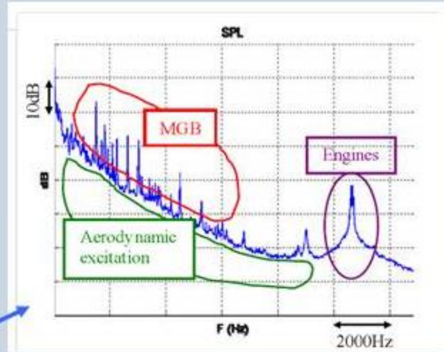
HC/EG-28, about internal noise and associated passive acoustic solutions (soundproofing, e.g. 1cm-thick trim panels designed for optimizing the absorption or the transmission loss), development of a vibro-acoustic model of the cabin (SEA coupled with FEM), human factors (subjective annoyance, speech 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 should result in a benchmark of the appropriateness of tools for complex configurations (multiple anisotropic layers with various mechanical characteristics, effect of confined medium on internal noise).

Members of the HC/AG-20 group are:

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

GARTEUR Responsable:
B. Demaret ONERA

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

HC/AG-20	**CABIN INTERNAL NOISE : SIMULATION METHODS AND EXPERIMENTAL METHODS FOR NEW SOLUTIONS FOR INTERNAL**
Monitoring Responsable:	B. Demaret ONERA
Chairman:	Dr. F. Simon ONERA

- **Objectives**

EG28, about internal noise and associated passive acoustic solutions (soundproofing, e.g. 1cm-thick trim panels designed for optimizing the absorption or the transmission loss), development of a vibro-acoustic model of the cabin (SEA coupled with FEM), human factors (subjective annoyance, speech intelligibility)" brought to launch the AG20.

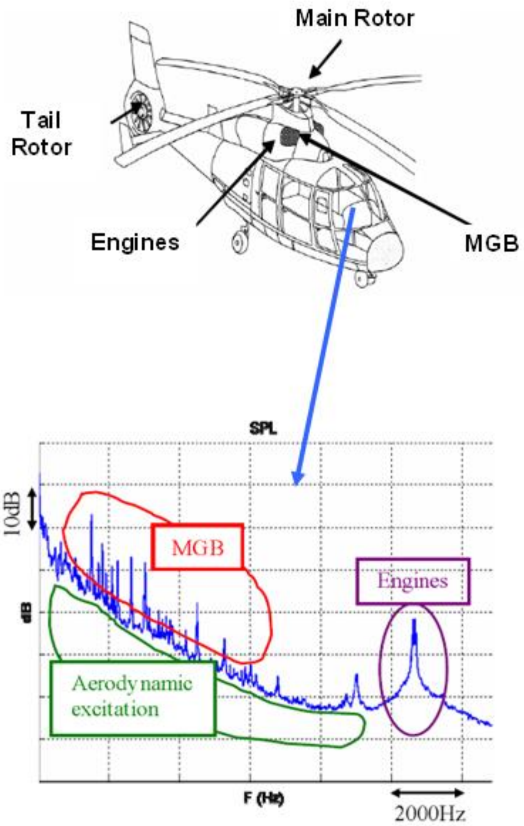
The EG28 conclusions listed the following needs:

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

- **Activities**

The activities of AG20 in 2014 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.

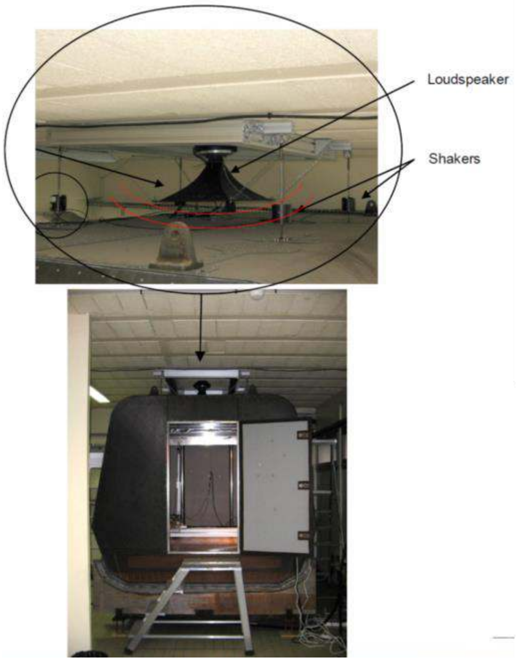


- **Management issues**

In 2014 there were two technical progress meeting, one on February 10th and the second on November 4th at NLR.

- **Expected results/benefits**

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



- **HC/AG-20 membership**

Member	Organisation	e-mail
Andrea Grosso	MICROFLOWN	grosso@microflown.com
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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

Expression of interest:
University of Liverpool, UK – Mark White

- **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.

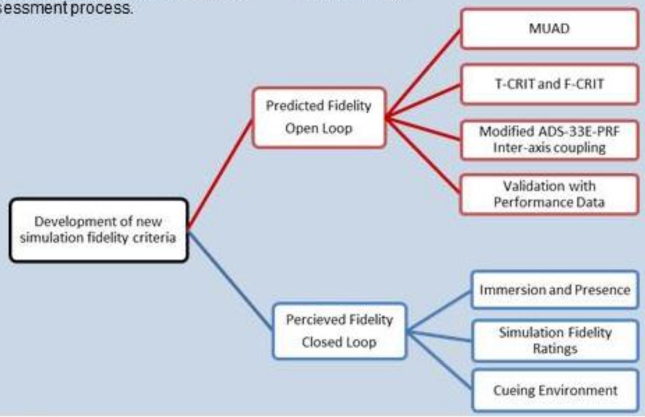
The work programme has two strands:

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.



Results

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

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

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

Members of the HC/AG-21 group are:

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

GARTEUR Responsable:

J. Haakkart	NLR

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

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..

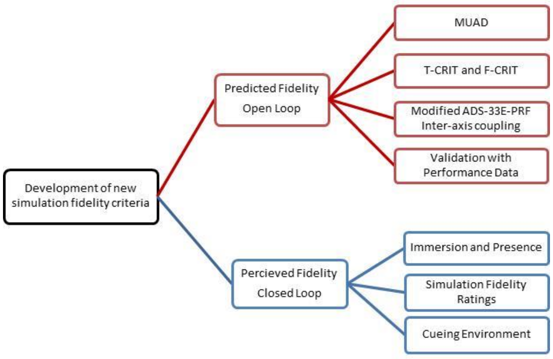
Specific areas of interest for helicopter flight simulation device fidelity include:

- 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. Maximum unnoticeable added dynamics (MUAD) envelopes have been proposed to define regions of acceptable levels of mismatch in equivalent-system matching processes. GARTEUR AG-09 developed time and frequency domain modelling criteria, VAL-CRIT-T and VAL-CRIT-F, which are based on statistical methods; the use of this technique for model validation will be further investigated in the AG. A modified ADS-33E-PRF (Handling Qualities Requirements for Military Rotorcraft) time-domain cross coupling metric has been proposed for fidelity assessment to improve on the rotorcraft simulator qualification requirement for proof of match data to show "correct trend and magnitude". The output form this work will be the definition of new criteria for rotorcraft flight simulation model validation. There will be some overlap with activity 2 as the validated models would be available for use during the perceived fidelity assessment work. Activity 2 will focus on perceived fidelity assessment both in examining the effect of the cueing and virtual environment on subjective evaluation of fidelity but also to refine existing techniques to obtain quantitative measures of perceived fidelity.

- **Management issues**

The Chair was able to organise the kick-off meeting on April 23rd 2013. During the meeting the membership, resources and work packages were discussed and confirmed. A progress meeting was held on October 31st 2013. Staffing issues were a problem in 2014 leading to slight delays in the planned activities.

- **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
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Holger Duda	DLR	Holger.Duda@dlr.de
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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	P18/A 15.5	P30/A 14.5	P18	P66
Other costs (in K€)	Actual/ Planned		P10/A 10	tbd	

- **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	2015	
WP3 Flight Loop Fidelity	2015	2015	
WP 4 Immersion and Presence	2015	2015	
WP 5 Perceived Fidelity Assessment	2015	2015	

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.

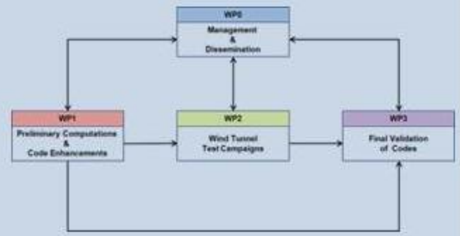
The timescale for the project is three years during which the following activities are planned:

- 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:

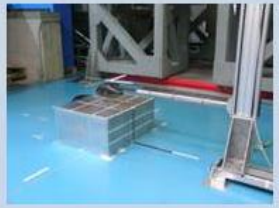
- WP0 – Management & Dissemination: is aimed at the fulfilment of all the obligations concerning the project management and the dissemination of the results;
- WP1 – Preliminary Computations & Code Enhancements: deals with a preparation phase during which partners are involved in literature review and 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.

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



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

Members of the HC/AG-22 group are:

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

GARTEUR Responsable:
K. Pahlke DLR

Centro Italiano Ricerche Aerospaziali
ONERA THE FRENCH AEROSPACE LAB

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:

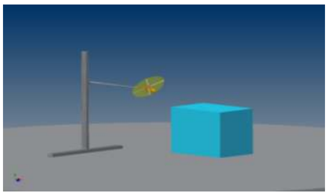
- primarily, the effects of the confined area geometry on a hovering helicopter rotor from the standpoints of both the phenomenological understanding of the interactional process and the evaluation of the forces acting on surrounding obstacles;
- secondarily, the downwash and its influence on the forces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

- **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.



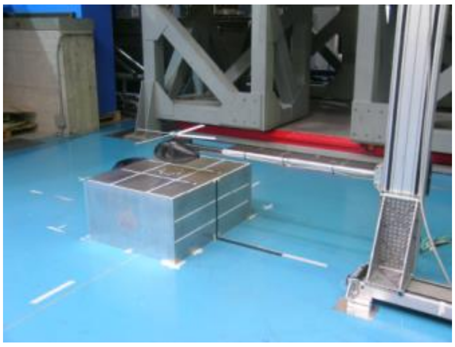
- **Management issues**

The kick-off meeting was held on November the 7th, 2014. During the meeting the membership, resources and work packages were discussed and confirmed.

- **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



- **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	Liverpool Uni.	g.barakos@liverpool.ac.uk

- **Resources**

Resources were confirmed during the kick-off meeting.

Resources		Year			Total 08-12
		2015	2016	2017	
Person-months	Actual/ Planned	P15	P18	P15	P48
Other costs (in K€)	Actual/ Planned	P20	P33	P20	P73

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.

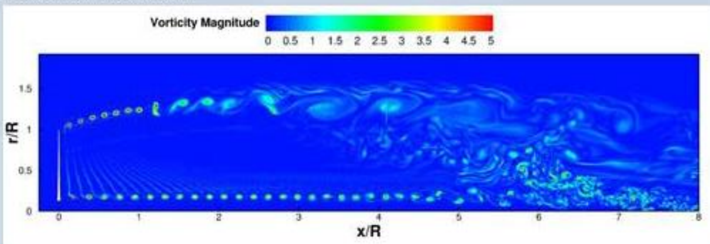
•The group should provide recommendations for legislation and disseminate the findings to the appropriate authorities and parties concerned.

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

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

Members of the HC/AG-23 group are:

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

GARTEUR Responsable:

J. Hakkaart NLR

UNIVERSITY OF LIVERPOOL — TU Delft (Delft University of Technology) — TECHNISCHE UNIVERSITÄT MÜNCHEN — NLR — ONERA (THE FRENCH AEROSPACE LAB) — CIRA — DLR

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:

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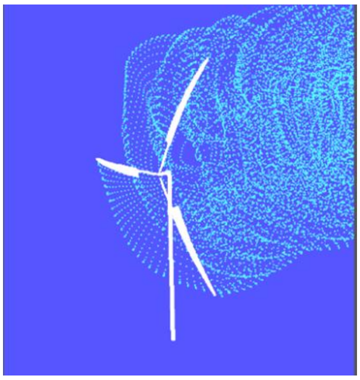
- Define representative test cases for a wind turbine and helicopter combination. Several combinations of small/large helicopter and wind turbines, depending on available experimental data, available helicopter models, pilot-in-the-loop facilities etc. should be considered
- Perform computations and 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.

- **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.

- **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	Liverpool Uni	g.barakos@liverpool.ac.uk
S. Voutsinas	NTUA	spyros@fluid.mech.ntua.gr

- **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 08-12
		2015	2016	2017	
Person-months	Actual/ Planned	P18	P22	P18	P58
Other costs (in K€)	Actual/ Planned	tbd	tbd	tbd	

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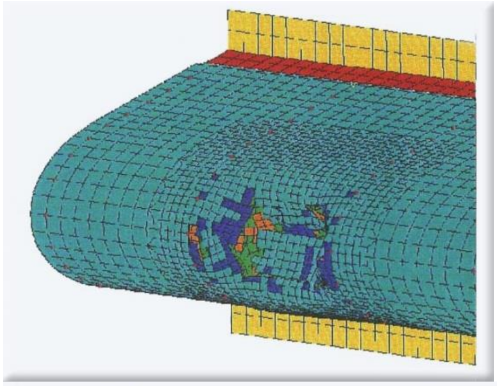
ANNEX E

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 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

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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 2014, the GoR(SM) held two meetings:

- 69th meeting on May 22 at Airbus, Bremen, Germany;
- 70th meeting on October 1 at SUN, Aversa, Italy.

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 2015 and 2016, GoR meetings are planned as follows:

- 71st meeting on March 3-4th 2015 at Qinetiq, Farnborough, United Kingdom;
- 72nd meeting on October 8-9th 2015 at INTA, Madrid, Spain;
- 73rd meeting on March 1-2nd 2016 at DLR, Stade, Germany.

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. Umberto Mercurio	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. Jose Maroto Sanchez	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. Sören Nilsson	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 2014:

- 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.

Exploratory Groups (EG)

The following Exploratory Groups were active during 2014:

- SM/EG-39: Design for high velocity impact on realistic structures. The SM/AG-36 may start in 2015.
- SM/EG-42: Bonded and bolted joints. This EG has started in the Fall of 2013 and no meeting has been held yet.
- 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 is scheduled on 10st April 2015.

The SM/EG-41 “Sizing of Aircraft Structures subjected to dynamic loading” topics have not received sufficient interest by the GoR-SM members and industrial point of contacts and are therefore stopped.

Future topics

The following topics for future Exploratory Groups are discussed:

- Thermo-Structure Interaction
- Aeroelasticity and aero-servo-elasticity
- Multi-functional Material
- Structural Uncertainties
- Damping in joints

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

- Large scale calculations – Virtual testing
- Benchmarking activities
- Hydrodynamic ram in the tanks
- Virtual manufacturing – predict distortion of structure due to thermal effects
- Ply-drop-offs and stringer run-outs

Other information:

The book on SM/AG-32 ‘Damage growth in composites’ (2009-2012) has been published by Springer and is available with the following link:
http://www.springer.com/engineering/mechanical+engineering/book/978-3-319-04003-5

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
Man-month	108	102,5	50	6	7	60,5	61
Other costs (k€)	117	128	40	10	2	65	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

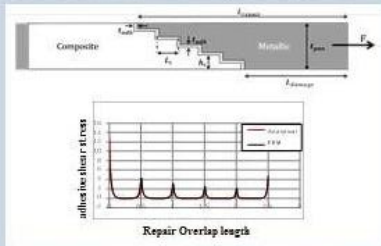
WP 5 EFFECTIVE REPAIR METHODS

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.



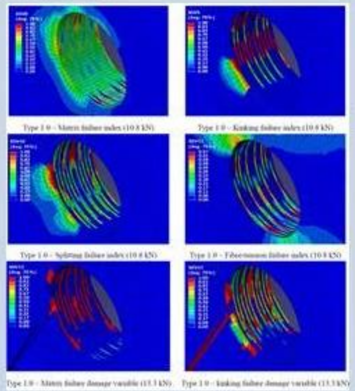
Development of an Analytical tool for Repair Design

Expected Results

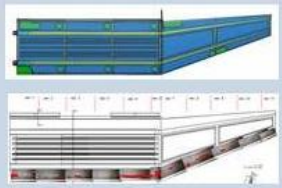
The effective outcomes can be summarized in:

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 selec ted for models validation.



Numerical Analysis - progressive Damage in composite Joint



Repair of an UAV wing

SM/AG-34 DAMAGE REPAIR WITH COMPOSITES

Monitoring Responsable: U. Mercurio, CIRA

Chairman: Dr. A. Riccio, SUN

- **Objectives**

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

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

This objective addresses the following issues:

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

- **Statement of work**

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

WP 1 Repair criteria (when undertaking repair)

- *Task 1.1) Methodologies for the assessment of residual strength in damaged composite components to decide when repair has to be undertaken*
- *Task 1.2) Crack growth analysis (static and fatigue)*

WP 2 Design of patches and repair strategies

WP 3 Analysis of the repair

WP 4 Manufacturing and 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.
- Actually in 2014 no meeting has been planned, however many partners have continued to work on the project's topic. The fourth meeting will be held during 2015.

Expected results/benefits

The effective outcomes can be summarised in:

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

- **SM/AG-34 membership**

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- **Resources**

Resources		Year					Total 12-15
		2012	2013	2014	2015		
Person-months	Act./Plan.	-	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 2015	Apr 2015	
WP3 Report	Apr 2015	Apr 2015	
WP4 Report	Apr 2015	Apr 2015	
WP5 Report	Oct 2015	Oct 2015	
Final Report	Oct 2015	Oct 2015	

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

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.

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:
Work has been performed by DLR to solve some problems with the probabilistic approach using Weibull theory.

Task 3;
-FK/NLR studies on a hybrid material (FML) with respect to curing temperature induced stresses in the metal layers were compared with test results.
-DLR presented results of studies of adhesion and degradation mechanisms of metal-polymer interfaces .
-FOI presented results of static and fatigue tests in a bi-axial test rig at elevated temperature on composite specimens.
- Saab conducted FEM studies on the static and fatigue test specimens of the FOI tests conducted in the bi-axial test rig.

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.

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 to solve some problems with the probabilistic approach using Weibull theory.

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°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.

Fokker/NLR studies on a hybrid material (FML) with respect to curing temperature induced stresses in the metal layers were compared with test results.

DLR presented simulation results of MMB tests with hydro-thermal ageing.

Saab conducted FEM studies on schematic hybrid wing torsion box model of Gripen under thermal and mechanical loads. Also impact damages were considered.

- **Management issues**

The second progress meeting was held on May 19th, 2014 at DLR in Köln. The third progress meeting was held on November, 12th 2014 at Fokker Aerostructures in Papendrecht.

- **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
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Dr. Jan Haubrich From 1/9/14	DLR	Jan.haubrich@dlr.de
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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	June 2016	June 2016
Task 2	June 2015	June 2016	June 2016
Task 3	June 2015	June 2016	June 2016
Report	October 2015	December 2016	December 2016

EXPLORATORY GROUP REPORTS

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

Monitoring Responsable: J. Maroto
INTA

Chairman: L. Iannucci
Imperial college

- **Objectives**

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

- **Benefits**

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

- **Progress**

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

Proposed Work package breakdown:

Task 1: Material characterisation for potential designs
- Testing of fibres or laminates, temperature and volume effects, high rate testing from existing projects and in-house data.

Task 2: Fundamental characterisation of relevant materials
- Testing associated with missing information from task 1.

Task 3: Review of high velocity resistance designs
- Detailed review of existing designs.

Task 4: Modelling strategies for features relevant to high velocity design
- Modelling sub-component impacts using novel designs or materials.

Task 5: Realistic design of representative components for high velocity impact
- Design of full size designs using numerical techniques.

Task 6: Fabrication of representative components
- Fabrication of designs.

Task 7: Testing of representative components
- Impact testing of selected high velocity resistance designs.

- **EG membership**

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

SM/EG-42 BONDED AND BOLTED JOINTS

Monitoring Responsable:

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**

The EG was formally started at the GoR fall meeting 2013. The work will start with a search for more interested members. An introduction with a literature review of the subject for a project plan has been written.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
FOI	Sweden	J. Schön

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 outline is scheduled for 10 April 2015.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
CIRA	Italy	R. Borelli
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GKN	United Kingdom	A. Bates
NLR	Netherlands	L. ‘t Hoen
Onera	France	M. Thomas