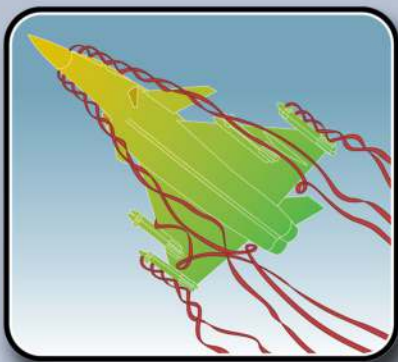
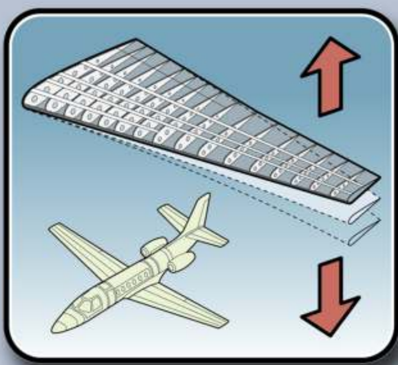
GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

Document X/D 48

GARTEUR
Annexes to the Annual Report 2013





May 2014

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GARTEUR X/D 48

Annexes to the GARTEUR Annual Report 2013 (X/D 47)

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

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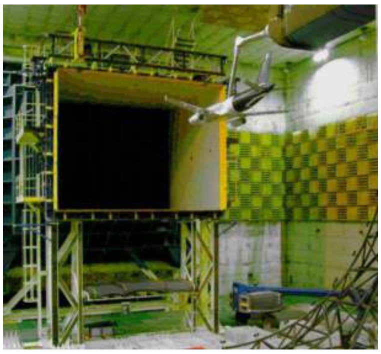
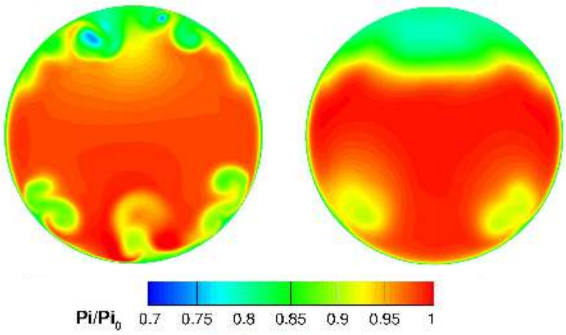
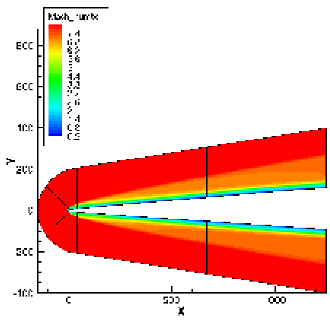
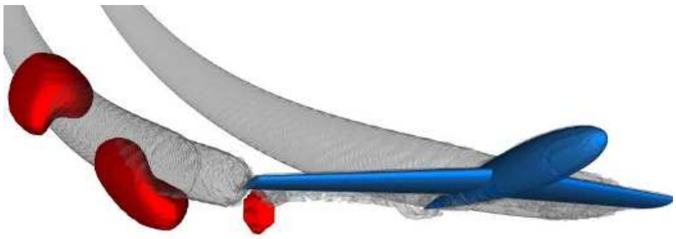
ANNEX A

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AERODYNAMICS"









Remit

GoR AD initiates and organises basic and applied research in aerodynamics, often coupled to other disciplines. Industrial demands and increasing computational capacity drive the trend towards more multi-disciplinary analysis. Recent and on-going research activities have been and are devoted to:

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

The activities are both computational and experimental with some more emphasis on the former. In some action groups, experiments are carried out for validation purposes, in others, research on measurement techniques are carried out. Recent action groups have investigated how to improve correction procedures of measurements and how to scale experiments to conditions for industrial applications. Numerical studies sometimes give insight to the mechanisms of basic flow mechanisms such as transition and flow control.
In other cases, integrated aerodynamic features of for instance air intakes or aerial vehicles are analysed.

Funding for GARTEUR activities is relatively small and in general not sufficient to start activities in new research fields. The AGs are therefore in most cases combined with research activities in EU-, STO- (NATO Science and Technology Organization) or national aeronautical research programmes. There are frequent collaborations between activities across the various programmes. Sometimes GoR AD-projects initiate activities in research fields that later lead to EU-proposals, other times GoR AD-projects complement activities in on-going EU-projects.
GoR AD pursues to do research that covers both military and civil aspects. The possibility to combine military and civil research has shown to open into fruitful collaborations.

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AERODYNAMICS

GoR-AD OVERVIEW

GOR ACTIVITIES

During 2013 three Action Groups, AD/AG-45 “Application of CFD to Predict High G Wing Loads”, AD/AG-47: “Coupling of CFD with Flight Mechanics” and AD/AG-50 “Effect of wind tunnel shear layers on aeroacoustic tests” were completed. One new Action Group was launched: AD/AG-53 “Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations”, chaired by FOI.

Ten Action Groups have been active during 2013:

AD/AG-44 “Application of transition criteria in N-S computations - Phase II” has for a couple of years been inactive without delivering the final report. At the first GoR-meeting 2013, it was decided to write a simplified report of activities in AD/AG-44. The GoR chairman wrote a skeleton report and Chris Newbold wrote the synthesis report. The participants have thereafter gradually improved their contributions. Now only ONERA’s report remains. A final report is expected in January 2014.

The purpose of AD/AG-45 “Application of CFD to predict high G Wing Loads” has been to investigate the maturity of CFD methods to tackle the load envelope of a civil aircraft. The final report was completed in mid-February 2013.

The main objective of Action Group AD/AG-46 “Highly Integrated Subsonic Air Intakes” is to analyse unsteady flow phenomena of subsonic air intakes with modern CFD methods (Detached Eddy Simulation DES). It pursues to support innovative design for highly integrated intakes of advanced subsonic aerial vehicles. Fundamental experimental studies of intake design parameters have been carried out in order to advance the knowledge of innovative design. The Action Group will submit five papers for the Special GARTEUR Paper Session at the AIAA Science and Technology Forum and Exposition 2014 (former AIAA Aerospace Sciences Meeting). The final report will be ready before the end of February 2014.

The main objective for AD/AG-47 “Coupling of CFD with Flight Mechanics” has been to provide a test platform for validation of development and applications of CFD coupling to flight mechanics models. The final report was delivered in January 2013.

The primary objective of AD/AG-48 “Lateral Jet Interactions at Supersonic Speeds” is to analyse the effect of the hot-gas jet from CFD simulations, and to define the most appropriate similarity parameters for ground-test facilities using cold-gas jet. The idea is to be able to translate wind-tunnel tests conducted using jets of cold air to free flight conditions with jets of hot multi-species gases. The first expected benefit, the assembly of a bibliography on similarity parameters is available now. The definition of the most appropriate similarity parameters based on these new CFD results is in progress. The final report is expected during spring 2014.

The overall objectives of AD/AG-49 “Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications” are to scrutinize, improve and assess some selected hybrid RANS-LES approaches in simulations of aerodynamic flows and ultimately to provide “best-practice” guidelines for industrial use relevant to aeronautic applications. The AD/AG-49 work contributes to a comprehensive understanding and assessment of hybrid RANS-LES modelling of typical aerodynamic flow physics, and to further modelling improvement. The results will facilitate use of hybrid RANS-LES methods in aeronautical applications. The final report is expected in the beginning of 2014.

AD/AG-50 “Effect of wind tunnel shear layers on aeroacoustic tests“ have investigated the effects of open jet shear layers on acoustic wind tunnel measurements. An empirical method has been developed to retrieve the correct acoustic power of tones measured outside the shear layer. The final report was delivered in December 2013.

The main objective of AD/AG-51 “Transition in hypersonic flows” is to improve knowledge and methods dedicated to prediction and triggering of laminar/turbulent transition in hypersonic flows.
During 2013 a report of experimental data (WP1) is almost ready. Linear stability calculation compared to experimental wall pressure spectra measured using miniature PCB pressure sensor. Transition prediction model has been extended to non-zero pressure gradients, for adiabatic wall. First computations on the LEA forebody are done at CIRA.

The Kick-off meeting for AD/AG-52 “Surrogate-based global optimization methods in aerodynamic design” took place at INTA Madrid on 12th-13th of February 2013. The duration of the project is three years. The Chairman is Esther Andrés from INTA and Monitoring Responsable is Fernando Monge. The objective 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.

The exploratory group AD/EG-66 “Receptivity and Transition Prediction” sent in a proposal for a new action group the 15th of April 2013. The proposal was accepted and AD/AG-53 “Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations” had its kick-off meeting on Sept 5, 2013 at University of Genova. 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.

Due to lack of interest, the exploratory meeting for AD/EG-68 “Fluidic and Synthetic Jets” was cancelled. At the subsequent GoR-meeting it was decided to close the exploratory group.

Four new Exploratory Groups have been launched 2013:

At the GoR February meeting a new exploratory group AD/EG-69 “RANS-LES interfacing for hybrid and embedded LES approaches” was launched. The main objective of the proposed AG work is to explore, to further develop and improve RANS-LES coupling in the context of embedded LES (ELES) and hybrid RANS-LES methods. The EG consists of ten members, seven from research organizations, two from university and one from industry.

AD/EG-70 “Plasma for Aerodynamics” was launched at the same GoR-meeting. Proposed activities are: improvement and development of plasma devices, improvement of physics understanding on actuation/flow interaction and flow control strategies development & associated physics. These are recommendations for future research topics from the finished EU-project PlasmAero. Chairman of the exploratory group is Dr Daniel Caruana from ONERA and monitoring Responsible is Eric Coustols. An Exploratory Group meeting is planned in March-May 2014 in Toulouse. Since the EG hasn’t had their first meeting yet and the membership list is unclear, there is no contribution to this annual report.

In May 2013 another exploratory group was launched AD/EG-71 “Countermeasure Aerodynamics”. The proposed work is aimed at obtaining further understanding of the flow physics involved and also to develop more accurate modelling methods. The planned activities are divided into two work packages, one for chaff and one for flares. The participating organisations are Airbus Military, LACROIX, FOI, MBDA France and NLR. Dr. Olof Grundestam from FOI is chairman and Torsten Berglind is monitoring Responsable.

At the GoR September meeting, a new exploratory group AD/EG-72 “Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations” was launched. Bimo Prananta, the former chairman of AD/AG-42 and AD/AG-47, will be chairman of the exploratory group and Koen de Cock is the monitoring Responsable. The group will exploit the results of AD/AG-47 and FM/AG-19. The mandatory case will consist of a manoeuver simulation with control surface input. NLR will organize a Kick-off meeting for the exploratory group in early January 2014.

MANAGEMENT ISSUES

It is now clear that UK take over the chairmanship 2014-15. Frank Ogilvie from UK ATI will be chairman and Koen de Kock from NLR will be vice chairman.

At the first GoR-meeting 2013 Norman Wood proposed that GoR AD should have a conference each year where GoR AD members met Action group members. This is similar to how NATO/STO arranges their meetings and it would make the meetings more attractive to industry. It will require that the AGs coordinate their meeting schedule with GoR AD such that the AGs plan to have a technical meeting the day before the conference. GoR AD will have a meeting after the conference. For a relatively small extra cost and some additional planning, GoR meetings could be made more interesting.
Not all members in the GoR-group will be able to host such meetings since it requires possibility to book conference rooms for 5-10 parallel AG meetings. On the other hand there are some obvious advantages, such that it will put pressure on the AGs to finish earlier, there will be direct contact between members of GoR AD and the research

scientists in the AGs. The first "GoR AD conference meeting" will take place at FOI in Stockholm on 24th of September 2014.

At the end of 2013 GoR AD proposed a candidate AG for GARTEUR Award of Excellence. AD/AG-46 "Highly integrated subsonic air intakes" was (the action groups AD/AG-45 and AD/AG50 were close behind) selected as the candidate after voting among the members.

DISSEMINATION OF GARTEUR ACTIVITIES AND RESULTS

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

AD/AG-48 presented a paper 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.

AD/AG-50 has published two conference papers, one at AIA-DAGA 2013 Conference on Acoustics and the other at 19th AIAA/CEAS Aeroacoustics Conference.

AD/AG-52 has participated and organised Special Sessions at EUROGEN 2013 and ECCOMAS CFD 2014.

FUTURE PLANS

Four AGs are expected to finish early 2014: AD/AG-44, AD/AG-46, AD/AG-48 and AD/AG-49 and two new action groups are expected to be launched in the beginning of 2014.
The continuation of AD/AG-49 "Scrutinizing Hybrid RANS-LES Methods for Aerodynamic Applications" was not able to start during 2013. The AD/AG-49 report is expected during January 2014. In parallel the group is preparing a proposal for a follow-on AG: "RANS-LES interfacing for hybrid and embedded LES approaches" that will be launched in the beginning of 2014.
AD/EG-71 "Countermeasure Aerodynamics" is almost finished and their proposal for an AG, which will be launched in the beginning of 2014.
According to the assumptions above there will be five active AGs in the middle of 2014. Of the two new exploratory groups AD/EG-70 and AD/EG-71 one might be launched before the end of 2014. It will therefore be important to continue to start new exploratory groups.

Currently following interesting proposals for new topics are discussed:

- Thrust vectorization

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

- Inlets and outlets for ventilation

There is strong industrial interest in this topic. Various proposals are suggested: to study concepts for location and shape of secondary inlets and outlets due to their application purposes, numerical investigations of a variety of concepts for secondary inlets and outlets, experimental investigations of selected concepts in order to establish a data base for typical applications, investigation of hidden integration of a secondary air intake within the engine air intake and its impact on aerodynamic performance etc.

- Measurement techniques

One topic that has been proposed is detection of laminarisation aiming at NLF-applications. Techniques like optical fibre or hot film would be considered. Surface roughness and contamination would be of primary interest. Another topic is about database for characterization of unsteady flow using PIV. This would require access to an industrial wind-tunnel.

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

Cat	Topic	2010	2011	2012	2013	2014	2015
AD/AG-44	Application of transition criteria in NS computations - Phase II			**Final report expected in January 2014**			
AD/AG-45	Application of CFD to predict high "G" loads						
AD/AG-46	Highly Integrated Subsonic Air Intakes						
AD/AG-47	Coupling of CFD with Flight Mechanics Model						
AD/AG-48	Lateral Jet Interactions at Supersonic Speeds						
AD/AG-49	Scrutinizing Hybrid RANS-LES for Aerodynamic Applications						
AD/AG-50	Effect of WT Shear Layer on Aero-acoustics	**EG 64 →**					
AD/AG-51	Laminar-Turbulent Transition in hypersonic flows		**EG65 →**				
AD/AG-52	Surrogate-based Global Optimization Methods in Preliminary Aerodynamic Design			**EG67 →**			
AD/AG-53	Receptivity and Transition Prediction			**EG66 →**			
AD/EG-69	RANS-LES interfacing for hybrid and embedded LES approaches						
AD/EG-70	Plasma for Aerodynamics						
AD/EG-71	Countermeasure Aerodynamics						
AD/EG-72	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations						

Active   Closed   Extended

MANAGED AND FORESEEN GOR ACTIVITY

In 2014 the first meeting will take place at NLR in Amsterdam, on February 19th-20th, 2014. The second meeting will be held September 24th-25th at FOI in Stockholm.

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

GOR MEMBERSHIP

No changes in GoR membership has occurred during 2013.

Current membership of the Group of Responsables Aerodynamics

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

Vice-Chairman			
Mr. Norman Wood	Airbus Operations Ltd	United Kingdom	Norman.Wood@airbus.com

Members			
Mr. Koen de Cock	NLR	The Netherlands	cock@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
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Mr. Geza Schrauf	Airbus Operations GmbH	Germany	geza.schrauf@airbus.com
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Mr. Michel Mallet	Dassault	France	michel.mallet@dassault-aviation.fr
Mr. Chris Newbold	QinetiQ	United Kingdom	cmnewbold@qinetiq.com
Mr. Didier Pagan	MBDA	France	didier.pagan@mbda.fr
Mr. Luis P. Ruiz-Calavera	Airbus Military	Spain	Luis.Ruiz@military.airbus.com

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

	46	48	49	50	51	52	53	69	70	71	72
Research Establishments											
CIRA			□	□	□	□	□	□			
DLR	□	□	□	□	□		□	□			
DSTL											
FOI	□	□	■			□	■	■		■	
INTA			□			■		□			
NLR			□	■				□		□	■
ONERA	□	□	□	□	■	□	□	□	■		
Industry											
Airbus Military	□					□				□	
Airbus Operations GmbH							□				
Airbus Operations Limited											
Airbus Operations S.A.S.				□							
Alenia Aeronautica	□					□					
CASSIDIAN	■										
Dassault-Aviation	□										
EADS							□	□			
LACROIX										□	
MBDA-F	□	□			□					□	
MBDA-LFK		□									
QinetiQ											
Saab	□					□		□			
Academic Institutes											
Imperial College							□				
ISL		■			□						
KTH							□				
Southampton Un. -ISVR				□							
TU Munchen			□					□			
UAH						□					
Univ. BwM *(Universität der Bundeswehr München)*					□						
University of Manchester								□			
UNIS						□					
Von Karman Institute *(VKI)*					□						
VUT						□					

□ = **Member**   ■ = **Chair**

For AD/EG-70 and AD/EG-72, memberships are not yet established.

TOTAL YEARLY COSTS OF AD/AG RESEARCH PROGRAMMES

GoR	AG	2010		2011		2012		2013		2014		2015	
		pm	K€	pm	k€	pm	K€	pm	K€	pm	K€	pm	K€
AD	43	2	0										
	44							1	0				
	45	5	10	5	10	5	5	1	0				
	46	12	0	10	0	3	0	3	3				
	47	15	0	10		10		1	0				
	48	17	27	11	22	3	6	6	8	1	0		
	49	21	171	20	170	15	89	7	70				
	50	16	60	16	60	17	0	10	20				
	51					14	41,5	14	77	12	77		
	52							20	45	23	63	23	63
	53							10	12	13	24	13	24
AD TOTAL		88	268	72	262	67	141,5	43	235	49	164	36	87

pm = Person-months
k€ = other costs

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

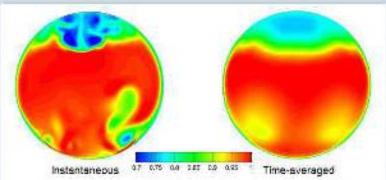
Application of modern hybrid CFD methods: Detached Eddy Simulation (DES) of internal flow field with separation, code validation

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

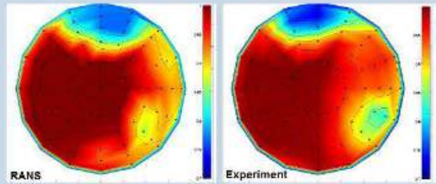
Programme/Objectives

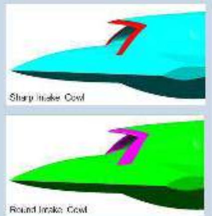
Main objectives of AD/AG-46: (1) to investigate the capability of modern CFD methods (Detached Eddy Simulation DES) to analyze unsteady flow phenomena of highly integrated subsonic air intakes, (2) to support innovative design for advanced subsonic aerial vehicles, and (3) to assess the flow behavior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

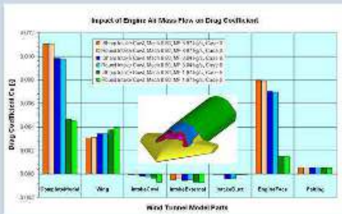
Focus: Numerical simulations of unsteady internal flow in a subsonic air intake highly integrated into the airframe of a UAV applying different standard CFD methods and DES, comparison with experimental data. Parametric studies of innovative intake design features accompanied by basic wind tunnel investigations 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.

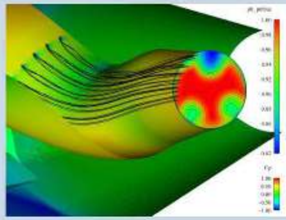
Partners: CASSIDIAN, ONERA, FOI, AIRBUS Military, DLR, SAAB, MBDA, Alenia, Dassault-Aviation

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.









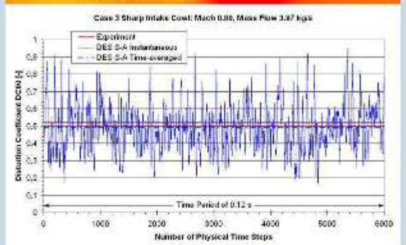
- Assessment of dynamic distortion coefficients at aerodynamic interface plane and comparison with test data
- Simulations for internal flow control by employing numerical models for vortex generators and micro-jets
- Computational investigation on intake lip shaping impacting intake performance and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

- **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.

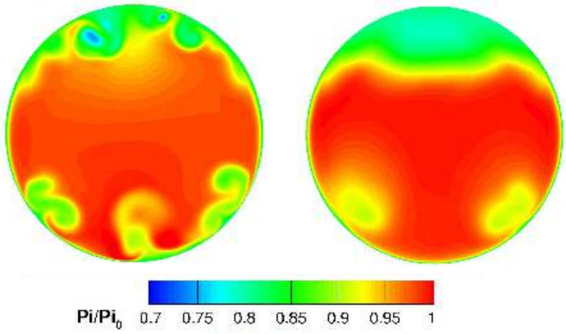


Fig. 1 Instantaneous (left) and time-averaged (right) total pressure ratio distributions in the AIP for Test Case 7 (Mach 0.6, mass flow 3.98 kg/s) from DES computations by CASSIDIAN

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.

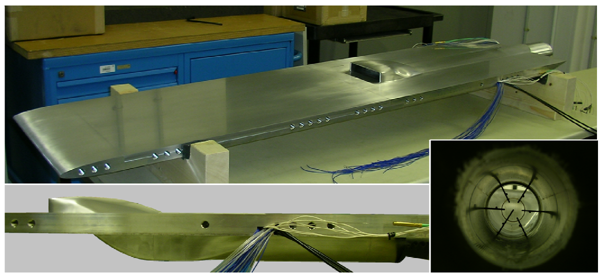


Fig. 2 Intake wind tunnel model with flat plate for parametric study in the DNW-KRG, Göttingen (top: 3D view, bottom left: side view, bottom right: view from the exit of the intake duct towards the measuring rake)

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 will be 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.

"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.

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

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

"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.

The reporting will be concluded in February 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**

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

- **Resources**

Resources		Year						Total 08-13
		2008	2009	2010	2011	2012	2013	
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	ongoing

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

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

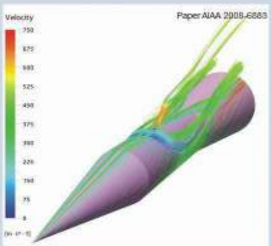
Action Group Chairman: Dr Patrick Gnemmi, ISL (patrick.gnemmi@isl.eu)

Background

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

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

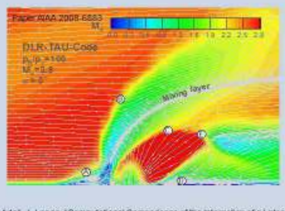
Challenge: defining the most appropriate similarity parameters for wind-tunnel tests using a cold-gas jet



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

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

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



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

Programme/Objectives

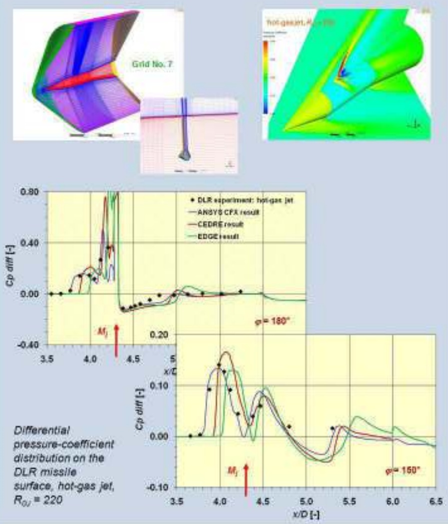
Main objectives of AD/AG48: (1) to accurately predict by CFD the steady-state aerodynamics of the interaction of a hot multi-species gas jet with the cross-flow of a supersonic missile at acceptable computational costs; (2) to deeply analyze the effect of the hot-gas jet from numerical simulations; (3)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

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

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

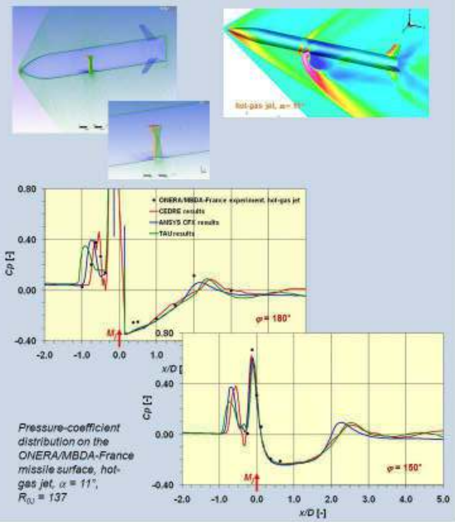
Activity: numerical simulations with different RANS codes and validations using high-quality wind-tunnel data

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



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

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



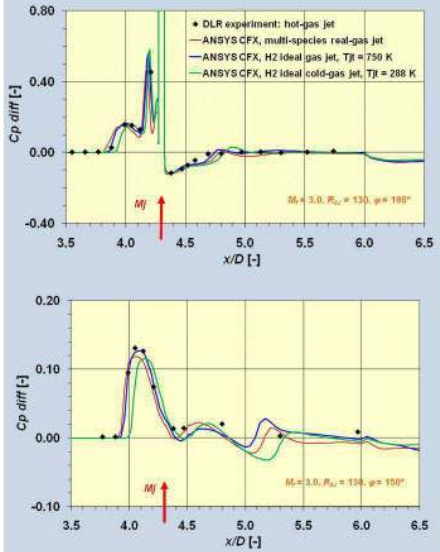
Pressure-coefficient distribution on the ONERA/MBDA-France missile surface, hot-gas jet, $\alpha = 11°$, $R_{0J} = 137$

DLR FOI ISL MBDA ONERA THE FRENCH AEROSPACE LAB

Results

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

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



AD/AG-48	LATERAL JET INTERACTIONS AT SUPERSONIC SPEEDS
Monitoring Responsable:	E. Coustols ONERA
Chairman:	Dr. P. Gnemmi ISL

- **Objectives**

In the past, the aerodynamic interference between the exhaust jet and a missile cross-flow has been investigated mainly from wind-tunnel tests.

The problems encountered in wind-tunnel testing concern the simulation of the flight conditions: Reynolds number, pressure ratio, jet gas. For the two first parameters, duplication of the flight conditions is often possible during wind-tunnel tests, or if not, extrapolation can be made confidently (using CFD for example). The third problem related to the effect of the jet gas is the most difficult. Knowing that wind-tunnel tests are generally conducted using cold air as a jet, whereas in free flight it is a hot gas coming from the combustion of propellants, similarity parameters must be considered.

The primary objective of this action group 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**

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P. Gnemmi *(c)*	ISL	patrick.gnemmi@isl.eu
C. Nottin	MBDA-F	christophe.nottin@mbda-systems.com
M. Leplat	ONERA	michel.leplat@onera.fr

- **Resources**

Resources		2008	2009	2010	2011	2012	2013	Total 12-13
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

(Columns 2008–2013 under the heading "Year".)

- **Progress/Completion of milestone**

Work package	Planned: Initially (end of …)	Planned: Currently (updated)	Actual
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.

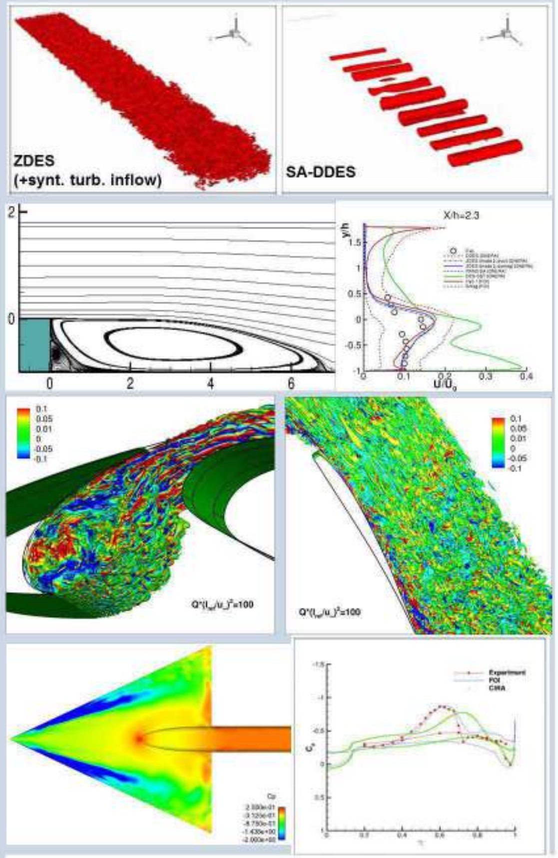
Work plan: The work in AG49 is divided into three tasks. Task 1 and Task 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3. AG49 was completed in April 2013.

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 TUM

AD/AG-49 HYBRID RANS-LES METHODS FOR AERODYNAMIC APPLICATIONS

Monitoring Responsable: T. Berglind
FOI

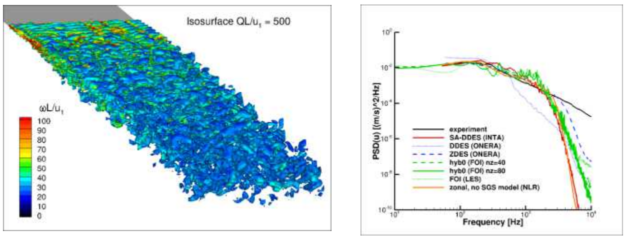
Chairman: Dr. S.-H. Peng
FOI

- **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.

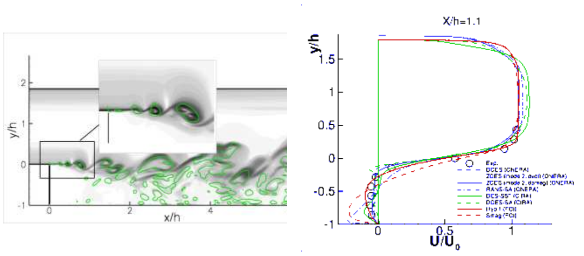
- **Main Achievements**

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.



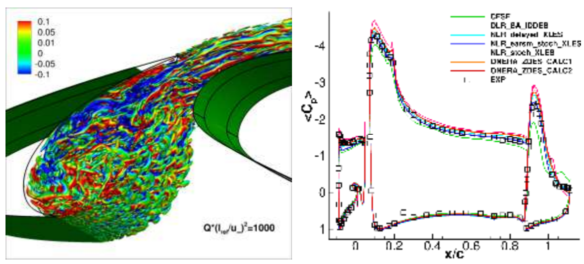
TC 1.1: Mixing layer. Resolved structures (left); PSD of stream-wise velocity fluctuations (right).

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.



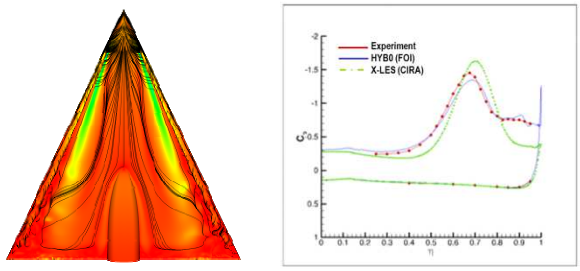
TC1.2: BFS. Resolved shear-layer motion (left) and mean velocity profile at x/h =1.1.

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-□ 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		Jan. 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 is planned to launch 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

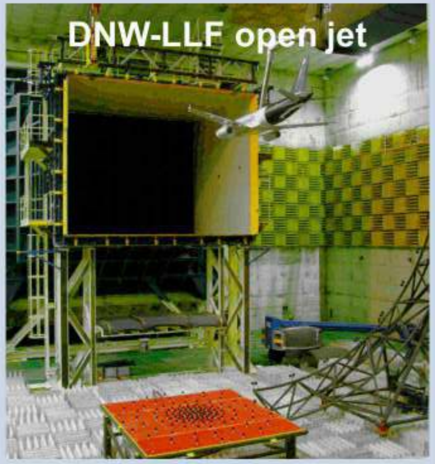
Aeroacoustic wind tunnel tests are typically conducted in open jets
Sound propagates through shear layer

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



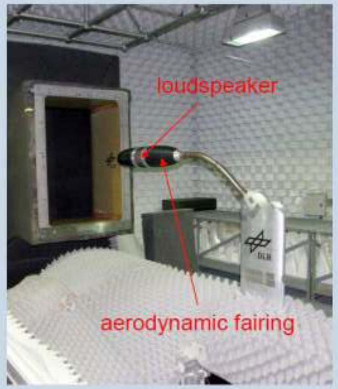
The Programme

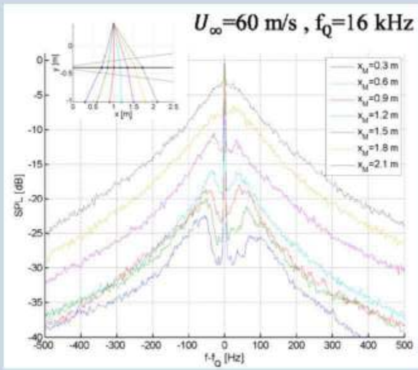
Objectives of AD/AG-50
- To improve the understanding of shear layer effects;
- To quantify the magnitude of shear layer effects, including the dependence on different parameters;
- To develop procedures to correct for shear layer effects;
- To investigate the possibilities to reduce shear layer effects.

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



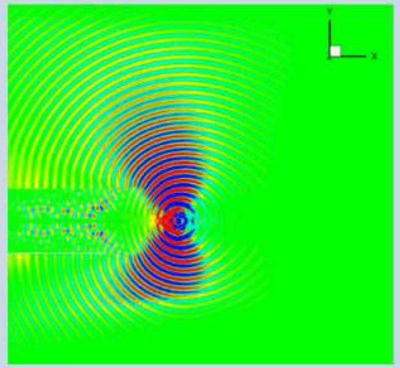


The Outcomes

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**

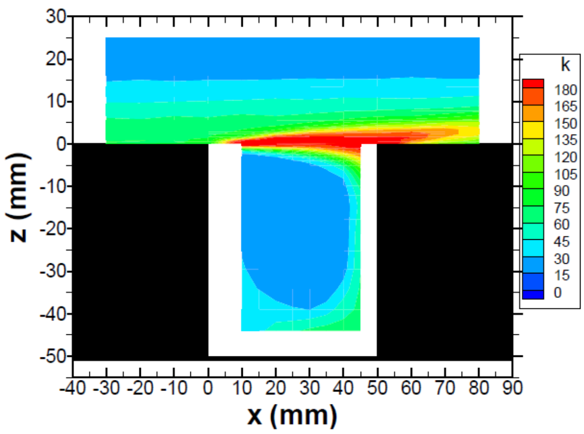
AD/AG-50 investigated the effects of open jet shear layers on acoustic wind tunnel measurements. Aeroacoustic wind tunnel tests are generally conducted in open jet wind tunnels (see picture below). The sound from the model has to pass through the open jet shear layer, which causes refraction, spectral 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.



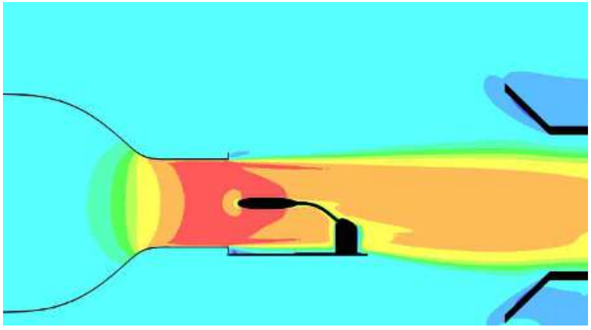
DLR and NLR carried out acoustic and aerodynamic measurements in the open jets of the DNW-PLST, NLR-KAT and DLR-AWB wind tunnels, to characterize spectral broadening as a function of wind speed, frequency, geometry and shear layer thickness. The test conditions for the different facilities were complementary 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

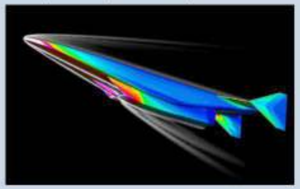
FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

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

The Background

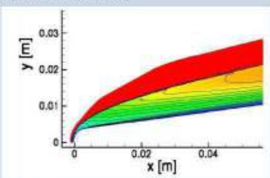
Transition laminar/turbulent:
Thrust-drag balance and air intake adaptation (air breathing hypersonic vehicles)
Heat fluxes (re-entry vehicles)



Different experimental data sources in Europe

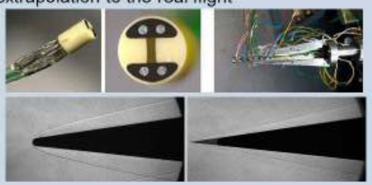
Increasing capability of CFD :
Need of tools/methods to predict laminar/turbulent transition in hypersonic using RANS code

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

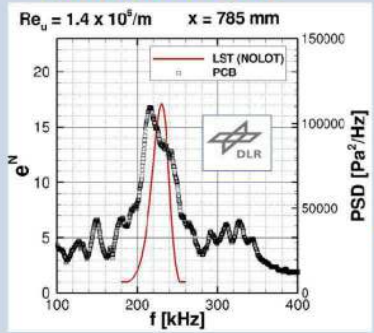


State of the art:
Linear stability theory, Wind tunnel experiments

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



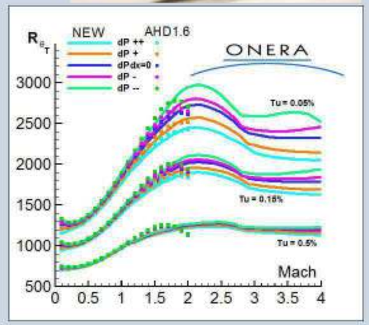
Activities 2013



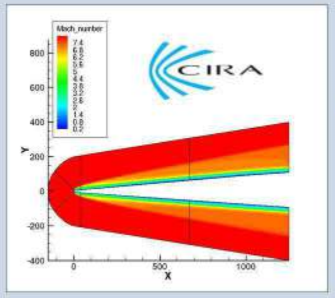
WP1 :
Experimental data described in a draft report, to be completed.
Part of the data bank available at ONERA ftp site.
Figure :
Linear stability calculation compared to experimental wall pressure spectra measured using miniature PCB pressure sensor.

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

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



WP3 :
First computations on the LEA forebody done at CIRA



Mach=[4-8]
Re=[1.4 – 14] 10^6/m

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

Programme

Objectives of the Action Group AD-AG51:

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

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

Current status :

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

Next Steps :

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

AD/AG-51	**TRANSITION IN HYPERSONIC FLOWS**
Monitoring Responsable:	D. Pagan MBDA-F
Chairman	J. Perraud ONERA

- **Objectives**

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

- **Progress**

AD/AG-51 was launched in September 2011. This Action Group is dedicated to laminar-turbulent transition prediction and control in hypersonic flows. Seven members are involved, 6 from research establishments (CIRA, DLR, ISL, ONERA, UniBwM and VKI) and 1 from industry (MBDA-F). (VKI is not a member of the GARTEUR organization but its participation was accepted by the GARTEUR council in January 2011).
The Kick-off meeting took place at ONERA Toulouse on 1st February 2012, and a technical meeting was organised at VKI in November 2012. Due to budget restrictions at ONERA, there was no technical meeting organised in 2013.
The Action Group is split into 3 work packages (WP) relating to natural and triggered transition. First WP deals with experimental database and identification of validation cases, the second WP deals with transition predictions tools, and the third WP covers validation of the transition prediction methods, the effect of wind tunnel noise and transition triggering.
The main goal of the first package is to build a well-documented experimental database, which will be used as validation tool during the numerical studies. The 7 partners agreed on 4 available experiments carried out by DLR, ISL, MBDA-F and VKI. These experiments focus on flight regimes with Mach number between 4 and 10 and altitudes up to 40 km with natural and triggered transition. Most configurations are academic, e.g. cones or flat plates, with the exception of the LEA forebody proposed by MBDA. Availability of well adapted meshes is to be explored since a proper description of the boundary layer will be necessary.
DLR provided wind tunnel test results on sharp and blunt cones (M=7 and Re=3.7 Millions/m) with heat-flux measurements carried out by using coaxial thermocouples and time resolved surface pressure measurements, compared to stability calculations. A first report was prepared and distributed at the VKI meeting.

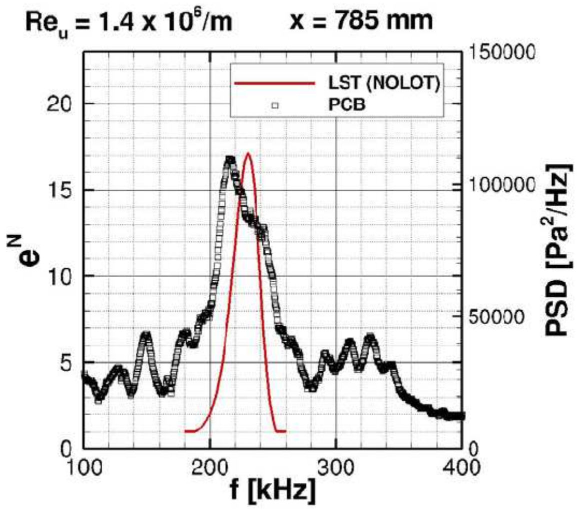


Figure 1 : Wall pressure spectrum compared to linear stability calculation (LST) - DLR HEG Mach 7.5 test of a blunted cone [1]

ISL agreed to provide shock tunnel test results on a sharp cone and on a blunt conical nose (Mach=6; Re = 23.5 10^6/m and 9.6 10^6/m) with visualizations and heat-flux measurements. Corresponding CAD files were uploaded to the ftp server.
MBDA-F provided extracts of wind tunnel test results performed at ITAM (Mach=4 and 8, Re = [1.4 – 7.1] 10^6/m). Measurements include Pitot pressure, Oil flow and Schlieren visualization, and TSP results in the presence of the triggering device. CAD files and meshes of the forebody have been also provided.
The VKI will provide a part of an existing database obtained on a flat plate with isolated roughness. Experiments on a cone started in 2012. This cone is equipped or not with roughness and inserted in the same wind tunnel. Infrared imaging has allowed demonstrating the case of natural and induced transition. Some of the cone experiment will also be shared with the partners. Because other financed projects will be running on the same topic additional run will be possible.
The second work package is dedicated to the extension to hypersonic flows of existing transition criteria and their implementation into CFD codes, starting with the boundary layer code 3C3D and the RANS elsA software. It is planned to study the extension to hypersonics by methods based on linear stability theory (LST), on transport equations models and on the use of transition criterion inserted into RANS codes when possible. Four different LST codes are available, which may run using velocity profiles obtained from RANS codes. LST results and experiments will be used for the validation phase.
Concerning the extension of the longitudinal criterion to Mach 4, pressure gradient effects were taken into

account based on about 50 velocity profiles from Falkner-Skan similarity solutions with several values of the Pohlhausen parameter $\Lambda_2 = \frac{\theta^2}{\nu}\frac{\partial U_e}{\partial x}$.

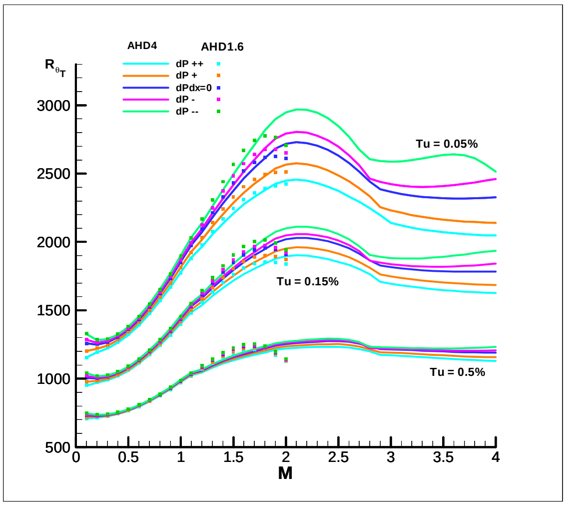


Figure 2 : Application of the new criterion up to Mach 4

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

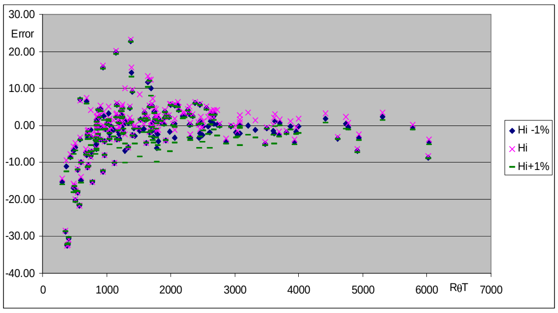


Figure 3 : Precision evaluation using similar profiles 1.1< Me< 4 ; -0.0265< □$_2$<0.015 ; .05% < Tu< 1%

Comparisons to exact stability calculations will be necessary to more precisely evaluate the errors in the presence of pressure gradients.
Extension to cold walls will be considered in 2014. A large number of stability calculations have already been made, but time was too short in 2013 to extend the model.

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

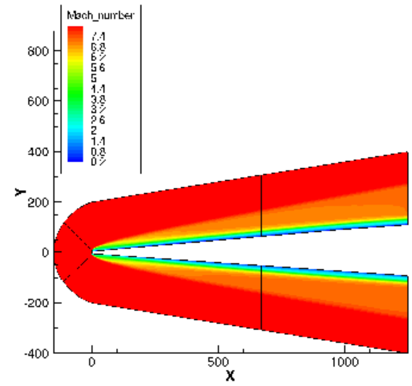


Figure 4 : Mach 8 computation of LEA forebody

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

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

- **AG membership**

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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.

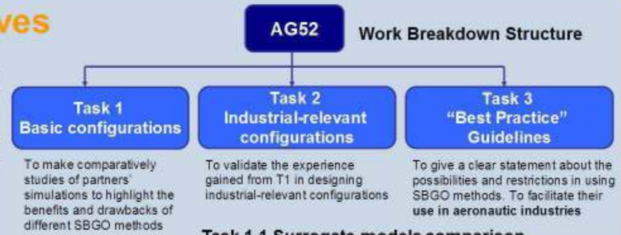
Current work in AG52 focuses on the assessment of different surrogate modeling techniques for fast computation of the fitness function and the evaluation of surrogate-based global optimization strategies for the shape design of the selected configurations.

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



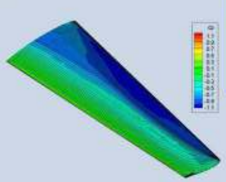
Main objectives: To analyze the feasibility and possible contributions of SBGO methods in an early phase of the aerodynamic design, where the design space will be broadly analyzed to get the optimum solution

Project duration: 3 years (2013-2015)

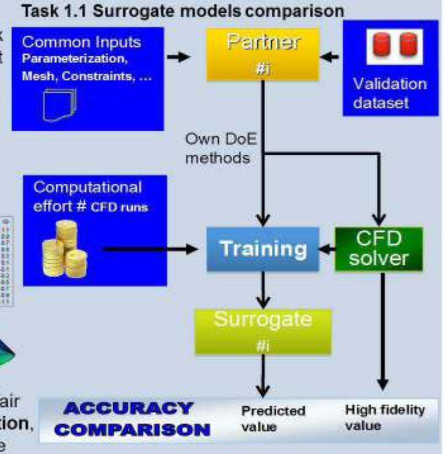
Work plan: The work in AG52 is divided into three tasks. Task 1 and 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3.

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). Objetive: Minimize C_D with constant C_L

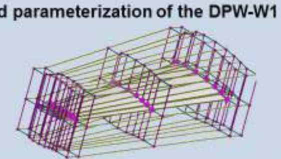


Task 1.1 Surrogate models comparison

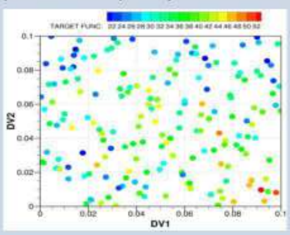


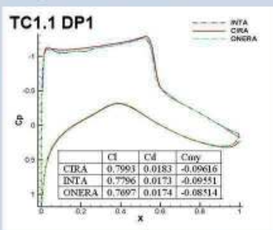
In order to minimize the sources of discrepancies and allow a fair comparison between surrogates, the **geometry parameterization**, the **computational grids** (unstructured and structured) and the **surface deformation algorithm** are **shared** between all partners.

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..





	Cl	Cd	Cmy
CIRA	0.7993	0.0183	-0.09616
INTA	0.7796	0.0173	-0.09551
ONERA	0.7697	0.0174	-0.08514

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 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/AG52 took off on February 2013. Nine members participate in this Action Group: four from research establishments (INTA, CIRA, FOI, ONERA), three universities (UAH, UNIS, VUT) and two from industry (AIRBUS-Military and SAAB). VUT is not a member of the GARTEUR organization but all partners agreed to welcome the VUT into the team and were accepted by the GARTEUR council.
The work in AG52 is divided into three tasks. Task 1 and 2 are test-case based and each contains two different test cases. "Best-practice guidelines" are addressed in Task 3.
Two test cases are defined in Task 1:
TC 1.1 RAE2822 air foil:
DP1: M=0.734, Re=6.5×10^6, AoA=2.65º.
DP2:M=0.754, Re=6.2×10^6, AoA=2.65º.
Objective: maximize C_L/C_D subject to certain aerodynamic and geometric constraints.

TC 1.2 DPW-W1 wing
DP1: M=0.76, C_L=0.5, Re=5×10^6
DP2: M=0.78, C_L=0.5, Re=5×10^6
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).

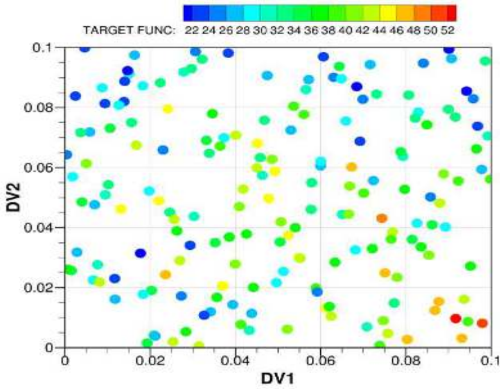


Figure 1: Sampled target response (aerodynamic efficiency) as a function of two design variables

- **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**

Member	Partner	E-mail
Esther Andrés	INTA	eandres@isdefe.es
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Gerald Carrier **Jacques Peter**	ONERA	gerald.carrier@onera.fr jacques.peter@onera.fr
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Leopoldo Carro **Sancho Salcedo**	UAH	leopoldo.carro@uah.es sancho.salcedo@uah.es
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Petr Dvorak **Ropert Popela**	VUT	dvorak.p@fme.vutbr.cz popela.r@fme.vutbr.cz

- **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	

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

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

Action Group Chairman: 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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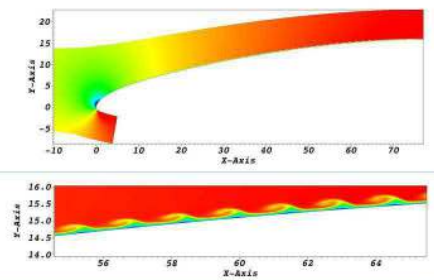


Direct numerical simulation around NLF (2)-0415. Lower figure is a close up of CF vortices in side the boundary layer caused by DRE.

The Programme

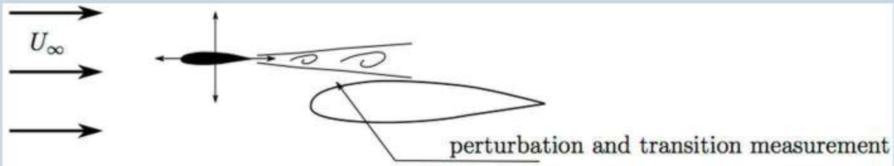
Objectives of AD/AG-53
Main objective of the proposed activities is to understand the effects of surface irregularities and perturbations in incoming flow on transition in three-dimensional flows and efficiency of transition control methods. The activities cover both experimental and numerical investigations.

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

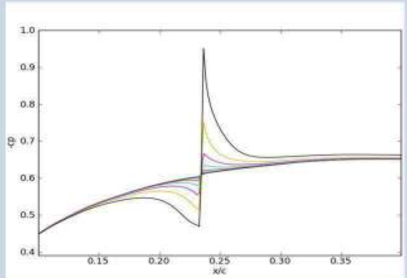


Schematic view of the experimental set-up in the ONERA Juju wind tunnel.

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**

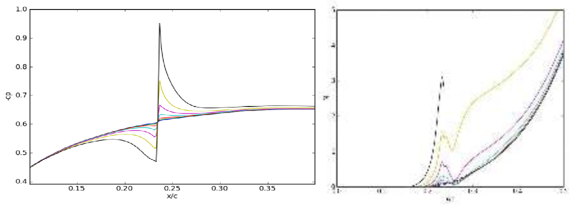
The transition process of boundary layers is mainly characterised by three stages. These are generation, growth and breakdown of disturbances. The process of birth of disturbances inside a boundary layer is called receptivity. Disturbances can be generated by surface roughness or other sources of forcing 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 have been carried out. Comparison of direct numerical simulations with simpler methods like linearized Navier-Stokes computations and adjoint methods.

- **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). A range of analytic filler profiles has been investigated including linear, quadratic (smooth at either upstream or downstream edge) and cubic (smooth at both edges). Parametric studies of TS N-factors have been made with PSE for a range of step heights.
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).

- **Management issues**

The AD/AG-53 had its kick-off meeting on Sept 5, 2013 at University of Genova. Position of R. Donelli (original CIRA representative) within CIRA has been changed and D. de Rosa has replaced him in this group. Since the proposal for Action Group was send in, EADS has joint the group.

- **Expected results/benefits**

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

- **AD/AG-53 membership**

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

- **Resources**

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

EXPLORATORY GROUP REPORTS

AD/EG-69 RANS-LES INTERFACING FOR HYBRID AND EMBEDDED LES APPROACHES

Monitoring Responsable: T. Berglind
FOI

Chairman: Dr. S.-H. Peng
FOI

- **Objectives**

The objective of AD/EG-69 is to explore RANS-LES coupling methods for hybrid RANS-LES and embedded LES modelling approaches. The EG consists of ten members, seven from research organizations, two from university and one from industry. The main objective of the proposed AG work 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 main objectives within the proposed AG work are:

- To evaluate current RANS-LES interfacing method in hybrid RANS-LES modelling.
- To address the so-called "grey-area" problem in association with RANS-LES interaction, as well as with the RANS and LES modes hybridized.
- To develop/improve RANS-LES coupling methods to be incorporated in hybrid RANS-LES modelling, including embedded LES methods.
- To verify and assess the developed methods in turbulence-resolving simulations of typical turbulent aerodynamic flows.

- **Main Achievements**

EG69 includes all the members of AG49, plus three new members and one industrial observer. The proposed AG work to some extent is a continuation of AG49 (completed in March 2013), but with a focus on exploration of RANS-LES coupling and new development hybrid RANS-LES methods to overcome some identified problems in existing modelling approaches, particularly to address the so-called "grey-area" problem for zonal and non-zonal methods.

On 8 March 2013, EG69 had its kick-off meeting after the final meeting of AG49 in Stockholm, at which all EG members and the industrial observer have presented their interest of a number of proposed new topics. Since then, members in EG69 have worked on the description of the proposed work in the new AG, and a draft of the AG proposal have been prepared and is now under further revision by the EG members.

To achieve the objective, three technical tasks are proposed in the AG work, based on numerical computations for several selected test cases. Task 1 deals with RANS-LES coupling for 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 will be explored. In these tasks, collaborative and in-depth analysis and evaluation of RANS-LES coupling methods invoked for existing hybrid RANS-LES models will be conducted in computations of some typical and important aerodynamic flow features. Comprehensive exploration and modelling improvement will be carried out on some typical RANS-LES coupling methods invoked in current hybrid RANS-LES modelling (including embedded LES). Along with 1-2 optional test cases, one mandatory test case is selected for task1 and Task 2 serving the modelling calibration and validation. A common mandatory test case is selected for the overall assessment of developed methods in Task 3.
Based on the EG69 work, the new AG aims to launch in March or April 2014.

- **EG membership**

Member	*Organisation*	*e-mail*
P. Catalano	*CIRA*	*p.catalano@cira.it*
T. Knopp	*DLR*	*Tobias.Knopp@dlr.de*
A. Probst	*DLR*	*Alex.probst@dlr.de*
D. Schwamborn	*DLR*	*Dieter.schwamborn@dlr.de*
S.-H. Peng	*FOI*	*Shia-Hui.Peng@foi.se*
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A. Skillen	*UniMan*	*Alex.skillen@machester.ac.uk*
L. Tourrette	*Airbus-FR*	*Loic.tourrette2airbus.com*

AD/EG-71	**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 system. Two commonly used countermeasures are chaff and flares.
Chaff consists of small pieces (or threads) of metal or metalized glass fibre. The chaff interacts with the electromagnetic radar wave and can thereby decoy or distract enemy radar. Chaff is dispensed in very large numbers from specific dispenser devices, 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 propagates 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 first figure. Flares, on the other hand, act more like solid bodies and from this point of view more conventional methods can be used to evaluate the aerodynamic properties. The second figure displays the computed flow around a flare (work by NLR).

- **Proposed work**

An exploratory group (AD/EG-71) was founded to assess the need for and possibility of performing collaborative studies in the field countermeasure aerodynamics. It was concluded that an Action Group proposal would be prepared. The proposed work is aimed at obtaining further understanding of the flow physics involved and also to develop more accurate modeling methods. The work is divided into two work packages, one for chaff and one for flares.

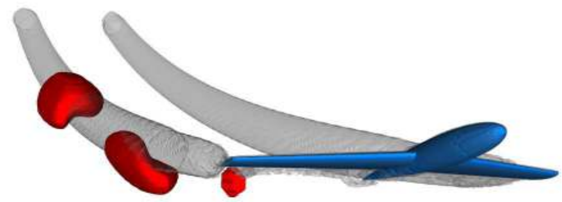

Fig.1 FOI simulation of chaff concentration transport.

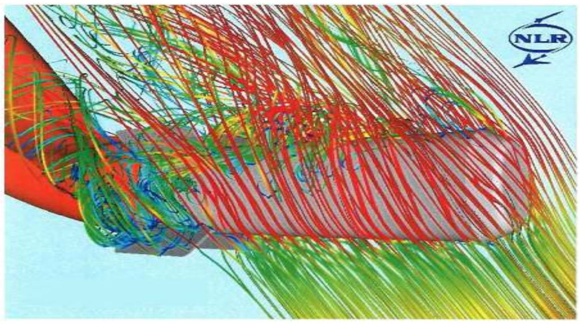

Fig. 2 Flow around a flare, computed by NLR.

The work related to chaff involves investigating methods for including the chaff orientation. This is an important factor when considering the defensive value of the chaff. The orientation of chaff can also be expected to affect the dispersion. Among the partners, two different chaff tracking methods have been used, the Lagrangian approach (tracking individual chaff) and the Eulerian approach (transporting the chaff concentration). These two methods will be further evaluated and compared. Comparisons might be performed by considering generic flows including, for instance, fibers. Furthermore, a simplified geometry (such as the VFE-2) with a refined wake will be considered.
For flares, the major interest will be to understand of how the burning of the IR payload affects the aerodynamics through the ejection of exhaust gases. This can be performed using CFD methods in combination with boundary conditions that account for the burn temperature of the payload and the mass flux of the exhaust gas species.

- **AD/EG-71 membership**

Member	Organisation	e-mail
L. Ruiz	Airbus Military	Luis.Ruiz@military.airbus.com
O. Estibals	Etienne Lacroix	Olivier.Estibals@etienne-lacroix.com
T. Berglind	FOI	Torsten.berglind@foi.se
O. Grundestam	FOI	Olof.grundestam@foi.se
C. Jeune	MBDA France	Christophe.jeune@mbda-systems.com
O. Boelens	NLR	Okko.boelens@nlr.nl

ANNEX B

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "FLIGHT MECHANICS, SYSTEMS AND INTEGRATION"

Remit

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

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

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

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

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FLIGHT MECHANICS, SYSTEMS AND INTEGRATION

GoR-FM OVERVIEW

GOR ACTIVITIES

2013 has been, in general, a transition year for the FM GoR. There have been several changes in membership and, as it was already reported, several members still face significant budget reduction.

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

Two Exploratory Groups have been under consideration in 2013:
- FM/EG-28 Non-linear flexible civil aircraft control benchmark for flight control methods assessment;
- FM/EG-29 Safety assessment of flight collision avoidance systems with formal V&V, simulation and proofs.

Still, under the threat of a lack of human resources among potential partners, mainly due to the lack of GARTEUR project funding sources, the first EG28 kick-off meeting took place on 23rd April 2013.

Other new topics under discussion have been discussed on the light of the existing EG´s, the feasibility of recovering part of AG19 and the previous ideas.

Only one action group was active in 2013, AG18.

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

FM/AG-19 looks at the problem of flexible aircraft modelling – in particular the problem of cross-coupling between rigid and non-rigid structures – although this is related to the critical area of flight control design. FM/AG-19, after suffering from severe delays in the critical path of the research activity up to more than 24 months has been definitely cancelled by FM GoR. It is to note that apart of delays and lack of resources, the AG has been influenced by the fact that an industrial partner was leading the research and this was not possible to continue because of heavy commitments in other duties. A plan has been set up as to recover the work done and make it useful for next research under EG28 consideration.

MANAGEMENT ISSUES

The GoR met on two occasions during 2013, with good attendance at each meeting. In addition to discussing new ideas, the GoR decided to as well play a more active role in the running AGs by participating in the AG meetings. Members of the GoR did continue to be engaged in current FP7 activities as well as in and the new H2020 near to start by the end of 2013. Close observation of these are being maintained by the GoR. Topics from unsuccessful bids are being considered for GARTEUR collaboration (since these are already considered a priority for nations).

Efforts have continued to increase the industrial participation, particularly by equipment/avionics partners; this will complement the group's manufacturing representatives. However, no new participation was secured in 2013with some of the current IPOCs having low profile activity in the Group.

FUTURE PLANS

During 2014 the GoR will continue efforts to establish new EGs.

The FM GoR will have its next meeting in ONERA Toulouse.

The FM GoR will continue its way on spending quite some time in active discussions with the running AGs, generation of pilot papers to consider new ideas, and consideration of topics to prepare and anticipate for Horizon 2020.

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					AGFinished	
A	Flexible Aircraft Modelling Methodologies	FM/AG-19					Cancelled	
A	Fault Tolerant Integrated Aircraft Management System	PP		On halt				
A	Non-linear control benchmark	EG						
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				
	Combined formal methods and A/C methods for the verification & validation of adaptive systems, with application to safety assessment of collision avoidance systems	PP						

AG	EG	Pilot Paper
Existing	Existing	Existing
Planned	Planned	Planned

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

MANAGED AND FORESEEN GOR ACTIVITIES

The following meetings were held during 2013:

- 99th GoR(FM) meeting at NLR, Amsterdam, 7th of June 2013;
- 100th GoR(FM) meeting at DLR, Braunschweig, 26th of Sept 2013.

Ten to twelve national representatives and IPOCs attended each of the meetings during 2013 to monitor the activities of the AGs and to discuss new ideas and pilot papers.
The estimated effort associated with these activities amounts to 2,5 man-months (50 man-days) in total and the associated travel and subsistence costs are roughly 20 k€.
The following meetings are planned for 2014:

- 101st GoR(FM) meeting at ONERA, Toulouse, France in February 2014;
- 102nd GoR(FM) meeting at CIRA, Capua, Italy, in September 2014.

Francisco Muñoz Sanz
Chairman
Group of Responsables
Flight Mechanics, Systems and Integration

GOR MEMBERSHIP

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

Chairman			
Mr. Patrick Fabiani (Jan.-Sept. 2013)	ONERA	France	Patrick.Fabiani@onera.fr
Mr. Francisco Muñoz Sanz (from Oct. 2013)	INTA	Spain	mugnozsf@inta.es

Vice-Chairman			
Mr. Francisco Muñoz Sanz (Jan.-Sept. 2013)	INTA	Spain	mugnozsf@inta.es
Mr. Rob Ruigrok (from Oct. 2013)	NLR	The Netherlands	ruigrok@nlr.nl

Members			
Mr. Antonio Vitale	CIRA	Italy	a.vitale@cira.it
Mr. Daniel Cazy	Airbus	France	daniel.cazy@airbus.com
Mr. Rob Ruigrok	NLR	The Netherlands	ruigrok@nlr.nl
Mr. Martin Hagström	FOI	Sweden	martin.hagstrom@foi.es
Mr. Bernd Korn	DLR	Germany	Bernd.Korn@dlr.de
Mr. Philippe Mouyon (from Oct. 2013)	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)

The following FM Action Group has been active during 2013:
FM/AG-18 “Towards greater Autonomy in Multiple Unmanned Air Vehicles”
FM/AG-18 has demanded and obtained a 6 month extension in order to prepare a series of publication in the international Bristol UAV Conference, to be held in May 2013.

The following FM Action Group has been stalled since end 2011.
FM/AG-19 “Flexible Aircraft Modeling Methodologies”
Neither the group, nor the GoR have been able to recover from the defection of expert and specific resources in the critical work package that was to provide the common working benchmark to the rest of the group. This led to FM GoR to decide to cancel the AG19.

Exploratory Groups (EG)

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

FM/EG-28 “Non-linear flexible civil aircraft control benchmark for flight control methods assessment”.
FM/EG-28 has started and held the Kick off Meeting in April 2013.

FM/EG-29 “Safety assessment of flight collision avoidance systems with formal V&V, simulation and proofs”.

FUTURE TOPICS

Any other new topics under discussion have been put on hold until one at least of the two EG is launched.

TABLE OF ACTION GROUPS AND EXPLORATORY GROUPS

Subjects	ST	2009	2010	2011	2012	2013	2014
FM/AG-15 IO–analys. and test techn. for prevention, II	AG						
FM/AG-16 Fault tolerant control	AG						
FM/AG-17 Nonlinear analysis and synthesis techniques	AG						
FM/AG-18 Towards greater Autonomy in Multiple Unmanned Air Vehicles	AG	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 2013

ACTION GROUP REPORTS

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

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

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

Background

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

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

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

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

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

Programme/Objectives

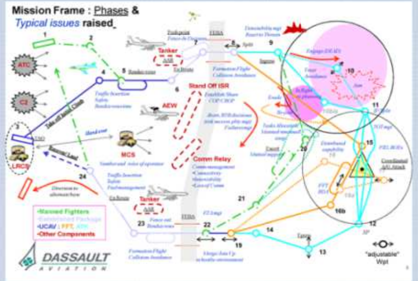
Within the aviation industry human supervisory control of complex systems has long been a requirement driven by the need to reduce air vehicle crew levels and workload, compensate for human frailty and latterly, the demands of UAVs deployed in many diverse tasks. The development of autonomous planning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

The objectives of the FM/AG-18 are:

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

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

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



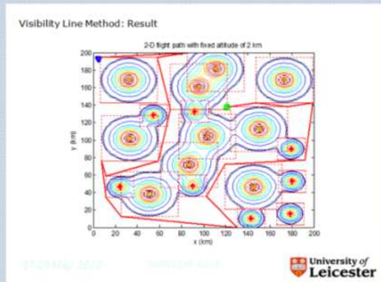
Typical mission framework showing mission phases

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

Results

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

On the basis of the results, indications will be given of spin-off applications and critical technology research areas for the future. How the candidate approaches can be applied to both military and civil systems with few or minor modifications will be articulated. The AG hopes to exploit its results by a dedicated session in the Bristol UAV conference in April 2013.



Screenshot of Path Planning work

FM/AG-18 TOWARDS GREATER AUTONOMY IN MULTIPLE UNMANNED AIR VEHICLES

Monitoring Responsable: P. Fabiani
ONERA

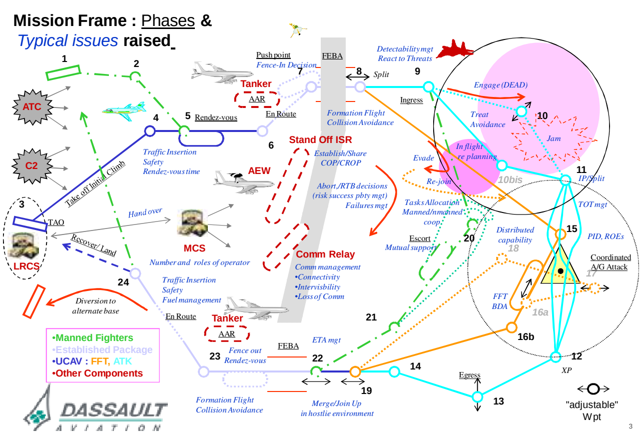
Chairman: Dr. J. Platts
QinetiQ

- **OBJECTIVES**

The objectives of the AG are to establish:

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

- **MAIN ACHIEVEMENTS**



Typical mission framework showing mission phases

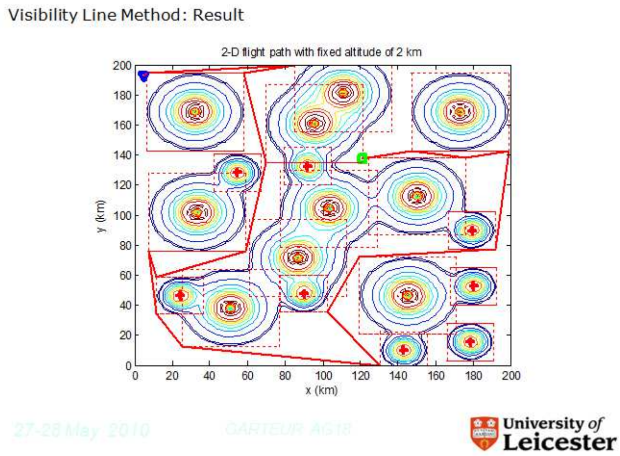
Work in FM/AG18 started in 2011. Some re-planning has taken place to accommodate changes to group membership due to funding problems of some members. Candidate methods have been identified and evaluated:

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

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

Next steps will include

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



Screenshot of Path Planning work

- **MANAGEMENT ISSUES**

It is planned to increase and extend the exploitation activities of this AG. E.g. it is planned to prepare papers for the Bristol UAV conference in May 2013. Therefore, the AG has been extended. Final report of FM/AG18 is currently in the process of being prepared.

- **EXPECTED RESULTS/BENEFITS**

Within the aviation industry human supervisory interaction with complex systems has long been a requirement driven by the need to reduce air vehicle crew levels and workload, compensate for human frailty and latterly, the demands of UAVs deployed in many diverse tasks. The development of autonomous planning and decision making techniques will increase vehicle autonomy thereby enabling a reducing in the number of operators required, or a reduction in operator workload, as well as compensating for human frailty. It is expected that the autonomous planning and decision making techniques to be developed in this AG will have application in a wide range of other domains.

- **FM/AG-18 MEMBERSHIP**

Member	Organisation	e-mail
Johan Dijkhuisen	NLR	
Matthijs Amelink	Thales NL	Matthijs.Amelink@D-CIS.NL
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Bruno Patin	Dassault	
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John-Loup Farges	ONERA	Jean-Loup.Farges@cert.fr
Vittorio Di Vito	CIRA	v.divito@cira.it

- **RESOURCES**

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

- **PROGRESS/COMPLETION OF MILESTONE**

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

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

FM/AG-19: Flexible Aircraft Modeling Methodologies

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

Background

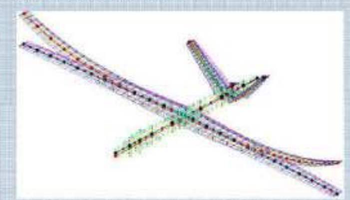
The next generation of air vehicles will have to face very challenging requirements in terms of performance, weight saving and overall performance efficiency. One way to achieve these targets is via an advanced flight control system performing multiple functions related with stabilization, envelope protection,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

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

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

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

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



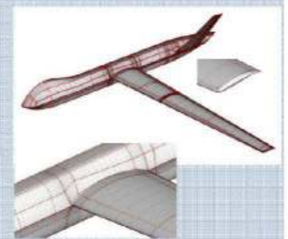
Programme/Objectives

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

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

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

CIRA
DLR
ONERA
NLR
DSTL
Airbus Military
CASSIDIAN
BAE Systems
Imperial College
Univ. of Liverpool
TU Berlin



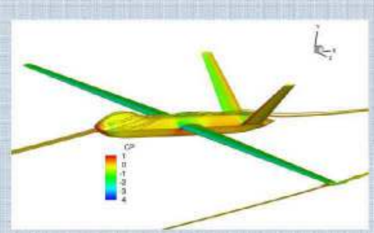
Results

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

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

Next actions will be:

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



FM/AG-19	**FLEXIBLE AIRCRAFT MODELLING METHODOLOGIES**
Monitoring Responsable:	F. Munoz Sans INTA
Chairman:	F. Asensio Airbus Military

- **OBJECTIVES**

The objective is to define a way of working for the integrated modeling activities, with the objective to generate an integrated aerodynamic and aeroelastic model to be used in the flight control laws design of advanced FCS. With this objective a number of work packages with a balance commitment in terms of disciplines and partners to ensure that all the required work can be addressed have been defined. Main work packages activities will include:

- Definition of the requirements that should be met for the FCS design point of view by an interdisciplinary flexible aircraft model to achieve two major objectives; FCS design and validation cycles reduction and to provide an early and accurate knowledge of the adverse effects due to structural flexibility.
- Define the mathematical formulation and develop a flexible aircraft model with the constrains requirements in the sense of being suitable for control laws design and analysis and keeping the matching between this low order model and highly complex physical models.
- Define a problem where the design should be challenging enough from a structural coupling point of view. It should be better is there would be a design already done using traditional methods.
- Built a software code including required data handling and analysis functions with a model applicable to a specific case under study that will be used for the model validation and functional application activities.
- Develop identification methods suitable for flexible aircraft allowing the definition of a process for model validation in ground and flight test. Developed methods will be applied using data generated by the high fidelity simulation model
- Perform an integrated design exercise and compare the result with the design performed following traditional methods.
- Perform a continuous industrial review activity in order to steer it an gathered the maximum benefit from the industrial perspective

- **MAIN ACHIEVEMENTS**

Main achievements comprise

- Requirements for software coding; draft deliver for partners review
- Flexible aircraft (review of existing approaches and models) state of the art finished
- Benchmark specification frozen. Catia CAD and FEM benchmark model release to the partners
- Rigid aerodynamic tables generated
- Model validation (basis philosophy established)

Next actions will be

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

- **MANAGEMENT ISSUES**

FM/AG-19 was kicked-off in November 2009. However, it had a slow start and most of the running work packages have been delayed. Mitigation and recovery actions have been put in place. However, situation has not improved significantly. Due to lack of resources at management level and within the individual work packages the activity was delayed by more than 24 months.

- **EXPECTED RESULTS/BENEFITS**

The next generation of air vehicles will have to face very challenging requirements in terms of performance, weight saving and overall performance efficiency. One way to achieve these targets is via an advanced flight control system performing multiple functions. In order to design the control laws algorithm within the flight control system it is essential to get precise mathematical models of the vehicle to be controlled.

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

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

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

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

- **AG MEMBERSHIP**

Member	Organisation	e-mail
Clement Toussaint	ONERA	Clement.Toussaint@onera.ft
Marco Cicala	CIRA	mcicala@cira.it
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Ken Badcock	Univ. of Liverpool	K.J.Badcock@Liverpool.ac.uk
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Francisco Asensio	Airbus Military	Francisco.Asensio@miltary.airbus.com

- **RESOURCES**

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

- **PROGRESS/COMPLETION OF MILESTONE**

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

FM/AG-19 stalled since 2011. Hence it was decided to close FM/AG-19 during the FM-GoR meeting in June 2013.

ANNEX C

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "HELICOPTERS"

Remit

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

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

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

- Decrease costs (development and operation) through CFD and comprehensive calculation tools, validated with relevant tests campaign;
- 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 2013 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 especially 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:

- 67th GoR Meeting: 18-19 February 2013, Eurocopter, Marignane, France;
- 68th GoR Meeting: 25-26 September 2013, Eurocopter, Donauwörth, Germany.

The main business of the meetings was to discuss about further topics and to implement the 3-5 year planning process as well as to present the status of the current AGs and EGs. The GoR meetings were used to harmonize the views and the involvement of members regarding preparations for proposals for FP7/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 2013 the activities in the HC-AGs was at a low level. Fortunately, the GoR was able to initiate several new ideas and pilot papers and to launch 4 new EGs in 2013.

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.

These topics can be:

- Conceptual Design of Helicopters;
- Performance, fuel efficiency;
- Safety (Crash, Hums, Crew Workload, all weather operations);
- Noise external (passive, active rotors, flight procedures, atmospheric effects, shielding);
- Noise internal (Comfort, Costs, Weight ➔ fuel consumption);
- 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”.

HC/AG-20 “Cabin internal noise: simulation methods and experimental methods for new solutions for internal noise reduction”.

HC/AG-21 “Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity”.

RUNNING EXPLORATORY GROUPS

HC/EG-29 “Intelligent Lifeing & HUMS”.

HC/EG-31 “PreFCS - Conceptual Design of Helicopters”.

HC/EG-32 “Forces on Obstacles in Rotor Wake”.

HC/EG-33 “Wind turbine wakes and the effect on helicopters”.

HC/EG-34 “CFD based flow prediction for complete helicopters”.

HC/EG-35 “Helicopter Fuselage Scattering (installation) Effects for Exterior/Interior Noise Reduction”.

GENERATING NEW TOPICS FOR COMMON STUDIES
ROLLING PLAN FOR HC/AGS AND HC/EGS

The 3–5 year planning will continue to be implemented and was presented in more details to the Council in the Autumn 2013 meeting in Amsterdam. This list is implemented with new topics according to the GoR discussions.

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

Topic	ST	2009	2010	2011	2012	2013	2014	2015	2016
Wake 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 =>				
(EG-28) Testing/Modell. for Internal Noise Investig.	HC/EG28			=> AG20					
EG-29 HUMS	HC/EG29								
EG-30 Simulation Fidelity	HC/EG30					=> AG21			
EG-31 Conceptual design of Helicopters CoDHe	HC/EG31								
EG-32 Forces on Obstacles in Rotor Wake	HC/EG32								
EG-33 Wind Turbine Wake and the effect on helicopters	HC/EG33								
EG-34 CFD based flow prediction for complete helicopters	HC/EG34								
EG-35 Helicopter Fuselage Scattering Effects for Exterior/In	HC/EG35								
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								
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.

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

REPORTS ISSUED
In 2013, no final reports were issued.

FORESEEN GOR ACTIVITY
Two meetings are planned in 2014; the first one on 6-7 March 2014 at CIRA, Capua, Italy and the second one on September in France.

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

GOR MEMBERSHIP

Membership of the Group of Responsables Helicopters (end 2013)

Chairman			
Lorenzo Notarnicola	CIRA	Italy	l.notarnicola@cira.it
Vice-Chairman			
Mark White	Uni of Liverpool	United Kingdom	mdw@liverpool.ac.uk
Members			
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Antonio Antifora	AgustaWestland	Italy	antonio.antifora@agustawestland.com
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Joost Hakkaart	NLR	The Netherlands	Joost.hakkaart@nlr.nl
Observer			
Richard Markiewicz	Dstl	United Kingdom	rhmarkiewicz@mail.dstl.gov.uk

HC-GoR visiting Eurocopter, Marignane, during the 67th GoR meeting (18-19 February 2013); Blanche Demaret, Joost Hakkaart, Klausdieter Pahlke, Elio Zoppitelli, Lorenzo Notarnicola.

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action Groups (AG)

The following Action Groups were active throughout 2013:

HC/AG-19 “Methods for Improvement of Structural Dynamic Finite Element Models Using In-Flight Test Data” has been started May 2010for a 3 years duration. This AG was extended up to the end of 2013, 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 2013 were focused on the set-up, testing and comparison 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.

Exploratory Groups (EG)

HC/EG-29 “Intelligent Lifeing & HUMS” was launched in 2011, and started in April 2013.

HC/EG-31 “PreFCS - Conceptual Design of Helicopters” has run smoothly at beginning 2013 but it stalled during the year; final decision early 2014.

HC/EG-32 “Forces on Obstacles in Rotor Wake” was launched in April 2013 and the kick-off meeting was held on 16-17 September. The objective is to investigate the problem of the evaluation of the forces that are exerted on obstacles by the wake of a helicopter rotor when flying in their proximity and to improve methods to allow assessment of ground interaction effects.

HC/EG-33 “Wind turbine wakes and the effect on helicopters” was launched in April 2013 and had the KoM in September 2013 with the objective to study the wind turbine wake and its effect on helicopter flight with regard to flying stability, handling quality and safety.

HC/EG-34 CFD based flow prediction for complete helicopters was launched during HC-GoR67 in Marignane (Feb. ‘13), but kick-off-meeting was not yet organized.

HC/EG-35 “Helicopter Fuselage Scattering (installation) Effects for Exterior/Interior Noise Reduction” was launched in September 2013 and the kick-off meeting is expected to be held early 2014.

TABLE OF PARTICIPATING ORGANISATIONS

	HC/AG number								
	AG19	**AG20**	**AG21**	**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)						□			

□ = Member ■ = Chair

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

TOTAL YEARLY COSTS OF HC/AG RESEARCH PROGRAMMES

	2009	2010	2011	2012	2013	2014	2015	Total
Person-month	42	35	27	14	44	56	38	218
Other costs (k€)	66	31	30	7	30	30	35	229

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. In 2013 full aircraft and subcomponent GVT, shaker test and 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.

University of Liverpool · Brunel University West London · LMS Engineering Innovation · University of Bristol · NLR · Sapienza Università di Roma · AgustaWestland · University Technology Centre

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:

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

GARTEUR Responsable:
Joost Hakkaart NLR

HC/AG-19	**METHODS FOR IMPROVEMENT OF STRUCTURAL DYNAMIC FE MODELS USING IN FLIGHT TEST DATA**
Monitoring Responsable:	J. Hakkaart NLR
Chairman:	H. van Tongeren NLR

- **Objectives**

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

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

The main purpose of this AG is to explore methods and procedures for improving finite element models through the use of in-flight dynamic data. For the foreseeable future it is expected that validated finite element models will be the major tool for improving the dynamic characteristics of the helicopter structural design. It is therefore of great importance to all participants that the procedure of validating and updating helicopter finite element models with such in-flight data is robust, rigorous and effective in delivering the best finite element model.
The members will present further developments of methods used to update the finite element model whether automated, manual or both. Advantages and disadvantages of the approaches should be given and possible future developments of the procedures for localizing the areas of the models causing the discrepancies and for improving the updating process presented.
The members will present developments of methods for the prediction of the effect of configuration changes on FRF behaviour. These can be based on a finite element model. Advantages and disadvantages of the approaches should be given and possible future developments of the procedures presented.
Finally the group shall assess the methodology with respect to evaluating vibration measurements from flight tests where effects of aerodynamic and rotating machinery affect the vehicle response. The objective is to extract modal parameters from in-flight measured data. Advantages and disadvantages of the approaches should be given and possible future developments of the procedures presented.

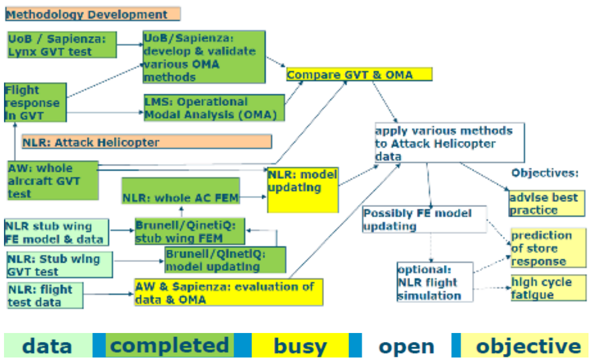
- **Main achievements**

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

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

The department of mechanical and aerospace engineering of “La Sapienza” University has a model helicopter at its disposal. A finite element model is available. The model has been reworked to represent the actual mass and configuration in a new ground vibration test that was conducted in January 2013.
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 almost 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 in January 2013. The model will be tuned with the GVT results. This work has been delayed due to high the work load for other projects at NLR.

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

Work on methods development at the universities has been completed. In 2013 methods are to be applied to the available flight data. Reporting will be completed early 2014.

- **Management issues**

After the Kick-Off meeting on 24th June 08 the first technical meeting took place on 20-21 Nov. 08 at Bristol University. There were no technical meetings in 2009. During 2010 two new members joined: University of Rome La Sapienza and LMS from Belgium. QinetiQ has left AG-19 in 2011. This AG effectively started in May 2010 and therefore the duration was extended until 2013. There were two technical meetings in 2012 (NLR in Amsterdam and La Sapienza in Rome) and one meeting in 2013. Final meeting planned for early 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**

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Nima Ameri	Bristol Uni	nima.ameri@bristol.ac.uk
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Cristinel Mares	Brunell Uni	Cristinel.Mares@brunel.ac.uk
Bart Peeters	LMS	bart.peeters@lmsintl.com
Hans v Tongeren *c*	NLR	Hans.van.tongeren@nlr.nl
Trevor Walton	Agusta Westland Ltd	Trevor.Walton@agustawestland.com

- **Resources**

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

- **Progress/Completion of milestone**

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

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.

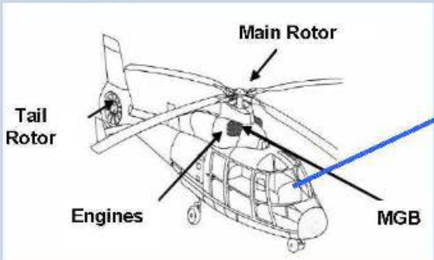
It appears that conventional passive systems (trim panels, passive anti-resonance isolation systems as well as classical vibration absorbers and pendulum absorbers) are still the main way to control the acoustic of the cabin whereas active systems (active vibration and noise control) are not completely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

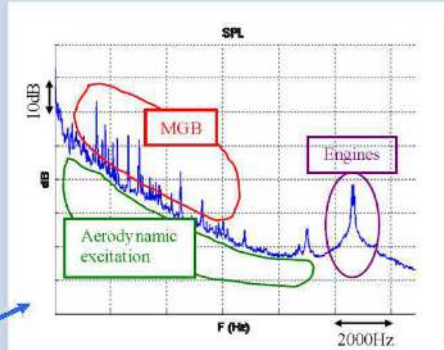
HC/EG-28, about internal noise and associated passive acoustic solutions (soundproofing, e.g. 1cm-thick trim panels designed for optimizing the absorption or the transmission loss), development of a vibro-acoustic model of the cabin (SEA coupled with FEM), human factors (subjective annoyance, speech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

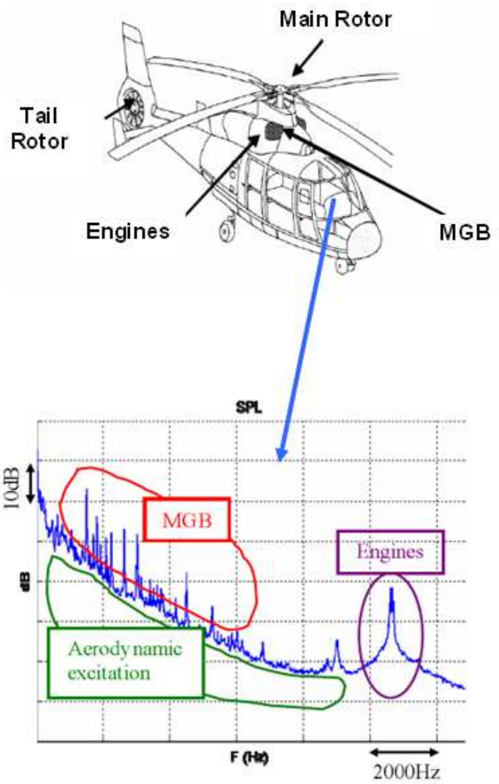
The EG28 conclusions listed the following needs:

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 2013 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.

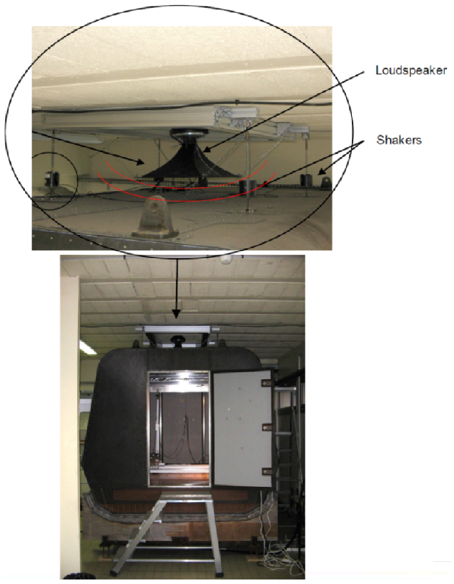


- **Management issues**

The Chair was able to organise the kick-off meeting via a webex on October 18th, 2012. During the meeting the membership, resources and work packages were discussed and confirmed. Actual starting date was January 1st, 2013. In 2013 there were two technical progress meeting, a face-to-face meeting on May 22nd in ONERA Toulouse and a video conference meeting on the 2nd of October.

- **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
Rik Wijntjes	NLR	Rik.Wijntjes@nlr.nl
Thomas Haase	DLR	Thomas.Haase@dlr.de
Frank Simon	ONERA	frank.simon@onera.fr
Pasquale Vitiello	CIRA	p.vitiello@cira.it
Gian Luca Ghiringhelli	PoliMI	gianluca.ghiringhelli@polimi.it

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.

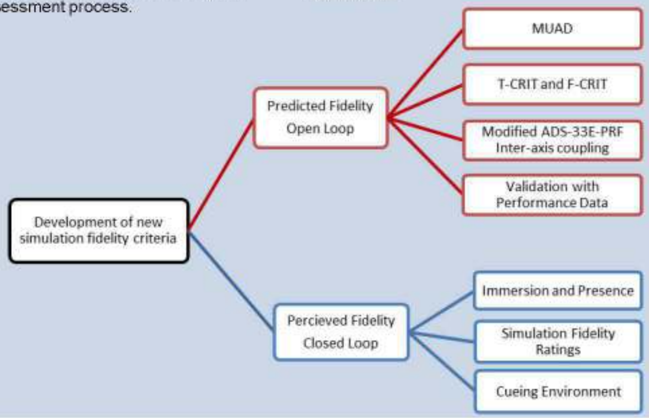
The work programme has two strands:

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.

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
H. Duda	DLR
F. Cuzieux	ONERA
B. Berberian	ONERA
D. Spira	CAE
S. Richard	Thales
C. Emmanuele	AgustaWestland

GARTEUR Responsable:
J. Haakkart NLR

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

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..

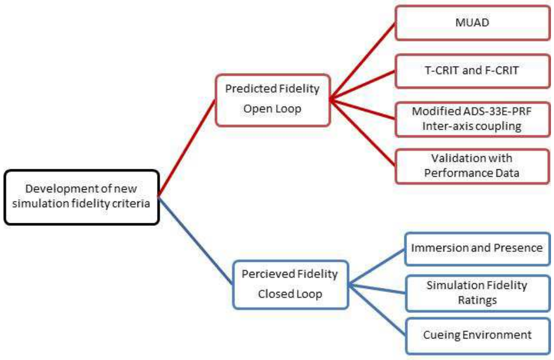
Specific areas of interest for helicopter flight simulation device fidelity include:

- 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.

- **Results/benefits**

The research outcomes would be in the form of new metrics which would define rotorcraft simulation fidelity boundaries together with guidelines for the subjective fidelity assessment process. It is anticipated that the outputs from this AG would be used to enhance the fidelity criteria that exists in current and emerging flight simulation qualification standards for rotorcraft.

- **HC/AG-21 membership**

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

- **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
		2013	2014	2015	
Person-months	Actual/ Planned	P18	P30	P18	P66
Other costs (in K€)	Actual/ Planned	tbd	tbd	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	
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	

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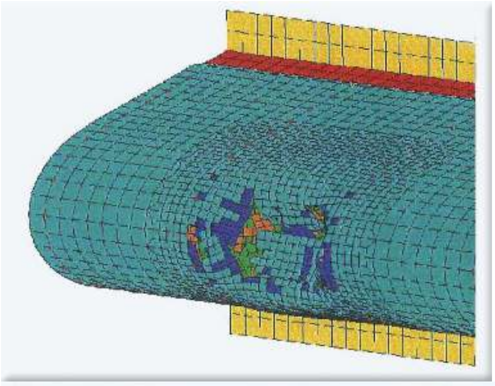
ANNEX D

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "STRUCTURES AND MATERIALS"



Remit

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

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

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

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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;
- Sizing of aircraft structures subjected to dynamic loading;
- Bonded and bolted joints.

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.

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

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.

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 2013, the GoR SM has almost recovered from the situation caused by the UK withdrawal four years ago. New Action Groups and Exploratory Groups have started and three final reports have been prepared but 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

No	Topic	2010	2011	2012	2013	2014	2015
SM/AG-30	High velocity impact				Report pending		
SM/AG-31	Damage management of Composite Structures						
SM/AG-32	Damage growth in composites						
SM/AG-33	RTM Materials properties during curing				Report pending		
SM/AG-34	Damage Repair with Composites			EG 40 ➔			
SM/AG-35	Fatigue and Damage Tolerance Assessment of Hybrid Structures			EG 38 ➔			

No	Topic	2010	2011	2012	2013	2014	2015
SM/EG-39	Design for High Velocity Impact on Realistic Structures						
SM/EG-40	Sizing of aircraft structures subjected to dynamic loading						
SM/EG-41	Bonded and Bolted Joints						

MANAGED AND FORESEEN GOR ACTIVITY

In 2013, the GoR(SM) held two meetings:

- 67th meeting on May 22 at Airbus Military, Manching, Germany;
- 68th meeting on October 1 at EDAS-IW, Suresnes, France.

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 2014, GoR meetings are planned as follows:

- 69th meeting on May 29 at Airbus, Bremen, Germany;
- 70th meeting on October 1 in Italy (venue to be decided).

Dr. Tomas Ireman
Chairman
Group of Responsables
Structures and Materials

GOR MEMBERSHIP

Current membership of the Group of Responsables Structures and Materials

Chairman			
Dr. Tomas Ireman	SAAB	Sweden	tomas.ireman@saabgroup.com
Vice-Chairman			
Dr. Jean-Pierre GRISVAL	ONERA	France	jean-pierre.grisval@onera.fr
Members			
Dr. Joakim Schön	FOI	Sweden	joakim.schon@foi.se
Dr. Henri de Vries	NLR	The Netherlands	henri.de.vries@nlr.nl
Mr. Jose Maroto Sanchez	INTA	Spain	marotosj@inta.es
Dr-Ing. Peter Weirach	DLR	Germany	peter.weirach@dlr.de
Dr. Aniello Riccio*	UNINA	Italy	aniello.riccio@unina2.it
Dr. Umberto Mercurio	CIRA	Italy	u.mercurio@cira.it
Industrial Points of Contact			
Dr. Roland Lang	EADS M.	Germany	roland.lang@eads.com
Vacant	Alenia	Italy	
Dr. Luc Hootsmans	Stork Fokker	The Netherlands	luc.hootsmans@stork.com
Mr. Angel Barrio Cárdaba	EADS CASA	Spain	angel.barrio@casa.eads.net
Dr. Hans Ansell	SAAB	Sweden	hans.ansell@saabgroup.com
Dr. Walter Zink	Airbus	Germany	walter.zink@airbus.com
Dr Sören Nilsson	SICOMP	Sweden	soren.nilsson@sicomp.se
Dr Andy Foreman	Qinetiq	United Kingdom	adforema@qinetiq.com
Dr Caroline Petiot	EADS-IW	France	caroline.petiot@eads.net

*) Associated member

STATUS OF ACTION GROUPS AND EXPLORATORY GROUPS

Action Groups (AG)

The following Action Groups were active during 2013:

- 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 à result from EG-38.

Exploratory Groups (EG)

The following Exploratory Groups were active during 2013:

- SM/EG-39: Design for high velocity impact on realistic structures. This EG is close to become an AG
- SM/EG-41: Sizing of aircraft structures subjected to dynamic loading. This EG was formally started 2012 but no meeting has been held yet
- SM/EG-42: Bonded and bolted joints. This EG has just started and no meeting has been held yet.

Future topics

The following topics for future Exploratory Groups are discussed:

- Virtual testing
- Effect of defects in composite structures
- Benchmarking activities
- Additive Layer Manufacturing

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:

- Compression testing
- Impact loading on transparent materials
- Fibre placement

TABLE OF PARTICIPATING ORGANISATIONS

• = Member ■ = Chair

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

TOTAL YEARLY COSTS OF SM/AG RESEARCH PROGRAMMES

	2007	2008	2009	2010	2011	2012	2013
Man-month	133,5	108	102,5	50	6	7	60,5
Other costs (k€)	238	117	128	40	10	2	65

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

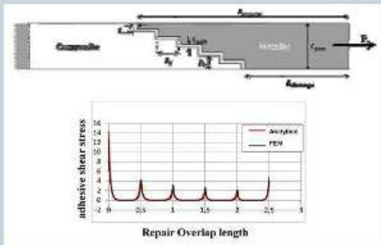
WP 5 EFFECTIVE REPAIR METHODS

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.



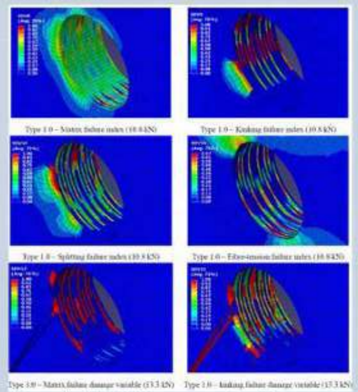
Development of an Analytical tool for Repair Design

Expected Results

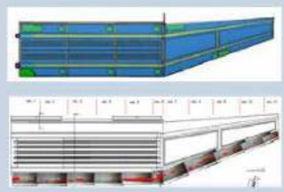
The effective outcomes can be summarized in:

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 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.

- **MAIN ACHIEVEMENTS**

Tasks accomplished in 2013
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 group is well assorted and complementary activities has been proposed in the frame of AG-34
The decision to test the developed models on common benchmark has been confirmed and three main Benchmark Have been proposed by INTA, CIRA and ALENIA. Around these three benchmark initial collaborations has started.
The Third meeting has been held on 24 October 2013 at INTA.

- **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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Giovanni Perillo	NTNU	giovanni.perillo@ntnu.no

- **RESOURCES**

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

- **PROGRESS / COMPLETION OF MILESTONE**

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

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

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

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

Background

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

1.Composite structure is sensitive to environmental conditions, metal parts usually are not. If it is decided not to perform fatigue- or residual strength tests under these conditions, which aspects should be taken into account via environmental factors on the applied loads?

2.Material scatter for composites is much larger than for metals; this is usually covered by a combination of a life factor and a load enhancement factor. However, to avoid non-linear behaviour of test set-up and too high stress levels in the metal parts a maximum overall load increase should be respected.

3.In general, damage growth in composite materials is most sensitive for compression-compression cycles, where metal fatigue initiation and crack growth are more sensitive to tension-compression and tension-tension cycles. A generic process for a load spectrum reduction technique covering both aspects should be discussed.

4.Spectrum truncation levels must be different for metals and composites. Where composites experience high damage from high peak loads, metals will experience crack retardation after application of a severe load condition.

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

Programme/Objectives

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

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

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

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

DLR FOI FOKKER AEROSTRUCTURES NLR SAAB

Results

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

A kick-off meeting was held at NLR on 28-02-2013 in Amsterdam and the first progress meeting was at FOI – Stockholm on 20-09-2013.

Task 1:
A conceptual definiton 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 propopal 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 simulation results of MMB tests with hydro-thermal ageing.
-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 schematic hybrid wing torsion box model of Gripen under thermal and mechanical loads. Also impact damages were considered.

SM/AG-35	FATIGUE AND DAMAGE TOLERANCE ASSESSMENT OF HYBRID STRUCTURES
Monitoring Responsable:	H.P.J. de Vries NLR
Chairman:	R.P.G. Veul NLR (till 31-08-2013) J. Laméris (from 1-09-2013)

• 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 Kick-off meeting was held on February 28th, 2013 at NLR in Amsterdam. In September Ruud Veul was succeeded by Jaap Laméris as chairman due to the former job change within NLR. The first progress meeting was held on 20 September 2013 at FOI in Stockholm.

• EXPECTED RESULTS/BENEFITS

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

• SM/AG-35 MEMBERSHIP

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Zlatan Kapidzic	SAAB	zlatan.kapidzic@saabgroup.com

• PLANNED RESOURCES

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

- **PROGRESS / COMPLETION OF MILESTONE**

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

EXPLORATORY GROUP REPORTS

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

Monitoring Responsable: J. Maroto
INTA

Chairman: L. Iannucci
Imperial college

- **Objectives**

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

- **Benefits**

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

- **Progress**

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

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

- **EG membership**

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

SM/EG-41 SIZING OF AIRCRAFT STRUCTURES SUBJECTED TO DYNAMIC LOADING

Monitoring Responsable: J. Schön
FOI

Chairman: P-O. Marklund
SAAB

- **Objectives**

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

- **Benefits**

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

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

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

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

Key issues to be addressed are:

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

- **Progress**

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

- **EG membership**

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

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. The work will start with a search for more interested members.

- **EG membership**

INSTITUTION	COUNTRY	Contact Point
FOI	Sweden	J. Schön
EADS-IW	France	
Eurocopter		