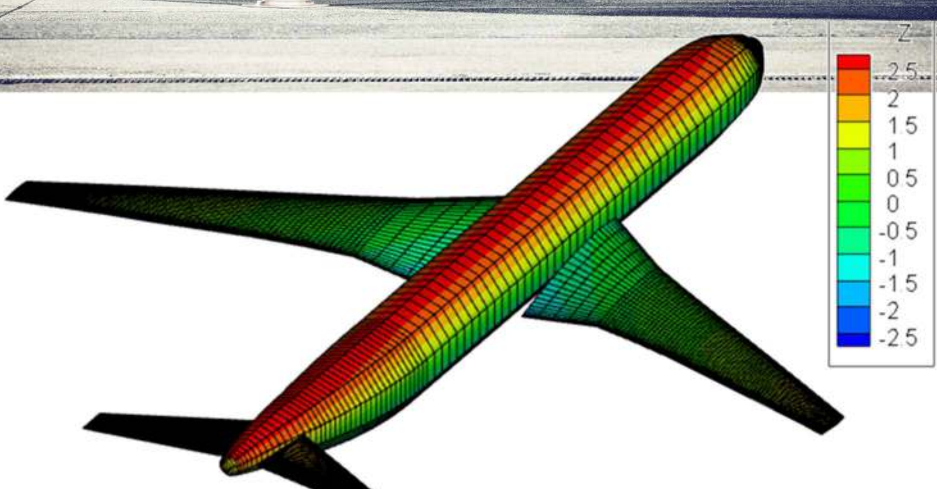
GARTEUR

ANNEXES - ANNUAL REPORT 2019



GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

Front cover image: Stock image. Panel model used to tune the wing structure for 10% tip deflection for worst-case gust (AG52 GoR AD)

Back cover image: Stock image

ANNEXES - GARTEUR ANNUAL REPORT 2019

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ANNEX 1

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AERODYNAMICS"

Remit

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

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

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

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

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

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

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AERODYNAMICS

GoR-AD Overview

GoR Activities

The primary task of the GoR is to monitor Action Groups, encourage Exploratory Groups and instigate new ideas. In 2019, two Action Groups (53 and 55) were completed, five were active (54, 56, 57, (EG75➔) 58, (EG76➔) 59), one Exploratory Group was cancelled (74) and two (77, 78) were active. Details about these groups can be found below.

Secondary task of the GoR is interaction with the other GoR's by promoting interdisciplinary topics. An example of such a topic is the aero-servo-elastic simulations of AG56. The chairs of the different GoR's interact primarily during the Council meetings.

New ideas for research may be formulated by GoR members or arise within GARTEUR organisations. As GARTEUR does not offer funding, it is essential that the research is supported by the organisations themselves. Therefore, the GoR critically reviews the research objectives and methodology, but does not select particular topics over others.

In 2019, several ideas for possible new Groups were on the table. Among those that have not yet resulted in an Exploratory Group are: Natural Laminar Flow Monitoring, Morphing, Convective Heat Transfer, Immerse Boundary Simulations, Hypersonics, Electrical Propulsion and Thermal Management on Engines, Corner Flows.

Management

Two meetings have been held in 2019. The meetings were physical meetings planned some weeks ahead of the respective Council meetings. The AD/A- 102 meeting took place at INTA, Madrid, March 5-6; and the AD/A- 103 meeting at ONERA, Toulouse, September 26-27.

Only five members attended physically the first meeting, while the second was attended by eight members. In average, three of them from Industry. As usual lack of funding and time were the reasons for the members who could not attend. In addition, a webex meeting was organized on Dec. 18, attended by five members.

There is still no British representation in the GoR. This is a point of concern, as British input in both GoR and Action Groups has always been much appreciated.

Two meetings are planned in 2020:

1) AD/A- 104 Meeting at NLR, Amsterdam on 3rd / 4th of March 2020

2) AD/A- 105 Meeting in (tbd) Sweden on 8th / 9th of September 2020

For the period 2020 – 2021 the chairs will be:

Chair: Kai Richter, DLR,

Vice-Chair: Giuseppe Mingione, CIRA

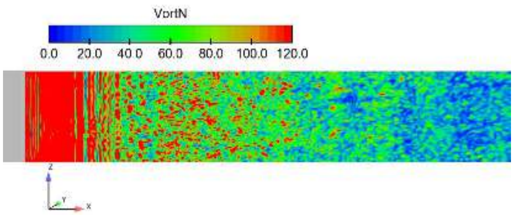
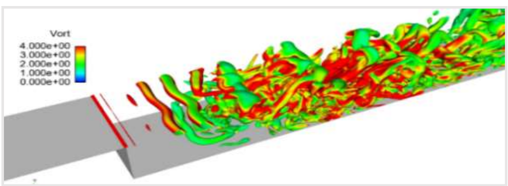
Dissemination of GARTEUR activities and results

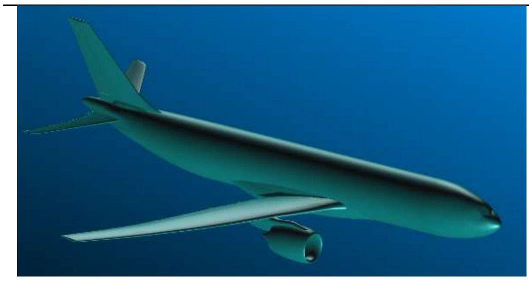
The following reports were published by AD Action Groups in 2019:

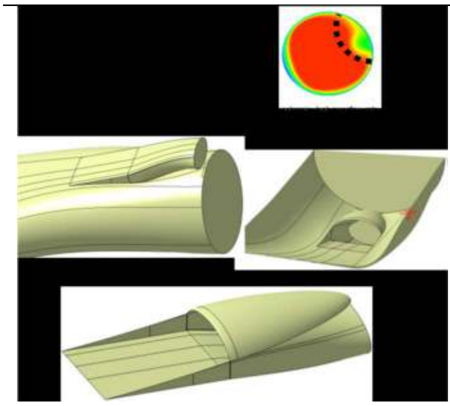
- AD/AG53 on “Receptivity and Transition Prediction: Effects of surface irregularity and inflow perturbations” (chair: Ardeshir Hanifi, KTH),
- AD/AG55 on “Countermeasure Aerodynamics” (chair: Torsten Berglind, FOI).

Status of Action Groups and Exploratory Groups

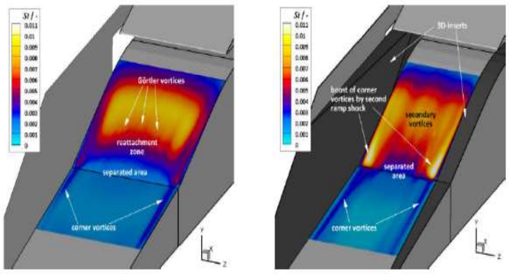
Five Action Groups and two Exploratory Groups were active in 2019. Two of the new AGs started during 2019.

AD/AG-54	RANS-LES Interfacing for Hybrid and Embedded LES approaches
 	The overall objective of AG54 has been to explore and further to develop and improve RANS-LES coupling for embedded LES (ELES) and hybrid RANS-LES methods, particularly, to address the “grey-area” problem present in zonal and non-zonal hybrid models, for aerodynamic applications. Both zonal and non-zonal approaches are considered. Three fundamental flows have been selected to test the different methods. The project started in April 2014, the final meeting took place in Nov. 2018 and the Final Report will be ready in 2020. The Chairperson is Shia-Hui Peng (FOI).

AD/AG-56	Coupled fluid dynamics and flight mechanics simulation of very flexible aircraft configurations
	Light-weight constructions require multi-disciplinary design tools. The action group, AD/AG-56, had its kickoff in 2018. The various simulations in this project are expected to enhance the understanding, tools and capabilities of partners in the nonlinear aeroelastic domain. Secondly, this project will allow for benchmarking of inhouse tools amongst the partners through the use of a common research model. The Chairperson is Mario Verhagen (NLR).

AD/AG-57	Secondary Inlets and Outlets for Ventilation
	Aircraft require a variety of secondary inlets and outlets mostly for environmental control systems, APU operation, ventilation and cooling purposes, e.g. engine bay ventilation or cooling of electronic equipment. New shapes of aircraft wing secondary inlets and outlets could be designed and assessed in search for optimized solutions. New concepts include adaptive structures and hidden integration within the engine intake. The action group had its kick-off in 2018. The Chairperson is Jose Angel Hernanz-Manrique (Airbus Operations).

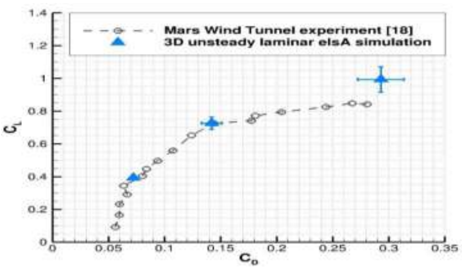
AD/AG-58	Supersonic air intakes
	Supersonic air intakes are of foremost importance in the design of a supersonic air-breathing vehicle, whatever its propulsion system: turbojet, ramjet or scramjet. Investigations may include the control of cowl



oblique shock / boundary layer interactions, internal bleed flows, or shaping effects of diffusors on the flow distortions at the end of the diffusors. A meeting was held in May 2017 and a final proposal was prepared in 2018.

The Chairperson is Christoffe Nottin (MBDA).

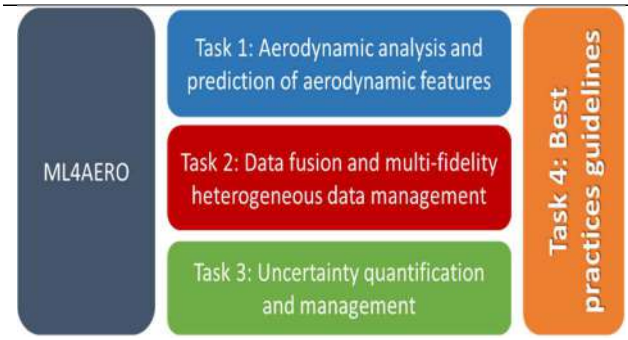
AD/AG-59	Laminar separation bubbles



Laminar separation bubbles are one of the main critical aspects of flows at low Reynolds number, of order of magnitude 10^4 to 10^5, which are relevant for small aircraft such as UAV. The proposed action group will deal with the numerical reproduction of laminar separation bubbles. The kick-off meeting took place in Feb. 2019 at CIRA.

The Chairpeson is Pietro Catalano (CIRA).

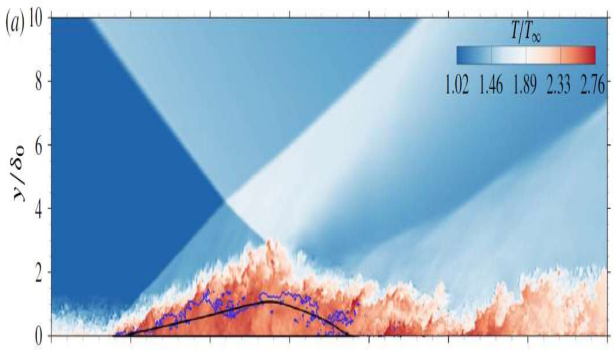
AD/EG-77	ML4AERO – Machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification



The kick-off meeting was held in Madrid on the 24 and 25th of September, 2019.

At the end of the proposed AG, the involved partners will have improved machine learning capabilities and valuable knowledge of the selected set of data-driven techniques. Through the proposed activities, it is expected that some "best practice" guidelines will be concluded and, consequently, facilitating the use of machine learning methods in aeronautic industries.

The Chair-person is Esther Andrés (INTA).

AD/EG-78	WMLES and Embedded LES
	This proposal is a follow-on of AG54. A meeting was held in Toulouse on 25-26 September 2019. Objective: Basically, hybrid RANS/LES methods can be distinguished whether the boundary layers are treated entirely (Family I e.g. standard DES-like) or partially (Family II e.g. Wall-Modelled LES) in RANS mode. This proposal is entirely focused on the most advanced methods (Family II). The Chair-person is Nicolas Renard (ONERA).

Rolling plans

Cat	Topic	2015	2016	2017	2018	2019	2020	2021
AD/AG53	Receptivity and Transition prediction							
AD/AG54	RANS-LES Interfacing Hybrid RANS-LES and embedded LES approaches							
AD/AG55	Countermeasures Aerodynamics							
AD/AG56	Coupled Fluid Dynamics and Flight Mechanics simulation for very flexible Aircraft Configurations			EG72 ➔				
AD/AG57	Secondary Inlets and Exhausts for Ventilation			EG73 ➔				
AD/AG58	Supersonic Air Intakes				EG75 ➔			
AD/AG59	Laminar Separation Bubbles				EG76 ➔			
~~AD/EG74~~	~~Integration of innovative nozzle concepts with thrust vectoring for subsonic aircraft~~							
AD/EG77	Machine learning … approaches for aerodynamic optimization and UQ							
AD/EG78	WMLES and Embedded LES							

GoR membership

Chairman		
Fernando Monge	INTA	Spain

Vice-Chairman		
Kai Richter	DLR	Germany

Members		
Eric Coustols	ONERA	France
Giuseppe Mingione	CIRA	Italy
Bruno Stefes	Airbus Operations GmbH	Germany
Harmen van der Ven	NLR	The Netherlands
Per Weinerfelt	SAAB	Sweden
Magnus Tormalm	FOI	Sweden

Industrial Points of Contact		
Nicola Ceresola	Leonardo Company	Italy
Michel Mallet	Dassault	France
Didier Pagan	MBDA	France
Luis P. Ruiz-Calavera	Airbus Defence & Space	Spain

Table of participating organisations

	AG-53	AG-54	AG-55	AG-56	AG-57	AG-58	AG-59	EG-77	EG-78
Research Establishments									
CIRA	□	□		□	□		■	□	□
DLR	□	□		□	□		□		□
FOI		■	■			□		□	□
INTA		□						■	
NLR		□	□	■	□			□	□
ONERA	□	□		□	□	□	□	□	■

Industry									
Airbus Defence & Space			□	□				□	
Airbus Operations GmbH	□			□				□	
Airbus Operations S.A.S		□			■				
Airbus Group Innovations	□								
Leonardo Company									
Dassault Aviation									
EADS		□							
LACROIX			□						
MBDA-F			□			■			
MBDA-LFK						□			
SAAB		□				□			□
Academic Institutions									
Imperial College	□						□		
Royal Inst. of Technology KTH	■								
Technical Univ. Munich		□							□
University of Manchester		□							□
Zurich Univ. of Applied Sciences		□							□
Univ. of Napoli “Federico II”							□		
Marche Polytechnic University							□		
IRT Saint Exupéry								□	
Univ. of Strasbourg							□		
Univ. of Southampton							□		
Institute of Marine Engineering (INMCNR)							□		

Total yearly costs of AG research programmes

GoR	AG	2014		2015		2016		2017		2018		2019	
		pm	k€	pm	k€	pm	k€	pm	k€	pm	k€	pm	k€
	51	12	40	0	0	0	0	2	0	2	0		
	52	23	63	23	63	23	63						
	53	13	24	13	24	2	12	2	0	2	0		
	54	18	100	22	140	18	80	20	100	12	50		
	55			16	24	18	24	16	24	4	5		
	56									14	7	8	7
	57									21	29	22	29
	58												
	59											16	9,3
AD	**TOTAL**	**66**	**227**	**74**	**251**	**61**	**179**	**40**	**124**	**55**	**91**	**46**	**45,3**

Action Group Reports

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

AD/AG-54: RaLESin

RANS-LES Coupling in Hybrid RANS-LES and Embedded LES

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

Background

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

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

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

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

Programme/Objectives

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

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

Task 1: Non-zonal modelling methods

(Task Leader: **NLR**)

For models with the location of RANS-LES interface regulated by modelling (not prescribed), typically, for DES-type and other seamless hybrid methods. Two TCs are defined.

TC M1 Spatially developing mixing layer

Initiated from two BLs of U_1 = 41.54 and U_2 = 22.40 m/s, respectively, with Re_θ = 2900 and 1200. Focus on modelling/resolving initial instabilities of the mixing layer.

TC O1 Backward-facing step flow

Incoming BL with U = 50m/s and Re_h = 40000. Focus on modelling/resolving the free shear layer detached from the step (h = step height).

Task 2: Zonal modelling methods

(Task Leader: **UniMan**)

For models with the location of RANS-LES interface prescribed, Including embedded LES. Two TCs are defined.

TC M2 Spatially developing boundary layer

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

TC O2 NASA hump flow

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

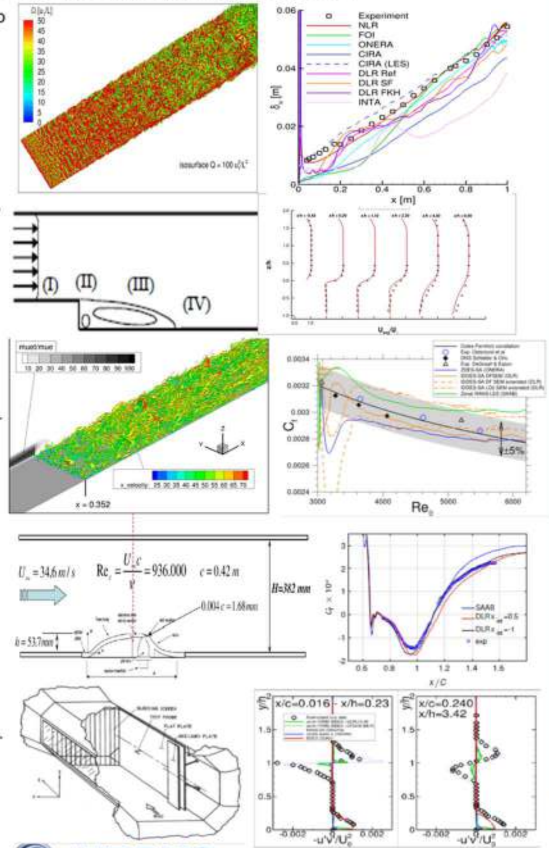
Task 3: Modelling assessment

(Task Leader: **ONERA**)

Evaluation and assessment of the methods developed in Tasks 1 and 2 with one TC.

TC M3 Co-flow of BL and wake

Re = 2.4×10^6/meter and M = 0.2. Examination of modelling capabilities for a complex flow case.



Results

- Further calibration and evaluation of hybrid RANS-LES methods of zonal and non-zonal modelling in computations of all test cases.
- Improved modelling formulation to enhance turbulence-resolving capabilities with special focus on "grey-area" mitigation.
- Assessment and verification of improved modelling in computations of different test cases by means of cross comparisons.

Summary:

The project kick-off took place in 2014. Since then, AG54 has had four progress meetings with the following results reported by AG members.

- Evaluation of existing baseline hybrid RANS-LES models in TC computations, including SST- & SA-IDDES, HYB0, HYB1, X-LES, ZDES, 2-eq. based hybrid zonal model, 2-velocity method, WMLES, LES, RSM-based hybrid model and other variants.
- For non-zonal hybrid RANS-LES modelling, improvement has been made on, among others, stochastic backscatter model plus temporal and spatial correlation, velocity-gradient-based energy backscatter, vorticity-based length scale and other verified hybrid length scale, commutation terms etc..
- For ELES and zonal hybrid RANS-LES modelling, methods of generating synthetic turbulence has been examined, among others, the synthetic eddy method (SEM) and its improved variant (e.g., DFSEM).
- All test cases have been well defined and experimental data have been used for modelling validation and verification.
- Progress of AG work has been made in line with the plan. Computations of TCs have been progressed well with relevant results reported and in cross plotting of partners results.
- Progress meetings were held in Oct. 2014, Oct. 2015, Nov. 2016 & Nov. 2017, respectively.

AD/AG54:	RaLESin: RANS-LES coupling in hybrid RANS-LES and embedded LES approaches
Monitoring Responsable:	Mr. M. Tormalm, FOI
Chairman:	Prof. S.-H. Peng, FOI

- *Objectives*

The overall objective of AG54 has been, by means of international collaborative effort, to explore and further to develop and improve RANS-LES coupling for embedded LES (ELES) and hybrid RANS-LES methods, particularly, to address the “grey-area” problem present in zonal and non-zonal hybrid models, for aerodynamic applications. The main objectives have been: (1) To evaluate RANS-LES interfacing methods adopted in current hybrid RANS-LES modelling approaches; (2) To develop “Grey-Area” Mitigation (GAM) methods for improving RANS-LES interaction, as well as improving further the RANS and LES modes in hybrid modelling; (3) To develop improved RANS-LES coupling methods for zonal and non-zonal hybrid RANS-LES modelling, and for embedded LES methods; (4) To verify and assess the developed methods in scale-resolving simulations of test cases.

- *Main Achievements*

AG54 consists of 12 members, including three universities, six research organizations and three industries. The work in AG54 has been divided in three technical tasks. Task 1 deals with non-zonal hybrid RANS-LES methods, and Task 2 focuses on RANS-LES coupling for zonal (including wall-modelled LES, WMLES) and embedded LES. Two test cases, a mandatory TC and an optional TC, are defined respectively for Tasks 1 & 2. The methods developed are then further verified and assessed in Task 3 in computations of a mandatory and relatively complex flow test case.

In 2018, the group has progressed in line with the technical work plan and has successfully completed the overall technical work. The main activities and achievements have in general been marked by: (a) Completion of computations of all TCs for evaluating zonal and non-zonal hybrid RANS-LES methods; (b) Progress made in coordinated cross-plotting and comparisons of results for all three mandatory TCs, as well as the two optional TCs, based on contributions by involved AG members; (c) Refined modelling to enhance turbulence-resolving capabilities with special focus on the “grey-area”; (d) Assessment and verification of modelling methods based on comprative studies of computations of the TCs. (e) Setup of a framework of the final report in terms of the technical contents and timelines.

Task 1 has been progressed in addressing the “grey-area” problem for non-zonal (or seamless) hybrid modelling by means of improved modelling formulation, among others, X-LES based model with stochastic backscatter, high-pass filter and/or temporal/spacial correlation, HYB0- and HYB1-based energy backscatter using velocity gradients and vorticity-based LES length scale, improved ZDES with vorticity-based length scale, SST-IDDES model with a well-defined hybrid length scale, commutation terms as a measure for ehnancing resolved turbulent diffusion. Figure 1 shows an example of computations using non-zonal methods for the minxing layer (TC M1) and a cross-plotting example of some partners’ contributions, which show the improved capabilities in resolving the mixing layer and mitigating the grey-area in the initial stage of the mixing layer.

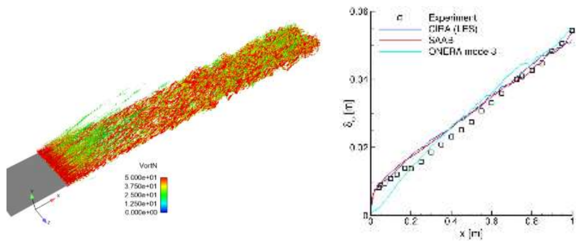


Figure 1: An example of some computations for TC M1 (mixing layer). Resolved turbulent structures (Left) and predictions of mixing-layer vorticity thickness (Right).

For zonal hybrid RANS-LES modelling in Task 2, the main work has been dedicated to improving the method of generating synthetic turbulence (ST) for improving RANS-LES interface and enabling effective grey-area mitigation. The modelling verification is based on TC M2 (Spatially developing turbulent boundary layer), of which an example is shown in Figure 2 to illustrate the synthetic-turbulence method as a robust GAM method.

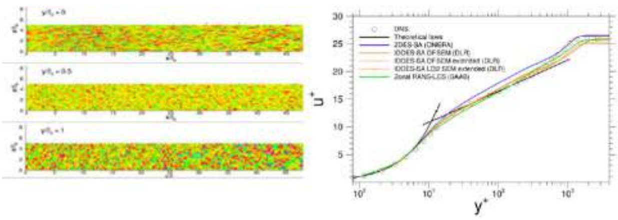


Figure 2: Computation of TC M2 (spatially developing turbulent boundary) using synthetical turbulence. Turbulent structure in relation to ST (Left) and mean Velocity in the boundary layer (Right).

The effectiveness of re-establishing turbulence after the RANS-LES interface section is further verified in Figure 3 for test case TC O2 (NASA hump flow) by displaying the predicted wall surface pressure along the bottom wall and the resolved turbulent stress profile at x/C=1.1 in comparison with measured data, showing reasonable agreement.

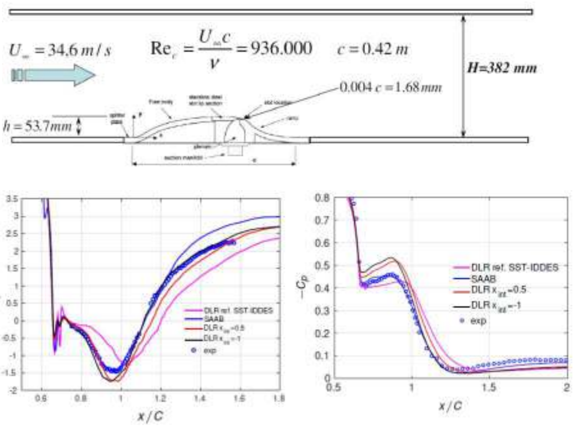


Figure 3: Example for TC O2 using zonal modelling supported by ST methods. The lower row shows bottom wall skin-friction coefficient (Left) and pressure coefficient (Right).

TC M3 (co-flow of boundary layer and wake) in Task 3 has been adopted for overall assessment and verification of methods developed in Tasks 1 & 2. All partners have made computations using the IDDES, WMLES, DDES, ZDES and HYB0 models, and some are further supported by ST and low-dissipative/dispersive schedmes. Some results by partners are compred for this test case in Figure 4.

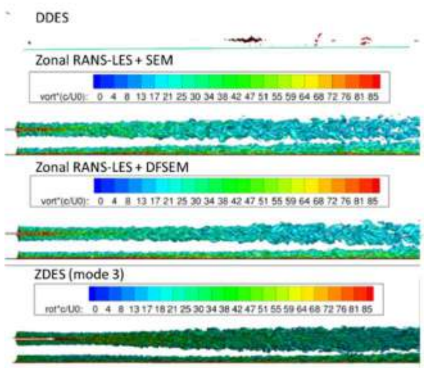


Figure 4: Example for TC M3. Resolved turbulent structures downstream by means of zonal methods supported by ST after the RANS-LES interface.

In addition to the mandatory test cases (M1, M2 and M3) and the optional case TC O2 shown here, computations on the optional case TC O1 have also been carried out by a few partners. For all these test cases, cross-plotting has been processed.

- *Resources*

Resources		Year 2014	2015	2016	2017	2018	Total
Person-months	Actual/ Planned	A18 P18	A22 P22	A18 P18	A20 P20	A12 P12	A90 P90
Other costs (in K€)	Actual/ Planned	A100 P100	A140 P138	A80 P80	A100 P100	A50 P50	A470 P468

- *Completion of milestones*

Work package	Planned: Initially	Planned: Currently	Actual
Kick-off meeting	April. 2014		April 2014
Tasks 1, 2 & 3 def. TCs	Oct 2014		Oct. 2014
1st progress meeting	Oct. 2014		Oct. 2014
Tasks 1, 2 & 3: Website	Oct. 2014		Nov. 2016
Expt. data of all TCs	Sept. 2015		Nov. 2015
2nd Progress meeting	Oct. 2015		Oct. 2015
3rd Progress meeting	June 2016	Nov.2016	Nov. 2016
4th Progress meeting	Nov., 2017		Nov., 2017
Final meeting	Nov. 2018		Nov. 2018

- *Expected results/benefits*

AG54 has successfully achieved its technical goals, by which a set of zonal and non-zonal hybrid models have been improved with particular focus on the grey-area problem existing in hybrid models. These improved methods have been, or will be, implemented further into the CFD tools of AG members and, consequently, being exploited in other related R&D activities and in industrial applications.

- *AG membership*

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

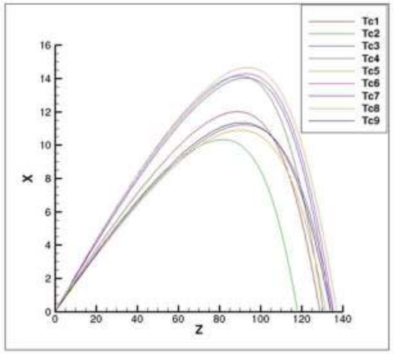
AD/AG-55: Countermeasure Aerodynamics

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

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

The Background

Countermeasures are used to decoy enemy tracking systems. Two commonly used countermeasures are chaff and flares, which are the main focuses of this action group.
Chaff is a radar countermeasure consisting of small pieces or threads of metal or metalized glass fibre. Flares are used against IR-seeking missiles. They are a few decimetres in length and can have built in propulsions systems. In the test cases of this action group, counter-measures are ejected from generic aerial platforms. Their trajectories are significantly affected by the surrounding air.



Experimental flare tracks

The Programme

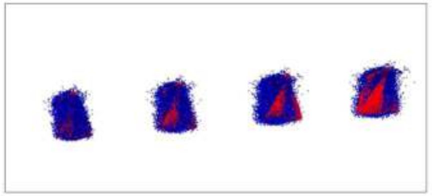
Objectives of AD/AG-55
The main objective is to evaluate computational methods to predict movement of countermeasures. The purpose of predicting chaff clouds is to be able to support development of tactics for usage of chaff. The trajectory of flares are important to predict accurately since the flare might damage the aircraft.

Approach
There are two main methods to simulate chaff dispersion, an Eulerian approach in which the chaff concentration is represented as a scalar field, and a Lagrangian approach in which individual chaff are tracked. Both methods are applied in a separate post processing step, assuming that the countermeasures do not affect main flow field properties.

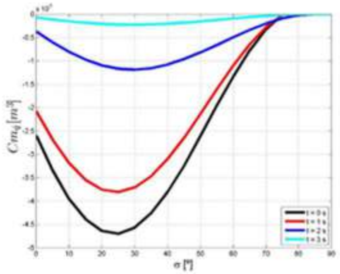
The ejection of a flare involves complicated physics. The cold flare model includes changes in shape, mass, moments of inertia in addition to 6 DoF movement. The hot flare model consists of the same features and in addition includes high boundary temperature flow and exhaust gases. The objective is to determine an appropriate level of modelling the flare that gives sufficiently accurate flare trajectories.

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

Project duration: January 2015 – June 2018



Lagrangian simulation of spherical chaff dispersed from a generic helicopter, FOI's results in blue and NLR's in red. The temporal increment between the chaff clouds is 0.1 sec.



Pitch damping coefficent

The Outcomes

Expected results/benefits
The action group is expected to yield increased understanding of simulation of chaff dispersion and flare trajectory modelling. A natural outcome is also that the partners obtain improved simulation tools

Management issues
One physical meeting, where all member organisations except LaCroix participated, was held at NLR in Amsterdam April 18th and 19th. In addition, four tele-conference meetings where hold on January 31st, June 20th, September 12th and November 8th.
This Action Group has applied for a 6 month extension since some additional computations and the major part of writing the final report remain.
The next tele-conference meeting is planned on February 7th. Eventually, there will be an additional physical meeting in Madrid during spring 2018.

Main achievements
A thorough investigation of deviations between FOI's and NLR's results has led to good agreement of the computational results. Evaluation has started comparing the movement of mass centre and standard deviation of chaff particle clouds.
Aerodynamic databases have been created for both the cold flare and hot flare models. Airbus D&S and MBDA have delivered a model for the aerodynamic damping of the flare.

FOI AIRBUS DEFENCE & SPACE LACROIX Protection Superiority MBDA MISSILE SYSTEMS nlr

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

AD/AG-55	COUNTERMEASURE AERODYNAMICS
Monitoring Responsable:	M. Tormalm FOI
Chairman:	T. Berglind FOI

- *Background*

This action group has studied movements of countermeasure objects, chaff and flares, ejected from generic aerial platforms.The main objective has been to evaluate computational methods predicting movement of counter-measure objects.

- **Main achievements**

A remaining computational investigation is evaluation of chaff clouds modelled as thin circular cylinders.

Chaff cloud evolution without turbulent dispersion behind a generic helicopter. Cylindrical chaff particles are initially aligned with the z-direction. FOI's results in green and NLR's in blue. The temporal increment between chaff clouds is 0.1 sec.

- **Management issues**

This year has mainly been devoted to finalise the report. Tele-conference meetings where hold on February 16th and April 13th.

One physical meeting, where all member organisations except LaCroix participated, was held at Airbus in Madrid the 13th – 14th of June. The flare part of the action group is since September considered as finished.

- **Expected results/benefits**

The project is expected to yield increased understanding of simulation of chaff and flare trajectory movements.

- *AD/AG-55 membership*

Member	Organisation	e-mail
L. Ruiz	Airbus D&S	Luis.Ruiz@military.airbus.com
S. Cid Arroyo	Airbus D&S	sergio.cid@airbus.com
O. Estibals	Etienne Lacroix	Olivier.Estibals@etienne-lacroix.com
C. Saez	Etienne Lacroix	christian.saez@etienne-lacroix.com
T. Berglind	FOI	torsten.berglind@foi.se
O. Grundestam	FOI	olof.grundestam@foi.se
S.-H. Peng	FOI	shia-hui.peng@foi.se
C. Jeune	MBDA France	Christophe.jeune@mbda-systems.com
S. Tusseau	MBDA France	simon.tusseau@mbda-systems.com
H. Van der Ven	NLR	Harmen.van.der.ven@nlr.nl

- *Resources*

1. Resources		Year				Total
		2015	2016	2017	2018	
Person-months	Actual/ Planned	16 16	18 16	18 16	9 16	61 64
Other costs (in K€)	Actual/ Planned	24 24	24 24	24 24	10 24	82 96

- *Progress/Completion of milestones*

Mile stone	Planned		Actual
	Initially (end of …)	Currently (updated)	
MS 1: Provide helicopter test case + grid + flow field (NLR)	Jul 2015	Oct. 2015	Delivered
MS 2: Use VULCAD to compute flare section and evolution vs time (Lacroix)	Jul 2015	Sep. 2015	Delivered
MS 3: Grid around initial flare geometry (MBDA)	Aug 2015	Jul. 2009	Delivered
MS 4: Aero data base for flare without exhaust gases (Airbus, MBDA and FOI)	Nov 2015	June 2016	Delivered
MS 5: Comparisons of chaff computations with Eul. and Lagr. Appr. (FOI)	Feb 2016	June 2017	Delivered
MS 6. Determine the inertia properties for the flare (Airbus D&S)	Sep 2016	Oct. 2016	Delivered
MS 7. Determine the aerodynamic damping coeff. for the flare (MBDA)	Dec 2016	Apr. 2017	Delivered
MS 8. Deliver flare data properties: gas constant, □-value. If possible, chemical composition (Lacroix)	Dec 2016	Dec 2016	Delivered
MS 9 Skeleton report with responsible organisation for each chapter (FOI)	Feb 2017	Jan 2017	Delivered
MS 10. Computations of flare trajectory test cases (Airbus, MBDA, FOI)	Mar 2017	Dec 2017	Delivered
MS 11. Flare trajectory experiments(Lacroix)	Apr 2017	Apr 2017	Delivered
MS 12.Final report	Dec 2017	June 2018	In progress

AD/AG-56	COUPLED FLUID DYNAMICS AND FLIGHT MECHANICS SIMULATION OF VERY FLEXIBLE AIRCRAFT CONFIGURATIONS	
Monitoring Responsable:	H. Van der Ven NLR	
Chairman:	M. Verhagen NLR	

• Background

With the increasing importance of environmental issues, various technologies are being developed to create more efficient aircraft designs, reducing fuel burn. In terms of airframe enhancements, these include utilizing lighter structures and higher aspect ratio wings, leading to very flexible configurations. By more actively accounting for the large structural deformations in very flexible configurations, greater weight savings and larger aspect ratios can be realized.

To allow for better optimization of such flexible configurations, studies are carried out in bringing closer the various disciplines supporting aircraft design, especially taking into account the large structural deflections in flight mechanics analyses. Building upon GARTEUR (FM) AG-19 where use has been made of simplified aerodynamic models, AG-56 makes use of high fidelity aerodynamic models coupled with structural models for such very flexible aircraft. Within AG-56, capabilities will be developed to perform aeroelastic simulations of very flexible aircraft. These capabilities will be assessed and benchmarked by performing simulations with varying degrees of fidelity.

• Objectives

The goals of AG-56 are twofold: firstly, this endeavour aims to enhance each partner's capabilities in aeroelastic simulations pertaining to very flexible aircraft. This entails more accurately predicting aerodynamic loads and structural deformations for manoeuvre and disturbance conditions. A second aim of AG-56 is to define and develop a common test case in terms of aircraft and manoeuvre. This will allow the various partners to benchmark their solvers and tools.

This topic poses a challenge due to various requirements inherent to such analyses:

- A flight mechanics model for flexible structures,
- CFD methods with robust grid handling technique capable of modelling a combination of large rigid body motion and large flexible motion,
- Fluid-structure interaction procedures that are capable of modelling large translations and finite rotations.

• Approach

Analyses will be performed using the Airbus XRF-1 benchmark model which has been modified to accomodate for more wing flexibility. The baseline XRF-1 model has been made available by AI-O.

Four scenarios will be considered; two gust disturbance conditions and two manoevres. The manoeuvre conditions are a 2.5g pull-up and an elevator deflection. Aeroelastic simulations with six degrees of freedom will be performed in a CFD environment. To achieve this, the complexity of the simulations will be increased step-by-step, starting with a purely aerodynamic (assuming a rigid aircraft) simulation, subsequently followed by an aeroelastic simulation without motion, and finally the 6-DOF aeroelastic simulation. Results will be compared to lower fidelity aeroelastic simulations that do not consider a CFD environment. This is done in the NASTRAN and ZAERO environments by means of aeropanels. As stated earlier, the underlying goal of more accurate aeroelastic analyses for very flexible aircraft is to impose less stringent stiffness criteria, allowing for fuel burn reductions with lighter structures and higher aspect ratios. As such, a final analysis will consider an MDO optimized aircraft. This will provide insight in the potential gains and aeroelastic behaviour when optimizing very flexible aircraft wings.

• Main achievements

Due to challenges in obtaining the XRF-1 FEM and CAD models, work has been limited. In the first year, the main achievements were obtaining the model from Airbus with all associated legal requirements. Additionally, the disturbance and manoeuvre conditions have been defined. In this second year, the generic FEM and CAD models have been modified for AG-56 purposes, after which the envisioned simulations can commence in the near future. For the CAD geometry, modifications included geometry clean-up for CFD (un)structured mesh generation and the inclusion of an elevator surface (see fig. 1). For the FEM model, wing elasticity has been modified for increased tip deflections; aiming for 10 percent tip deflection in 1g flight (see fig. 2). This has been done for a worst case mass condition. The front and rear spar have been tuned to attain the desired tip deflection; iterating for the gust condition of interest in a panel code environment (see fig. 3). Partners will subsequently run the various simulations making use of these common CAD and FEM models. Given the completed underlying models, partners can now initiate rigid aerodynamic analyses, determining horizontal tailplane deflection angle for trimmed 1g flight; for the two flight conditions of interest. Results will be compared, after which the disturbance and control deflection conditions will be performed for rigid and aeroelastic models. Simulataneously panel code simulations will be performed.

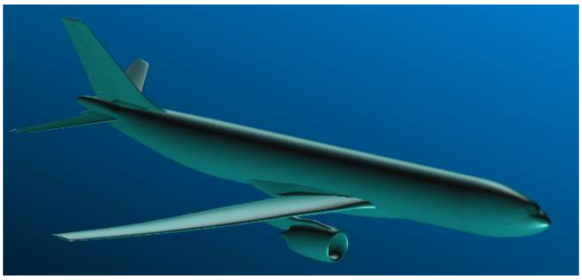


Fig. 1 The CAD geometry of the XRF-1.

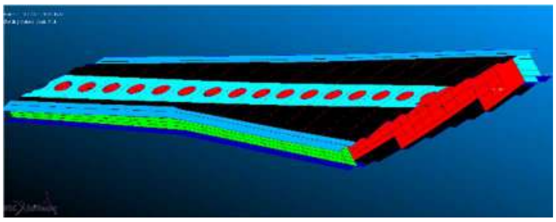


Fig. 2 Depiction of the wing structure in the FEM model. The elasticity of the front and rear spar are tuned for 10 percent tip deflection in 1g flight.

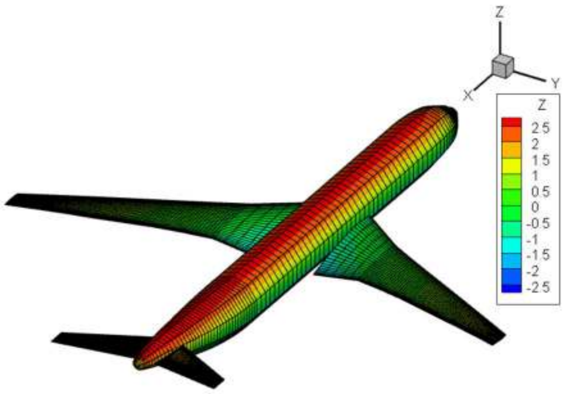


Fig. 3 Panel model used to tune the wing structure for 10% tip deflection for worst-case gust.

- **Project management**

It has been decided to have alternating physical and teleconference meetings every 3 months. The kick-off meeting took place on the 9th of March 2018 in Amsterdam, hosted by NLR. Two teleconference progress meetings have been held on the 25th of October 2018 and the 25th of March 2019, as well as a physical meeting in Manching, hosted by Airbus Defense and Space on January 24th, 2019. July 4th was the most recent teleconference meeting pertaining to model updates, while various teleconferences have been held between partners pertaining to model generation. A physical meeting will be scheduled for the very near future.

- **Expected results/benefits**

The various simulations in this project are expected to enhance the understanding, tools and capabilities of partners in the nonlinear aeroelastic domain. Secondly, this project will allow for benchmarking of inhouse tools amongst the partners through the use of a common research model.

- **AD/AG-56 membership**

Member	Organisation	E-mail
K. Elssel	Airbus D&S	kolja.elssel@airbus.com
H. Bleecke	Airbus O	hans.bleecke@airbus.com
P. Vitagliano	CIRA	p.vitagliano@cira.it
M. Ritter	DLR	markus.ritter@dlr.de
M. Verhagen	NLR	mario.verhagen@nlr.nl
F. Huvelin	ONERA	fabien.huvelin@onera.fr
C. Poussot-Vassal	ONERA	charles.poussot-vassal@onera.fr

- **Resources**

Resources		Year			Total
		2018	2019	2020	
Person-months	Actual/ Planned	14 14	8 12	12	38
Other costs (in K€)	Actual/ Planned	7 7	7 14	14	36

- **Progress/Completion of milestones**

Milestone	Status
MS 1: Access to common research model	Completed
MS 2: Completion of CAD model for CFD mesh generation	Completed
MS 3: Completion of FEM model for simulations	Completed
MS 4: Panel code lower fidelity free-free simulations (disturbance)	

MS 5: Initial CFD 1g static aerodynamic analyses around flight shape	
MS 6: Rigid structure CFD simulations (manoeuvre + disturbance)	
MS 7: Aeroelastic CFD simulations with linear structure (manoeuvre + disturbance)	
MS 8: Aeroelastic CFD simulations with non-linear structure (manoeuvre + disturbance)	
MS 9: Generation of MDO optimized linear XRF-1 aircraft model	
MS 10: Aeroelastic CFD simulations with MDO optimized linear structure (disturbance)	
MS 11: Cross-plotting and analysis of all results	
MS 12: Final report	

AD/AG-57	SECONDARY INLETS AND OUTLETS FOR VENTILATION
Monitoring Responsable:	G.Mingione CIRA
Chairman:	J.A. Hernanz Airbus OP

- **Background**

Aircraft capture outside air for the purpose of air conditioning, ventilation and cooling. This is achieved by means of secondary air inlets. Their shapes differ widely depending on integration possibilities, performance requirements and minimization of interference effects (including drag). In case of transport aircraft (civil and military), it is expected that the capabilities of secondary air inlets have to increase considering the tendency to replace bleed air from the main engines by the acquisition of outside air for air-conditioning purposes. This tendency is also driven by the requirement to prevent fumes from entering the cabin as well as to create a possibility to utilise engine bleed air for active flow control purposes.

Furthermore future propulsion technologies as hybrid or electrical engines are based in the used of storage batteries which required the evacuation of high level of heat. The correct design of auxiliary intakes and outlet permits an easily method to reject the heat without penalizing the new engines performances.

- **Objectives**

Analyse the efficiency of a submerged NACA type air intake for multiple flight envelopes using state-of-the-art CFD and performance evaluation methods. Investigate whether such an air intake can comply with novel requirements for air-conditioning for large transport aircraft (civil and military).

Analyse the feasibility of a low-observable secondary inlet integrated in the main air intake duct of a combat aircraft and assess the impact on the intake duct flow field and on engine/intake-compatibility. Investigate different types of secondary inlets, shapes, locations, and sizes with respect to advantages regarding radar cross section and aerodynamic performance.

- **Approach**

The proposed activities concern the application of secondary air inlets on multiple aircraft platforms, i.e. transport aircraft (civil and military) and combat aircraft. The submerged air intake (NACA type) is predominantly selected for application on the fairing of transport aircraft (civil and military) whereas the hidden inlet is utilized for application inside the engine air intake of combat aircraft in order to reduce the radar signature.

- **Main achievements**

WP 1: Submerged air intake studies

Task 1.1: NACA standard intake in a fuselage surface

- NLR preliminary geometry and mesh generation around NACA inlet first calculations to check the methodology
- CIRA Secondary NACA intake provided by AIRBUS has been simulated by means of the CFD code ANSYS Fluent R18
- After a preliminary check, the intake with Far Field and the exit duct has been meshed by means of the ANSYS ICEM CFD grid generator
- An unstructured grid of has been generated with about 20 layers on the body and a y+ close to 1

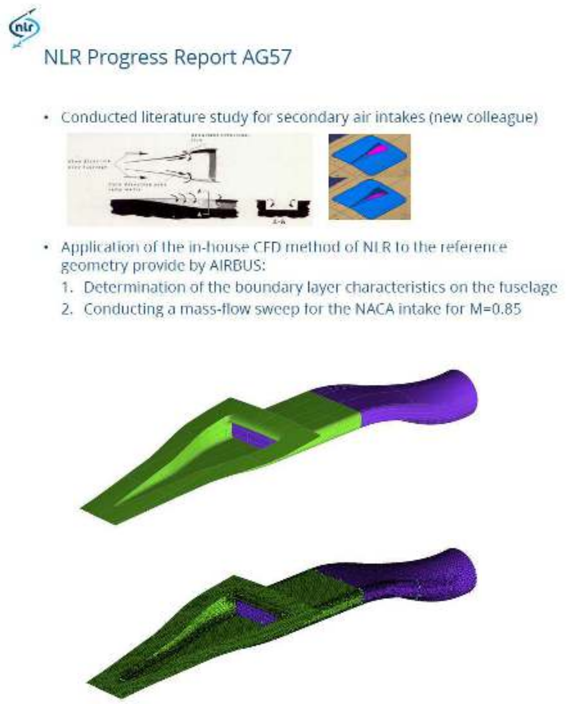


Fig. 1 NLR prelimnary studies, geometry cleaning and intake mesh for CFD

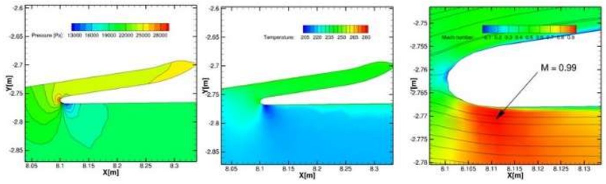


Fig. 2 CFD results of NACA intake prepared by CIRA. Detail of velocities in inlet lip

Task 1.3: Air outlet study for passive flow control

- DLR presented the results of a WTT campaign to evaluate the achievable mass flow at the flap outlet in the VTP for different open angles
- AI-Operation Bremen show the Hybrid Laminar Flow Control outlet flap performance validation with wind tunnel test 2D model (PIV measurements) and 3D (nearly) full size A320 VTP placed in Low Speed Wind Tunnel. In this model the flap outlet is located in a lateral zone of the VTP leading edge.

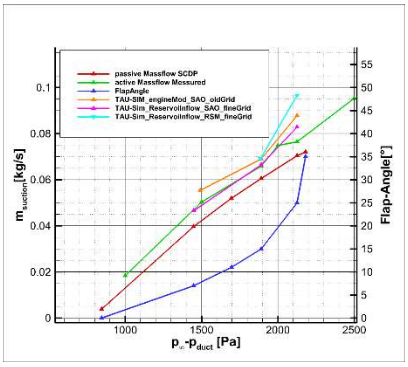


Fig. 3 Mass flow at flap outlet for a VTP function of the open angle. DLR wind tunnel test

Fig. 4 Project OptiHyL in DNW-LLF wind tunnel: Hybrid Laminar Flow Control (HLFC) / Low Speed Wind Tunnel campaign of A320 VTP in DNW-LLF facility / The Netherlands

Task 1.4: Inlets/outlets connection devices

- CIRA works in a code to code comparison, based on an existing actual air-intake, in order to assess methodologies able to carry out the secondary inlets design.
    - Secondary NACA intake, the P180 oil cooler & NACELLE provided by PIAGGIO AEROSPACE Inds
    - Its performance will be investigated by means of the CFD code ANSYS Fluent R18
    - After a preliminary check, the geometry has been meshed by means of the ANSYS ICEM CFD grid generator
    - An unstructured grid of «» has already been generated with about 20 layers on the body and a y+ close to 1
    - The far-field is located at 10 times the characteristic length L
- Airbus DS
    - Geometry checked and translated in ICEM CFD
    - Geometry modifications: dummy aircraft Wing-Body and nacelle rear components
    - Initial meshing checks .

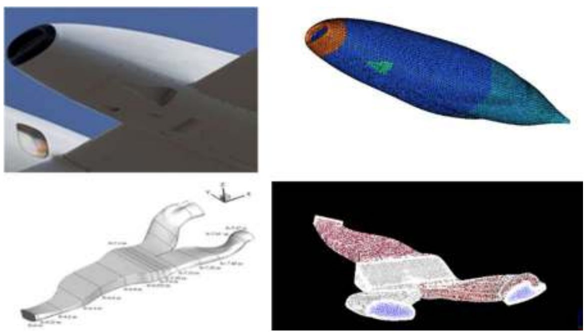


Fig. 5 CIRA generated grid for PIAGGIO nacelle and internal intake and outlet ducts

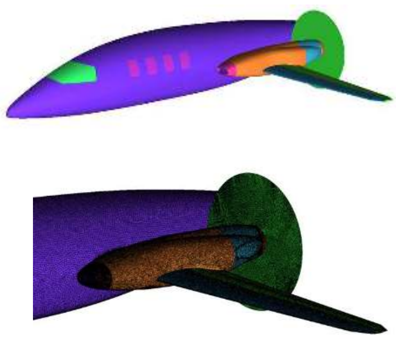


Fig. 6 Airbus DS generated grid for PIAGGIO nacelle and internal intake and outlet ducts including part of fuselage and wing

WP 2: Hidden secondary inlet within main intake studies

AI-DS presented some review of internal reports for the intake location in fan duct and has generated the first geometry including a first computational mesh

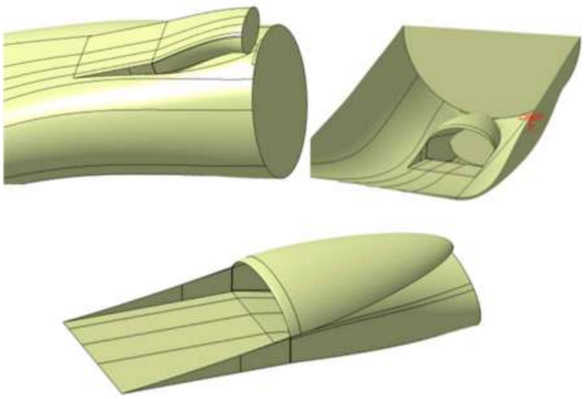


Fig. 7 Airbus DS generated geometry for inner fan duct at best location to improve fan inlet losses

- **Management issues**

Physical kick off meeting, where all member organisations, was held at Airbus DS in Manching May 17th 2018. In addition, two tele-conference meeting where held on September 2018 and February 2019. The next physical meeting is planned for May 9th 2018 in Amsterdam at NLR facilities

- **Expected results/benefits**

The project is expected to yield improve the capabilities of secondary air inlets for transport aircraft (civil and military) and combat aircraft facing increasing mass flow demands in combination with more stringent integration requirements

- **AD/AG-57 membership**

Member	Organisation	e-mail
J.A. Hernanz (chairman)	Airbus Op	jose.hernanz@airbus.com
U. Krause (vice chairman)	Airbus Op	udo.krause@airbus.com
R. Ehrmayr	Airbus DS	robert.ehrmayr@airbus.com
A. Carozza	CIRA	A.Carozza@cira.it
C. Gonzalez	Airbus DS	carlos.z.gonzalez@airbus.com
J. Himisch	DLR	Jan.Himisch@dlr.de
H. Maseland	NLR	hans.maseland@nlr.nl

- **Resources**

Participant	Year 1			Year 2			Year 3		
	MM	CPU	TS	MM	CPU	TS	MM	CPU	TS
CIRA	6	5	10	6	10	10	6		10
Airbus D&S	6	5	5	6	20	5	6		5
Airbus Op	3	5	10	4	10	10	4		10
NLR	2	5	2	2	10	2	2		2
DLR	4	5	2	4	10	2	4		2

- **Progress/Completion of milestones**

Status of planning activities for WP1

WP		YEAR 1 Q1	Q2	Q3	Q4	Status March 2019
1.1	Task 1.1 NACA standard intake in a fuselage surface					
1.1.1	Task 1.1.1 Design point simulation for code-to-code verification					
	Translation of geometries and grid for different solver					On time
	RANS simulations					On time
	Harmonization of Postprocessing					
	Finalization & Reporting					
1.1.2	Task 1.1.2: Assessment for the flight envelope of civil transport aircraft					
	Selection of the points of flight envelope					not yet started
	RANS simulations					
	Harmonization of Postprocessing					
	Finalization & Reporting					
1.1.3	Task 1.1.3: Parameter study for main geometrical parameters					
	Translation of geometries and grid for different parameters					
	RANS simulations					
	Harmonization of Postprocessing					
	Finalization & Reporting					
1.2	Task 1.2: Assessment for the flight envelope of military transport aircraft					
	Selection of the points of flight envelope					not yet started
	RANS simulations					
	Harmonization of Postprocessing					
	Finalization & Reporting					
1.3	Task 1.3: Air outlet study for passive flow control					
	Translation of geometries and grid for distributed flap locations on the VTP					on going
	RANS simulations for a variation of pressure conditions					on going
	Harmonization of Postprocessing					
	Finalization & Reporting					
1.4	Task 1.4: Inlets/outlets connection devices					
	Translation of geometries and grid for different solver					on time
	RANS simulations					
	Harmonization of Postprocessing					
	Finalization & Reporting					

Status of planning activities for WP2

WP	WP 2 Time schedule plan Hidden secondary inlet whithin main intake studies	YEAR 1 Q1	Q2	Q3	Q4	Status March 2019
2.1	Preparation of first geometries and grid generation					on going
	Update of geometries and grid generation					
	Harmonization of Postprocessing					not yet started
2.2	Provision of operatiing conditions for simulations					not yet started
	First Navier-Stokes simulations					not yet started
	Navier-Stokes simulations for updated geometries					
2.3	Performnce assessment for first geometries					
	Performance assess mnet for updated geometries					
2.4	Secondary oulet study for passive flow control					
	Finalization & Reporting					

AD/AG-58	SUPERSONIC AIR INTAKES AERODYNAMICS
Monitoring Responsable:	D. Pagan MBDA
Chairman:	C. Nottin MBDA

- **Background**

Supersonic air intakes are of foremost importance in the design of a supersonic air-breathing vehicle, whether the propulsion system is a turbojet, a ramjet or a scramjet. They are critical in the performance (thrust, drag, consumption) but also in the mass budget, the general architecture and the radar signature. They need to be accurately designed very early in the development phase. Currently their design heavily relies on numerical simulations (CFD).

An Action Group on supersonic air intakes was completed in 2007 (AG34). It was focused on shock / boundary layer interactions and the modelling of porous walls and bumps. It is proposed to build on the results of this AG and to launch a new research activity in this domain which is of primary interest for military aircrafts and missiles.

- **Objectives**

The main objective for the AG-58 is to gather a database of relevant flow features on representative test cases and validate CFD codes on these specific topics. The following investigation themes are proposed:

- Cowl oblique shock / boundary layer / mixing layer interactions
- Internal bleed flows
- Supersonic air intake diffusers and scramjet isolators including corner flows description.

It is expected to support each theme with recent and detailed experimental data as well as CFD modelling and/or validation.

The main conclusions of the activities carried out during the proposed Action Group should cover the following specific issues:

- Clarify the benefit of new CFD methods (unsteady ZDES approach) and HPC capacities in comparison with the last AG34 for example,
- Assess RANS methodology (including turbulence modelling, grid mesh refinement) to tackle the proposed research topic, and
- Estimate the CPU cost of the comparative methodologies.

- **Main achievements**

WP1 : Management

One physical meeting, where all member organisations participated, was held at MBDA-France in Le Plessis Robinson in February 13th 2019.

A temporary file exchange server has been put in place by MBDA-F to share reports, presentations, CAD files and experimental results. However, due to its limitations in terms of data size and lifetime, a more performant potential solution is investigated at DLR. A tele-conference meeting was hold in January 2020 to fix all remaining decisions regarding the test-cases in WP3 and WP4 and to monitor progress on WP2. Tele-conferences will be planned every 3 months in 2020.

WP2 : Supersonic diffusers flows

The case proposed in WP2 involves shock trains prediction.
The main challenges are:

- prediction of shock / boundary layer interactions
- prediction of corner flow separations which distort the flow and affect the aerodynamic losses in a diffusor

The classical turbulence models based on linear closures generally fail to reproduce accurately these flows. More advanced models may be required based on RANS with non linear closures or LES/DES techniques.
A 3D test case with thick BLs $Re\delta 2 \approx 6000$ and strong effect of corner flows from Fiévet et al (AIAA J, 2017) was identified by ONERA but the paper seems not self-sufficient to be used as a test-case.
ONERA proposed to design of a test-case similar for AG58 but with well-known flow conditions at boundaries, see Figure 1.
Several RANS computations were performed by ONERA. Inlet flow profiles are now available to all partners, see Figure 2. Outlet condition is a prescribed back pressure. ONERA will perform a DES mode 3 calculation that can be used as a reference to compare with RANS models. Members will perform DES and/or RANS calculations including non linear closure turbulence models (SAQCR, RMS, …).

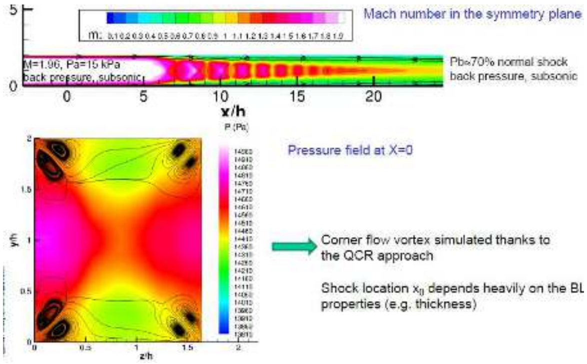


Fig. 1 Shock train in a rectangular cross-section channel. ONERA test-case.

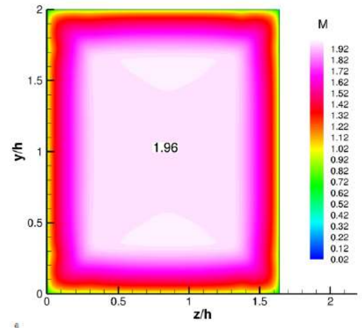


Fig. 2 Common inlet flow field proposed by ONERA for shock train case computations.

RANS computations were performed by ONERA using Spalart Allamaras (SA) and a non linear closure variant (SA-QCR). Results obtained with SA-QCR model are quite different compared to those obtained with the standard SA model. The prediction of the corner flows is strongly modified resulting in a non symmetric development of the shock train inside the duct for the SA and a symmetric one for the SA-QCR (cf. Fig. 3).

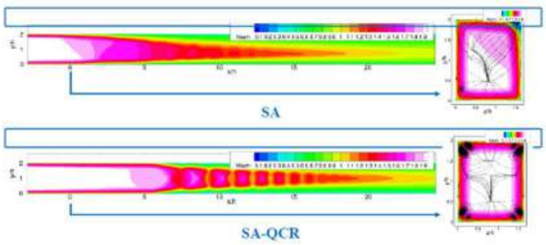


Fig. 3 Effects of QCR closure with the Spalart Allmaras model on corner flows and shock train development for WP2 test-case (ONERA).

Comparisons of CFD predictions with available pressure measurements and published DNS results show local improvements with the non linear closure of the turbulence model (cf. Fig. 4 and Fig.5).

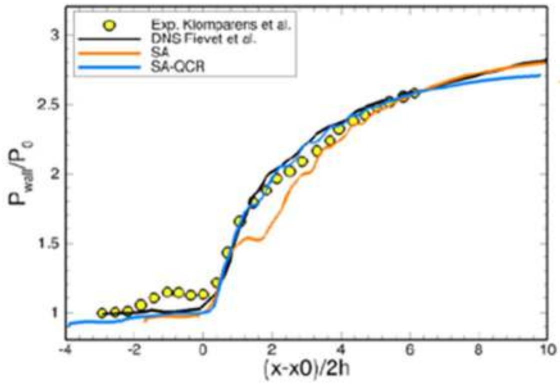


Fig. 4 Effects of QCR closure with the Spalart Allmaras model and comparison with wall pressure measurements (ONERA).

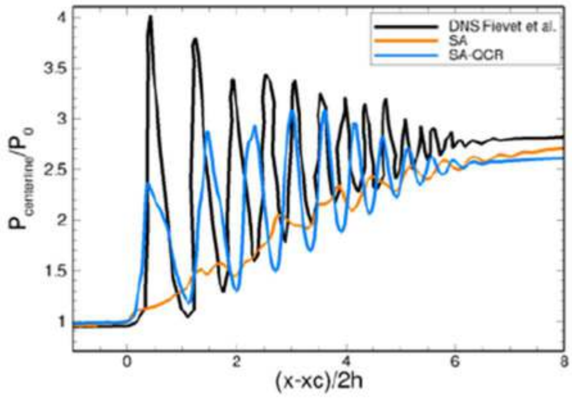
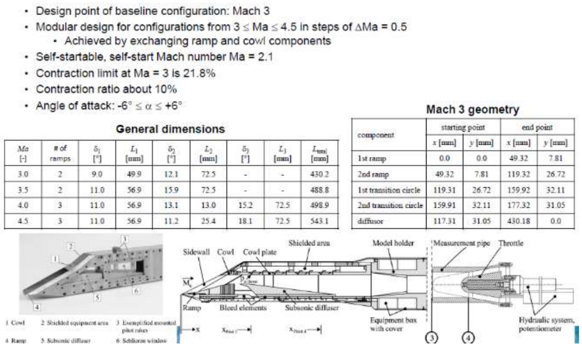


Fig. 5 Effects of QCR closure with the Spalart Allmaras model and comparison with axial pressure computations from DNS published by Fiévet et al. (ONERA).

Further investigation by ONERA and other partners will focused on SST, SST-QCR, Reynolds Stress Model (RSM) as well as ZDES turbulence models.

WP3 : Mach 3 ramjet intake

DLR has described in detail experimental results obtained in several existing wind-tunnel test campaigns for a ramjet intake design for Mach 3, see Figure 6.



General dimensions

Ma [-]	# of ramps	δ_1 [°]	L_1 [mm]	δ_2 [°]	L_2 [mm]	δ_3 [°]	L_3 [mm]	L_{total} [mm]
3.0	2	9.0	49.9	12.1	72.5	-	-	430.2
3.5	2	11.0	56.9	15.9	72.5	-	-	488.8
4.0	3	11.0	56.9	13.1	13.0	15.2	72.5	498.9
4.5	3	11.0	56.9	11.2	25.4	18.1	72.5	543.1

Mach 3 geometry

component	starting point		end point	
	x [mm]	y [mm]	x [mm]	y [mm]
1st ramp	0.0	0.0	49.32	7.81
2nd ramp	49.32	7.81	119.32	26.72
1st transition circle	119.31	26.72	159.92	32.11
2nd transition circle	159.91	32.11	177.32	31.05
diffusor	117.31	31.05	430.18	0.0

Fig. 6 DLR experimental model for the Mach 3 ramjet intake.

This large existing database includes several effects:

- internal bleed geometry, open or closed
- flow conditions such as Mach number (on and off design conditions) and angle of attack
- geometry of the ramps and cowl

It was decided to focus GARTEUR activities on bleed prediction effects in design and off-design Mach number conditions.

The members agreed to select the following experimental conditions:

- No bleed versus bleed 22/22 (bleed entrance length/bleed exit length in mm)
- Effect of Mach number : Mach 3.0 (on-design condition, shocks on cowl lip) and Mach 3.5 (off-design conditions, shocks from ramps interact inside the duct on the internal cowl).
- Tt0 = 290 K, pt0 = 5.8 bar, Re∞ = 40.8 · 106 m-1
- No Angle of attack and no sideslip
- Throttling effects at downstream sonic throat condition (throat section can be changed using a translating plug).

The available experimental data contain (cf. Fig. 7):

- Schlieren images
- Wall pressure measurements
    - o 34 pressure ports along centreline of ramp, cowl and diffuser
    - o Static pressure measurements with 8400 PSI System by Pressure Systems
    - o Instationary pressure measurements with XCL-100 Kulite sensors for frequency analysis of inlet buzzing
- Six Pitot rakes with different lengths available
    - o Can be integrated in four different axial locations in the diffuser section
    - o 2 additional Pitot rakes for exterior flow above and below the model
- Mass flow measurements by conical throttle
- Pressure measurements in throttle used for determination of pressure recovery.

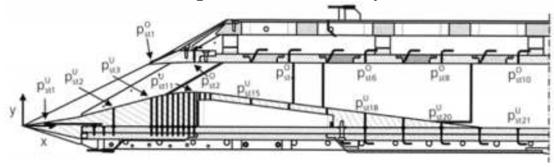


Fig. 7 DLR experiments with measurements and rakes location.

Accuracy on the air intake performances provided by DLR are presented below.

Table 4 Measurement uncertainties of throttle device

M_0	$\Delta(\dot{m}_3/\dot{m}_0)/(\dot{m}_3/\dot{m}_0)$, %	$\Delta p_{st3}/p_{st3}$, %	$\Delta A_3/A_3$, %	$\Delta(p_{t3}/p_{t0})/(p_{t3}/p_{t0})$, %
2.5	1.70	0.03	0.03	0.09
3.0	1.90	0.03	0.03	0.09
3.5	2.06	0.03	0.03	0.09

After a detailed investigation of the model and the boundary conditions needed for the calculations, DLR prepared and shared the CAD files with the fixed modifications commonly agreed at last teleconference meeting.

Regarding boundary conditions, DLR will assess by 2D computations the potential effect of wind-tunnel walls on the bleed mass flow rate, as the internal bleed has no sonic outlet as illustrated by Fig. 8.

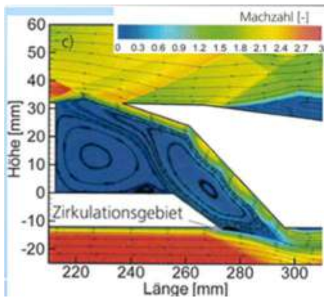


Fig. 8 Illustration of Mach number of the internal flow inside the bleed (DLR).

The 3D CAD file, ready to mesh, has been provided to all members (see. Fig. 9)

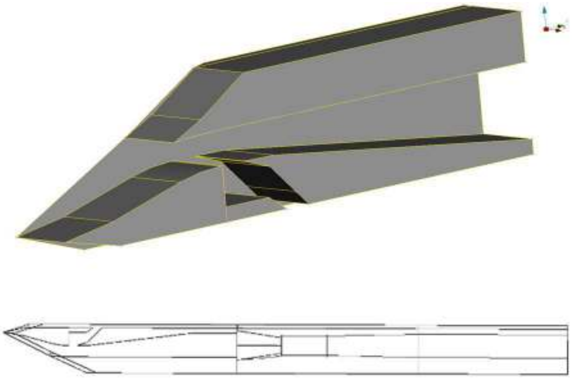


Fig. 9 CAD provided by DLR for the WP3 computation (open bleed case).

The CAD extension down to the throttling device (plug) has been provided as an option so that throattling effect can be computed either using back pressure on short domain or by modifying the sonic throat on the full domain in the computational process. This could have an effect in case unsteady computations of surging regime is planned (this is not a priority of the WP3).

The experimental measurements will be provided shortly by DLR to all members.

Computations efforts will be focused on RANS approach with same turbulence models effects as those proposed in WP2.

WP4 : Mach 7.5 scramjet intake

The proposed test-case is illustrated on the Figure 10.

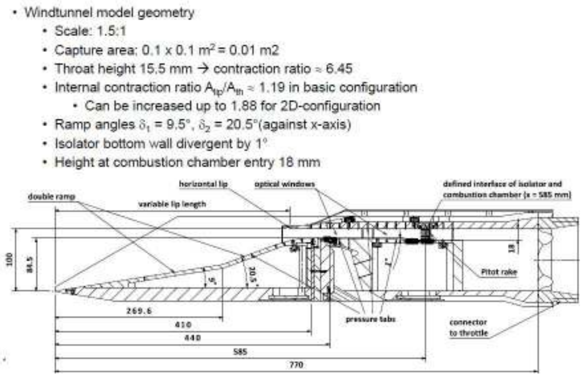


Fig. 10 DLR experimental model for the scramjet Mach 7.5 intake

One topic for WP4 will be the aerothermal fluxes prediction and effects of sidewalls compression, see some examples of experimental results on Figure 11.

It was decided to compute the closed bleed configuration in supercritical conditions with an downstream extension sufficient to include the Pitot rake available in the experiments.

The experimental conditions for CFD validation of heat fluxes still need to be fixed for future calculations as experimental tests were performed with different conditions depending on area of interest (pressure measurement inside the isolator or infrared measurements on the ramps for the heat fluxes).

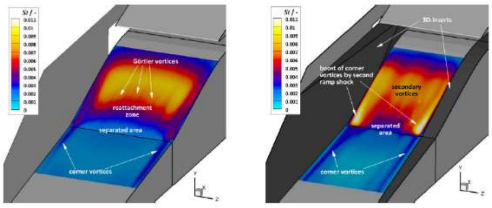


Fig. 11 DLR experiments on the scramjet intakes, with IR thermography. Effect of sidewalls compression on heat fluxes and corner flow.

The CAD, ready to mesh, provided by DLR is presented on the Figure 12. The exit plan is located downstream the isolator Pitot rake.

Computations efforts will be focused on RANS approach with same turbulence models effects as those proposed in WP2.

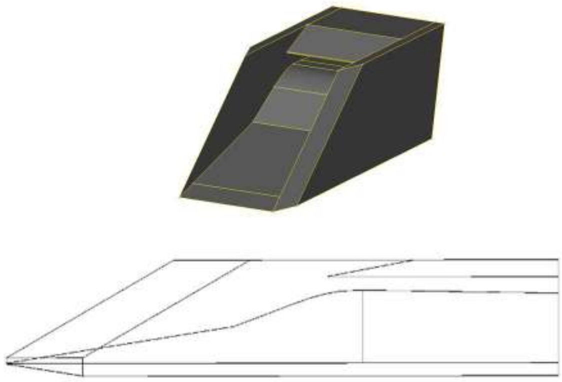


Fig. 12 CAD provided by DLR for the WP4 computation (closed bleed case).

- **Expected results/benefits**

The project is expected to yield increased understanding of turbulence modelling issues for complex internal flows in supersonic and hypersonic intakes. A natural outcome is also that the partners obtain improved best practices for intake flow computations.

- **AD/AG-58 membership**

Member	Organisation	e-mail
Patrick Gruhn	DLR	patrick.gruhn@dlr.de
Oliver Hohn	DLR	Oliver.hohn@dlr.de
Magnus Tormalm	FOI	magnus.tormalm@foi.se
Henrik Edefur	FOI	henrik.edefur@foi.se
Didier Pagan	MBDA France	didier.pagan@mbda-systems.com
Christophe Nottin	MBDA France	christophe.nottin@mbda-systems.com
Scott Schaw	MBDA UK	scott.shaw@mbda-systems.com
Sébastien Deck	ONERA	sebastien.deck@onera.fr
Neil Sandham	University of Southampton	n.sandham@soton.ac.uk

- **Progress/Completion of milestones**

Milestones	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1: Kick-off meeting	Q4 2018	February 2019	Done
WP1: 2020 Meeting	Q1 2020	January 2020	Done
WP1: 2021 Meeting	Q1 2021	Q1 2021	Not started
WP1: Final report and meeting	February 2022	February 2022	Not started
WP2: Definition of a numerical case for shock train computations	Q1 2019	Q1 2019	Done
WP2: Each member to prepare his grid and obtain RANS computations	Q4 2019	Q2 2020	In progress
WP2: DES computations	Q3 2020	Q3 2020	In progress
WP3: Fix experimental conditions and provide CAD file	Q3 2019	January 2020	Done
WP3: Each member to prepare his grid and obtain preliminary computations	Q4 2020	Q4 2020	In progress
WP3: Final computations	Q3 2021	Q3 2021	Not started
WP4: Fix experimental conditions and provide CAD file	Q4 2019	January 2020	Done
WP4: Each member to prepare his grid and obtain preliminary computations	Q4 2020	Q4 2020	Not started
WP4: Final computations	Q3 2021	Q3 2021	Not started

AD/AG-59	Improving the simulation of laminar separation bubbles	
Monitoring Responsable:		G. Mingione CIRA
Chairman:		P.Catalano CIRA

- *Background*

The laminar separation bubble is one of the main critical aspects of flows at Reynolds number of order of magnitude 10^4-10^5. However, the reproduction of this phenomenon results to be crucial also for flows at higher Reynolds number. In fact, very tiny laminar separation bubbles are present in airfoil used for turbine applications operating at Reynolds number of the order of magnitude of 10^6.

An interest is growing towards the employment of rotary wing aircraft as valid technological means for a rapid and efficient exploration of planet Mars. The challenge of this new technological solution lies entirely in the specific environmental conditions these aircraft will be required to operate in. Mars atmosphere is 95% constituted by CO_2 and the force of gravity is about 1/3 than the Earth's. The reduced atmospheric pressure and density, together with the low temperatures, produce flight conditions characterised by very low Reynolds numbers, about 2% of those on the Earth, in combination with high Mach numbers, 1.5 times higher than the terrestrial ones. The evaluation of the aerodynamic characteristics of airfoils and wings in such particular conditions, scarcely investigated so far, is becoming increasingly more important for the understanding of the feasibility of such technological solution.

- **Objectives**

The main objective is to improve the modelling of the numerical methods used in the reproduction of the laminar separation bubbles and the consequent effects on flow instability. The main issues to be addressed are:
•The determination of the transition location and of transition region,
•The enhancement of the production of the turbulent kinetic energy in the separated flow inside the recirculation region,
•Evolution of the bubble with the incidence and with turbulence level,
•Possible burst of the bubble at high incidence and consequences on the stall characteristics,
•Critical evaluation of the laminar boundary-layer instability analysis methods treatment of laminar separation bubbles.

- **Approach**

The focus is placed on the methods based on the Reynolds Averaged Navier Stokes (RANS) equations and on the hybrid RANS-LES methods. Boundary layer instability analysis tools will also be used and compared with the RANS results to ascertain deficiencies of the turbulent onset point; moreover, the RANS embedded turbulence/transition models will also provide significant insight into the efficacy of the boundary-layer instability and hence transition criteria. A particular contribution will be provided by the Zurich University of Applied Sciences (ZUAS) that will apply the open-source code SU2, a flow solver that is becoming more and more popular in the aerospace community. The action group represents a good chance to compare the reliability and accuracy of SU2 with several codes developed by Universities and research centers

- **Main achievements**

The ftp site has been set-up. The letters of acceptance and adherence have been signed by all members. A review of test cases has been performed. The test cases for WP3 and WP4 have been fixed while a test case for WP2 has been deleted. First results for all test cases have been obtained.

- **Management issues**

The kick-off meeting was held at CIRA on February 13th and 14th 2019. The first annual review meeting has ben held on-line on March 4th 2020.
One member, the Zurich University of Applied Sciences, left the action group.Two new members, the Institute of Marine Engineering of Research National Council of Italy and University of Starsbourg, joined the action group.

- **Expected results/benefits**

The project is expected to yield increased understanding of modelling of laminar separation bubbles. A natural outcome is also that the partners obtain improved simulation tools.

- **AD/AG-59 membership**

Member	Organisation	e-mail
P.Catalano	CIRA	p.catalano@cira.it
D. deRosa	CIRA	d.derosa@cira.it
G. Delattre	ONERA Toulouse	gregory.delattre@onera.fr
l. Bernardos	ONERA Meudon	luis.bernardos_barreda@onera.fr
P. Molton	ONERA Meudon	pascal.molton@onera.fr
S. Hien	DLR	stefan.hein@dlr.de
M. Righi	University of Strasbourg (Visiting scientist)	rigm@zhaw.ch
R: Tognaccini	University of Napoli	rtogna@unina.it
B. Mele	University of Napoli	benmele@unina.it
Z. HU	University of Southampton	Z.Hu@soton.ac.uk
V. D'Alessandro	Marche Polythecnic University	v.dalessandro@univpm.it
S. Mughal	Imperial College	s.mughal@imperial.ac.uk
M. Miozzi	Institute of Marine Engineering (INM-CNR)	massimo.miozzi@cnr.it
Yannick Hourau	University of Strasbourg	hoarau@unistra.fr

- **Resources**

	Year			Total
Resources planned	2019	2020	2021	
Person-months	16	21	21	58
Other costs	9.3	12.5	14	35.8

- **Progress/Completion of milestones**

Milestone	Planned	Actual
MS 1: first assessment of models)	T0+15	T0+22
MS 2: Resutls for optional test cases of WP 1	T0 + 27	
MS 3: Results for test cases of WP 2	T0 + 29	
MS 4: Resutls for mandatory test cases of WP 1	T0 + 30	
MS 5: Results for 2D test cases of WP 3	T0 + 21	deleted
MS 6. Resutls for 3D test case of WP 3	T0 + 27	

AD/EG-77	MACHINE LEARNING AND DATA-DRIVEN APPROACHES FOR AERODYNAMIC ANALYSIS AND UNCERTAINTY QUANTIFICATION
Monitoring Responsable:	**F. Monge (INTA)**
Chairpersons:	**E. Andrés (INTA)** **E. Iuliano (CIRA)**

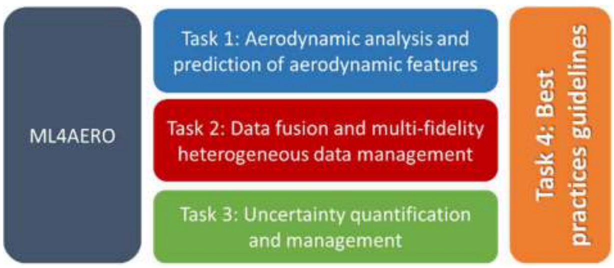
The GARTEUR AD/EG77 was established to investigate the potential application of machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification .

- **Objectives**

The objectives of the proposed Action Group are:

- **Objective 1**: Extensive comparison of deep learning, surrogate models and machine learning techniques for aerodynamic analysis and prediction;
- **Objective 2:** Exploitation of the potential of data fusion (Multi-fidelity) within surrogate modelling by efficient management of heterogeneous data from different sources (CFD with different precision, wind-tunnel, flight test data, etc.);
- **Objective 3:** Exploration of the potential of machine-learning and data-driven techniques for uncertainty quantification and management.

The activities of this AG have been structured in four main tasks, according to the three defined objectives:



The AIRBUS XRF1 configuration will be used as the common test case for methods comparison.

- **Progress**

An Exploratory Group kick-off meeting was held in Madrid on the 24 and 25th of September, 2019. As the result of the Exploratoy Group, a proposal for the establishment of an Action Group is in preparation and it is expected to be accepted in the GoR meeting at the beginning of next year. The expected starting date for the AG is June, 2020. The initial duration of the project is two years.

- **Benefits**

This AG is expected to yield better understanding of machine learning techniques and their application to aerodynamic analysis and uncertainty quantification. At the end of the proposed AG, the involved partners will have improved machine learning capabilities and valuable knowledge of the selected set of data-driven techniques. Through the proposed activities, it is expected that some “best practice” guidelines will be concluded and, consequently, facilitating the use of machine learning methods in aeronautic industries. It is also foreseen that the AG will lead to several publications, either as conference papers or as journal articles.

- **AG membership**

The action group consists of 8 partners, including six research establishments (CIRA, NLR, INTA, FOI, ONERA and IRT) and two industrial partners (AIRBUS-Military and AIBUS).

Country	Organization	PoC	E-mail
THE NETHERLANDS	NLR	Robert Maas	Robert.Maas@nlr.nl
FRANCE	ONERA	Jacques Peter	Jacques.Peter@onera.fr
	IRT	Anne Gazaix	anne.gazaix@irt-saintexupery.com
		Matthias De Lozzo	matthias.delozzo@irt-saintexupery.com
ITALY	CIRA	Emiliano Iuliano	e.iuliano@cira.it

SWEDEN	FOI	Olivier Amoignon	olivier.amoignon@foi.se
SPAIN	AIRBUS-Military	Sergio de Lucas Bodas	sergio.delucas@airbus.com
		Daniel González	daniel.gonzalez.j@airbus.com
	AIRBUS	Daniel Redondo Marta Gonzalez	daniel.redondo@airbus.com
	INTA	Esther Andrés	eandres@isdefe.es

- **Resources planned**

Resources	Year			Total
	2020	2021	2022	
Person-months	14	15.5	9.5	39
Other costs (in K€)	31	39	23	93

ANNEX 2

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "AVIATION SECURITY"

Remit

The Group of Responsables on Aviation Security was created during the GARTEUR Council meeting in March 2014. This new GoR is composed of specialists from Research Establishments and Industry who have identified relevant topics to be studied in the Aviation Security area. GoR AS pursues to do research in the Aviation Security field dealing with both military and civil R&T. Future GoR AS projects will initiate activities in research fields regarding cybersecurity in the aviation sector, CBE detection, dazzling or RPAS.

Table of Contents

AVIATION SECURITY

GoR-AS Overview

GoR Activities

The GoR AS focusses on basic and applied research in Aviation Security, exchanging ideas and experiences matured in different contexts. This topic is quite new in the scenario and expertise and results are spread over different activities. Most of work has a significant amount of multi-disciplinary content especially in domain different from aviation, so a lot of efforts have been dedicated to analyse external sources of information and assess current initiatives on aviation security with the aim to get awareness on the state of the art and build within GARTEUR a coherent harmonised approach with the external initiatives. This trend is driven by industrial interests, which have been properly analysed and the importance of multi-disciplinary work is likely to increase in the future. Two thesis have been finalised to build a common knowledge on topics of interest in the AS area.

During 2019 work has been done by the active members on two research themes:

- Cybersecurity
- Malevolent use of RPAS

The approach in 2019 has aimed at keeping links with other running initiatives like ES4AWG, Optics2 project, ACARE WG4.

Furthermore the chairperson has attended the SAGAS meeting.

The intention to start an action group was agreed among the members. The investigated topics have been kept :

- in line with FlightPath 2050;
- further dealt in the ACARE SRIA update and its dedicated Challenge on Aviation Safety & Security;
- fitting with the PADR(Preparatory Action for defence research) in Horizon 2020 and FP9.
- aligned with EREA Security for Aviation initiative
- a priority for Europe

The main actions in 2019 were:

1. To further develop and share ideas among the active members (CIRA, ONERA, INTA) to identify research challenges and collaboration approaches.
2. To involve the industries interested in the chosen topics Eurocontrol, AENA(the first airport operator company in the world by number of passengers), ENAIRE (the Spanish air navigation service provider), Soulsoftware, ALISCARL, Leonardo, Hungarocontrol, Embraer.
3. To support existing initiatives in aviation security at European level in order to promote harmonization among them and with Garteur.
4. To monitor current funded initiatives to apply for with a collaborative approach involving other key players

Management

A meeting was held in Bucharest Aerodays 2019 to assess the related activities.

A preparation meeting (webex) was held among the AS GOR in May at the AEROSDAYS in Bucharest between CIRA and INTA and the other colleagues were contacted by phone.

During this meeting information was shared about the current activities in each involved institution to finalize the action group decision.

A survey among AS Gor participants was performed to assess the interest to participate in a Sesar proposal which fitted the topic of the action group.

The call was under H2020-SESAR-2019-2 (SESAR 2020 EXPLORATORY RESEARCH), the topic asking for protection of airport operations by intruder's attacks.

In Italy contacts with the following stakeholders increased awareness about their interests.

- SMEs: Strong Detection and Identification Capability Distributed Jamming Capability
- Leonardo: Hostile Drone Interception , Drone Identification Drone Localization & Tracking and challenge

ONERA, INTA and CIRA started to define the concept.

They contacted other industrial stakeholders to participate in the call for proposal and in the development of the research concept.

Specifically they contacted the following stakeholder who accepted to participate:

- Eurocontrol,
- ENAIRE, the Spanish Air Navigation Service Provider
- Aena, the first airport operator company in the world by number of passengers.
- SoulSoftware SRL
- Aerospace Laboratory for Innovative components (ALI Scarl)

- Two Italian companies providers of counter drone solutions.

The concept was developed and the proposal submitted obtaining a very high score but due to budget constraints it was put in the reserve list.

EASA together with other relevant stakeholders provided the endorsement letter to participate in the advisory board.

The strategy consisted of supporting current European initiatives in aviation Security in order to avoid duplication of efforts and harmonize vision, AS GOR members, as members of ACARE WG4 and another initiative within EREA focussing on aviation security (EREA Security for Aviation Working Group), have actively participated in specific meetings and events. The intent has been to harmonize all existing initiatives, as well as build consortia to propose Garteur topics in E.C. calls.

Dissemination of GARTEUR activities and results

The dissemination events during 2019 are represented by the following list:

- EASN conference in Athens (Radian project).
- EREA Security For Aviation Working Group, meeting held in (2019) in Brussels with EREA representatives.
- The Industrial pull on a national basis has been promoted during a one-day meeting organized with the Italian SMes
- Presentation of GARTEUR and AS GoR
- Presentation of the cybersecurity theme
- Presentation of the MalURPAS theme
- Discussion and planned actions

The aims were to:

- share information on and status of current issues ad proposed research activities in the field of Security for Aviation,
- discuss options for establishing new cooperation and a possible joint approach for the potential development of research issues.

Other meetings and contacts with Italian stakeholders have allowed the collection of information about the initiatives in progress on the chosen topic.

Reports issued

Proposal on the collaboration topic (September 2019).

Minutes of meetings

Power point presentations.

Status of Action Group

A proposal for H2020 has been submitted.

An extended team (made by ASGoR and industrial stakeholders, LEAs and Authorities has been set up for identifying collaboration opportunities at national and European level.

GoR membership

Chairman		
Angela Vozella	CIRA	Italy
Vice-Chairman		
Francisco Munoz Sanz	INTA	Spain
Members		
Pierre Bieber	ONERA	France
Rene Wiegers	NLR	Netherlands
Andreas Bierig, Hans-Albert Eckel	DLR	Germany
Clive Goodchild	BAE Systems	UK

Total yearly costs of EG research programmes

	<2017>	<2018>	<2019>	<Year>	<Year>	<Year>	<Year>	<Year >	Total
Person-month	2	3	4						
Other costs (k€)	1	1							

Pilot Paper: Cyber Attacks to Small Civil Drones in order to use them for malicious purposes

Background:

The use of small (below 150 kg) Unmanned Aerial Systems (UASs), commonly calle drones, today is massively growing with a wide range of purposes, it is estimated that i the next four years the number of drones will triple (mass market) and these aircraft wil crowd the skies of all the world. Unmanned Aerial Systems can be remotely pilote (RPAS - Remotely Piloted Aircraft System) or they can automatically fly, thes modalities are both technological and regulatory different, and above all pose differen safety and security issues. The number of civil applications where they can be bot effectively and efficiently used has increased in recent years, thanks to a considerabl reduction in costs. The same government agencies in many countries have equippe themselves with drone fleets for security, rescue and recovery applications. Other area of application can be found in science and research, and many private companies hav been created to offer paid services for the most disparate business applications. Ther are applications that can be carried out with a single drone, but recently applications ar emerging which require the use of fleet of drones (both formation and swarm flights) t ensure better performance and reliability. Due to their broad diffusion and low costs they represent an attractive target for intentional attacks, which can turn them i weapons.

Some applications require the use of drones in critical areas, where there are sensitive infrastructures and/or gatherings of people, in these cases security, as well as safety issues, become crucial. In fact, while drones are operating in applications, hostile subjects with malicious purposes can exploit them to create damage to objects and people.

In the Cybersecurity Roadmap published in 2015 EASA strongly supports the development of a resilient and secure European Aviation System operating through promotion, regulatory activities as well as international cooperation to incorporate the cybersecurity in the existing safety notion. Indeed our countries' critical infrastructures are vulnerable to operation disruption which may result from many kinds of hazards in terms of physical and/or cyber-attack on installations and their interconnected systems.

EASA in the European Plan for Aviation Safety EPAS 2018-2022, considering drones as an emerging safety issue, asks for a coordinated research effort for assuring the safe integration of such systems.

The complete assessment of the vulnerabilities of such systems in order to check wher security can be compromised, as well as the danger deriving from the cyber-attack which depends on the mission scenario, represents a prerequisite to properly identif possible countermeasures and mitigations which can be adopted.

Last but not least, the degree of residual danger after the countermeasures for specific missions and application domains has to be properly analysed.

Proposal Abstract:

The Project proposes to investigate vulnerability of airport under the different types of threat and possible ways of response as well as to study the interrelations between all those aspects involving different scenarios. Risk analysis shall reveal and categorize the problem, from that, an architecture will be developed, dealing with the different steps and elements that can impact on operations, establishing adequate levels of alert, response and, if needed, neutralization. In this way, the stepped approach of the project will show these mainstreams: 1. Identification of problem: Threat(s), assets to protect (Airport, ATM, Aircraft), operations, 2. Setting scenarios: Risk and vulnerability assessment, hierarchization, selection, requirements. 3. Definition of an operational oriented architecture: a) At managerial level: Alert system and levels, Communications, Decisions, Response. b) At Specific technology elements: Detection, Identification, Tracking, Neutralization. 4. Concept Validation activities: HMI based solutions, sensitivity studies, integration of elements and subsystems in the airport environment. 5. Concept Support activities: Review and assessment of regulations and procedures (normal and emergency). ASPRID consortium members have experience with Airport and ATM operations as well as with drone performances and capabilities. A part of the consortium is also experienced in the development of SW and SW/HW based solutions to approach a system which is able to cope with the problem of decision making in real time by providing the end users with the correct level of awareness and response to deal with the type and level of threat.

Proposal of work:

It is proposed that a GARTEUR EG be called to generate the TOR for an AG to investigate the concept of *Cyber Attacks to Small Civil Drones in order to use them for malicious purposes*

The main activities will be:

- A classification of the possible application domains in order to identify the classes of missions, focus will be put on transport critical infrastructures.
- For each class of mission the characteristics of the drones, the level of required autonomy, the fleet size, the onboard sensors, the level of interoperability and other attributes that can be associated to the particular application.
- The identification and classification of the possible operating scenarios associated with the applications.
- The assessment of the vulnerabilities of both drone (fleet or single) and Groun Control Station (communications, onboard operational systems, decision making algorithms), in order to check where security can be compromised, as well as the danger deriving from the cyber-attack which depends on the mission scenario.
- According to the type of cyber-attack, the identification of possible countermeasures and mitigations which can be adopted, as well as the degree of residual danger after the countermeasures for specific missions and application domains.
- Fast-time numerical simulations or even in-flight tests definition and implementation in order to validate the results of the analyses carried out in this work.

The participants in this EG are the following:

Angela Vozella - CIRA

Francisco Muñoz Sanz – INTA

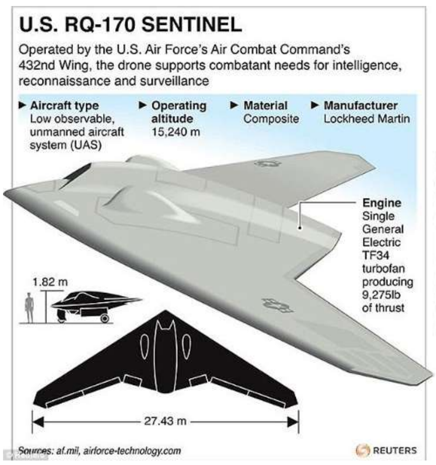
Rene.Wiegers – NLR

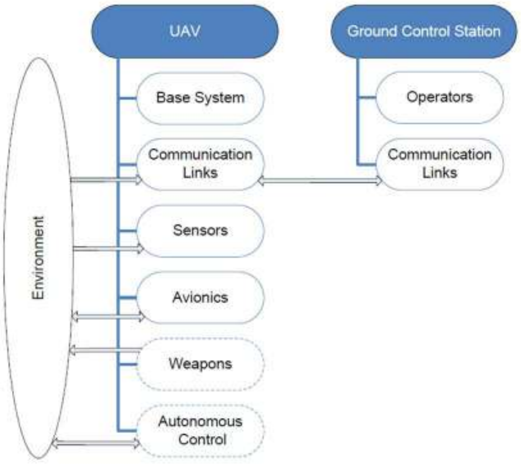
Pierre Bieber – ONERA

Issues and enablers:

Cyber Attacks classification

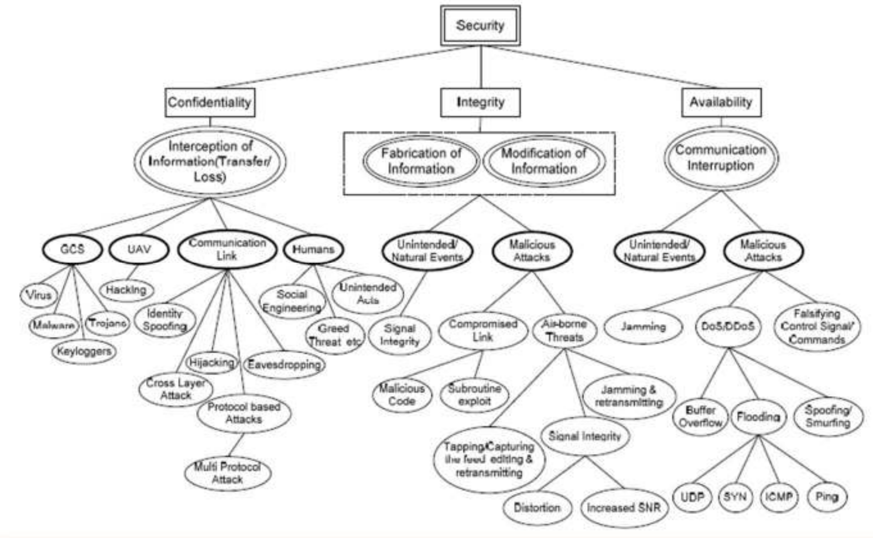
- Hardware Attack: attacker has access to the UAV components directly
- Wireless Attack: Attacker carries out the attacks through one of the wireless communication channels
- Sensor Spoofing: attacker passes false data through the on-board sensors of the UAV





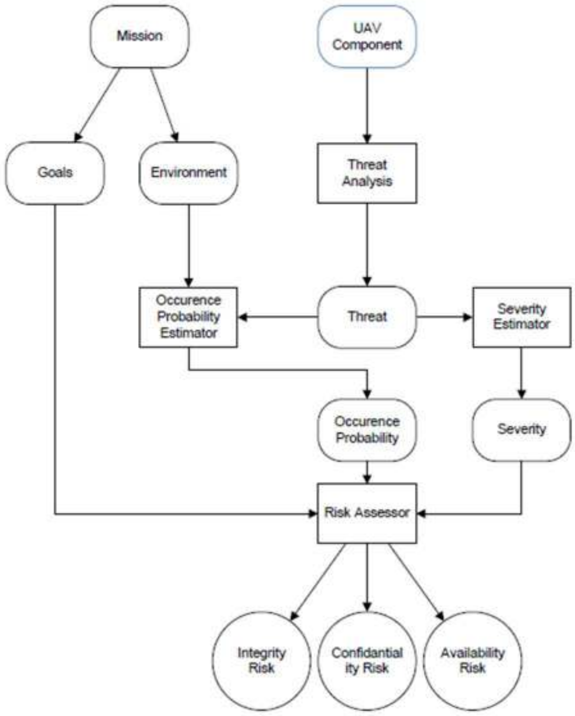
Comprehensive analysis of threats on RPAS security and integrity according to the security threats

- Study of GPS, C2 link, ADS-B Vulnerabilities
- Jamming
- Denial-of-service
- Eavesdropping (Spoofing)
- Analysis of their functional consequences



Future work:

- Study of protection techniques and operational procedures
- Investigate an autopilot system robust to gps spoofing
- Define a standard VV plan according to the risk model
- Model the integration of a Cyber risk assessment within engineering lifecycle phases
- Investigate a complete taxonomy to better understand the propagation mechanisms of attacks and handle them in attack models
- Analyse the challenge of Interoperability among heterogenous aerial platforms and study security of protocols (e.g.: Mavlink)



International collaboration

Collaboration within the NATO Information Systems Technology Panel

NATO IST-151 'Cyber Security of Military Systems'

- CAN (chair), CCDCOE, DEU, ITA, NLD, TUR

Objective: Share and apply methodologies, processes, tools and technologies to assess military systems' cyber security. Report lessons learned and, potentially, assessment results and mitigations

NATO IST-ET-099 'Mission Assurance and Cyber Risk Assessment for Multi-Domain Unmanned/Autonomous Vehicles and Systems'

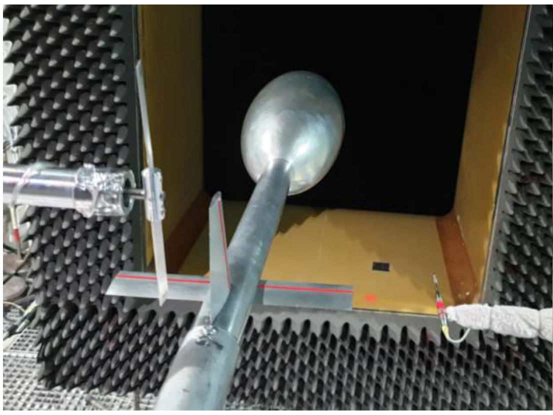
- USA (chair), NATO CMRE, NOR, NLD, ITA, DEU, PRT

Objective: Consider existing/emerging methods and frameworks in mission assurance, cyber security and risk assessment.

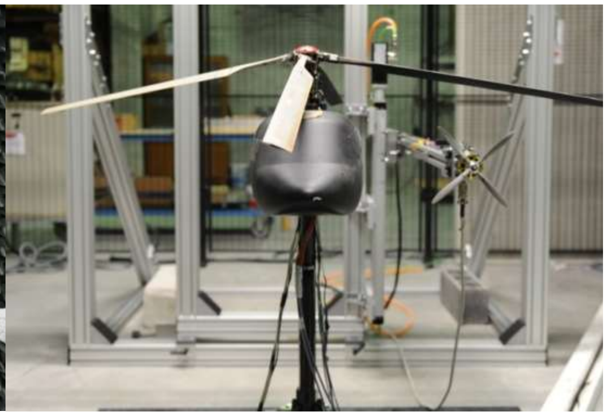
Modeling of multi-domain (air and maritime) mission conducted by UAxSs and Cyber Physical Systems; Preliminary cyber security analysis

ANNEX 3

ANNUAL REPORT FROM THE GROUP OF RESPONSABLES "HELICOPTERS"



Scattering Test with rotor model(HC/AG-24)



Generic Main Rotor/Propeller Configuration (ONERA) (HC/AG-25)

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 vehicles (helicopters and VTOL aircraft, such as tilt rotors, compounds and multicopters) 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 Virtual Engineering using numerical tools based on low-order (analytical, BEM) to high-order (CFD) methods, validated with relevant tests campaigns
- Increase operational efficiency (improve speed, range, payload, all weather capability, highly efficient engines, more electric rotorcraft ...)

- Increase security, safety
    - Security studies, UAVs, advanced technologies for surveillance, rescue and recovery,
    - Flight mechanics, flight procedures, human factors, new commands and control technologies,
    - Increase crashworthiness, ballistic protection, …
- Integrate rotorcraft better into the traffic (ATM, external noise, flight procedures, requirements/regulations)
- Tackle environmental issues:
    - Greening, pollution
    - Noise (external, internal)
- Progress in pioneering: breakthrough capabilities

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

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

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

Table of Contents

GoR 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 represent more than 60% of the civil helicopters delivered worldwide.

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, including 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. 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, even if the number of helicopter dedicated projects within H2020 has significantly been reduced compared to previous framework programmes.

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

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

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

Management

The chairmanship in 2019 was held by Klausdieter Pahlke (DLR). Vice Chairman is Joost Hakkaart (NLR).

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 2 Joint Technology Initiative and especially for Fast Rotorcraft IADP, the GoR members are active. In the view of the GoR-HC, 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:

- 79th GoR Meeting: 26- 27 Febr. ‘19, DLR, Braunschweig, Germany,
- 80th GoR Meeting: 9-10 October ‘19, CIRA, Capua, Italy.

The main business of the meetings was to discuss about further topics and to implement the 3-5 year planning process as well as to present the status of the current AGs and EGs. The GoR meetings were used to harmonize the views and the involvement of members regarding preparations for proposals for H2020. These meetings were also used to discuss about Clean Sky 2 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 Vertical Flight Society (VFS) (former American Helicopter Society (AHS)) and the Asian/Australian Rotorcraft Forum (ARF) was harmonized and supported.

In 2019 the activities in the HC-AGs were at a low level. 2019 started formally with four active Action Groups and three Exploratory Groups; two of the Action Groups closed their activities with their report delivered.

Dissemination of GARTEUR activities and results

Results coming from Action Groups are traditionally prone to publication either in Journals or in Conferences. In the field of Helicopters, the two conferences having the greatest impact are the European Rotorcraft Forum and the Annual Forum of the Vertical Flight Society. The following tables lists the technical publications achieved in 2019.

AG	Conference	Venue, Date	Authors	Title
HC/AG-23	45th European Rotorcraft Forum	17-20 September 2019, Warsaw, Poland.	Alexander Štrbac, Tanja Martini, Daniel H. Greiwe, Frauke Hoffmann, Michael Jones	ANALYSIS OF ROTORCRAFT WIND TURBINE WAKE ENCOUNTERS USING PILOTED SIMULATION

AG	Journal	Venue, Date	Authors	Title
HC/AG-24	JOURNAL OF AIRCRAFT Vol. 56, No. 4, July–August 2019	DOI: 10.2514/1.C035009	Jianping Yin	Investigation of Rotor Noise Shielding Effects by the Helicopter Fuselage in Forward Flight
HC/AG-24	CEAS Aeronautical Journal, Vol 10 (2), Seiten 531-551. Springer.	DOI: 10.1007/s13272-018-0333-0 ISSN 1869-5590	Yin, Jianping und Rossignol, Karl-Stephane und Barbarino, Mattia und Bianco, Davide und Testa, Claudio und Brouwer, Harry und Janssen, Stevie Ray und Reboul, Gabriel und Vigevano, Luigi und Bernardini, Giovanni und Gennaretti, Massimo und Serafini, Jacopo und Poggi, Caterina	GARTEUR activities on acoustical methods and experiments for studying on acoustic scattering.

Reports issued

In 2019, two AGs published their final reports:

AG	Report	Reference	Authors	Title
HC/AG-23	GARTEUR	TP-192	Richard Bakker	GARTEUR HC/AG-23 Wind Turbine Wake and Helicopter Operations
HC/AG-24	GARTEUR	TP-194	Jianping Yin	"Final Report of Action Group HC AG24: Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction", report number is TP-194, October 2019

Status of Action Groups and Exploratory Groups

Action groups (AG)

The following Action Groups were active throughout 2019:

HC/AG-21	*Rotorcraft Simulation Fidelity Assessment. Predicted and Perceived Measures of Fidelity* Main goal of the project is the development of new simulation assessment criteria for both open-loop predictive fidelity and closed-loop perceived fidelity. Final simulation trials were done in 2016 and analysed in 2017. All technical activities are closed. The final report is in its proof reading phase and finalization is expected in 2020.
HC/AG-23	*Wind turbine wake and helicopter operations* The objectives are the analysis of the behaviour of helicopters in a wind turbine wake, the identification of the safety hazards and the definition of measures to mitigate identified safety issues. Partners have updated their computational flow and flight mechanics tools. Turbulent unsteady wind turbine wake fields have been computed and have been used to assess handling qualities of helicopter – Wind Turbine wake encounters. Piloted simulations have been performed. The final report was delivered in January 2019.
HC/AG-24	*Helicopter Fuselage Scattering Effects for Exterior/Interior Noise Reduction* The main objective is to examine rotor noise propagation in the presence of a fuselage. The activity established an experimental acoustic database and prediction design tools for main and tail rotor noise in the influence of a fuselage (2016-17 activities) and also include main/tail rotor interactions (on-going). The last test campaign initially planned for September/October 2017 was postponed to I/2019. The final report was delivered in October 2019.
HC/AG-25	*Rotor-Rotor-Interaction*

The main objective is to investigate, both numerically and experimentally the effect of rotor / rotor and rotor / propeller wakes interactions on high speed rotorcraft operating in low speed conditions with the aim to establish low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes. The AG startet in October 2019.

Exploratory groups (EG)

The following Action Groups were active throughout 2019:

HC/EG-38	*Verification & Validation: Metrics for the Qualification of Simulation Quality* To define metrics for the qualification of the quality of rotorcraft simulations, as a contribution to the Verification and Validation (V&V) process of numerical codes. The progress in this EG was limited and the workshop didn't bring the expected clarity for the next steps. As the topic is very relevant HC GoR will try support this EG in order to produce meaningful Terms of Reference for possible AGs.
HC/EG-39	*Testing and modelling procedures for Turbulent Boundary layer noise* To identify ways how to reduce the flow induced noise in rotorcraft. The chairman is currently a visiting scientist at NASA working on other topics. He will take up the EG-lead after his return in Sept. 2020.
HC/EG-40	Gust Resilience of VTOL Aircraft The objective is to set-up a team of researchers able to investigate and test the different approaches that might be employed to achieve gust resilience of multi-rotor vehicles. This EG was identified in 2019 and is expected to be active in 2020.

Rolling plans

The 3–5 year planning will continue to be implemented and was presented in more detail to the Council in the April 2019 meeting in Madrid. 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	2014	2015	2016	2017	2018	2019	2020	2021
Methods for Impr. Of Struc. Modell. In-Flight Data	HC/AG-19								
Simulation/Testing for design of passive noise absorption panels	HC/AG-20								
Rotorcraft Simulation Fidelity Assessment	HC/AG-21							=>	
Forces on Obstacles in Rotor Wake	HC/AG-22	EG32 =>							
Wind Turbine Wake and the effect on helicopters	HC/AG-23	EG32 =>							
Helicopter Fuselage Scattering Effects for Exterior/interior Noise Reduction	HC/AG-24	EG34 =>							
Rotor-Rotor-Interaction	HC/AG-25					EG36 =>			
HUMS	HC/EG-29				x				
Simulation Fidelity	HC/EG-30	=> AG21							
Conceptual design of Helicopters CoDHe	HC/EG-31	x							
Forces on Obstacles in Rotor Wake	HC/EG-32	=> AG22							
Wind Turbine Wake and the effect on helicopters	HC/EG-33	=> AG23							
CFD based flow prediction for complete helicopters	HC/EG-34	x							
Helicopter Fuselage Scattering Effects for Exterior/interior Noise Reduction	HC/EG-35	=> AG24							
Rotor Rotor Interactions	HC/EG-36						=> AG25		
Noise Annoyance Generated by Helicopters	HC/EG-37						x		
V&V: definine metrics for the quality of simulations	HC/EG-38								
Testing and modelling procedures for TBL noise	HC/EG-39								
Gust Resilience of VTOL Aircraft	HC/EG-40								
Acoustics of rpm controlled rotors	HC/EG-41								
Modelling of electric systems for eVTOLS (pre-design) ==> UAV-Topic?	ID								
Drone impact on Helicopters (rotating parts)	ID								
Ice accretion and performance prediction on rotary wings	ID								
HF issues and Training methods for complex automation in cockpit	ID								
PSP/TSP for rotors/propellers (drone,e-VTOLS...)	ID								
Drag break down from CFD for rotorcraft application	ID								

▲ final report delivered
X EG closed without releasing a TOR for an AG.

GoR membership

Chairman		
Klausdieter Pahlke	DLR	Germany
Vice-Chairman		
Joost Hakkaart	NLR	The Netherlands
Members		
Mark White	Uni. of Liverpool	United Kingdom
Arnaud Le Pape	ONERA	France
Antonio Visingardi	CIRA	Italy
Francois-Xavier Filias	Airbus Helicopters	France
Rainer Heger	Airbus Helicopters	Germany
Antonio Antifora	Leonardo	Italy
Observer		
Richard Markiewicz	Dstl	United Kingdom

Table of participating organisations

	AG23	AG24	AG25	EG38	EG39
Research Establishments					
ONERA	□	□	■	□	■
DLR	□	■	□	□	□
CIRA	□	□	□		
NLR	■	□		□	□
Dstl					
CNR-INSEAN		□			
Industry					
Airbus Helicopters, France				□	
Airbus Helicopters, Germany				□	
AgustaWestland / Leonardo					
Thales					
LMS (Belgium)					
CAE (UK)					
ZF Luftfahrttechnik GmbH (D)					
IMA Dresden (D)					
MICROFLOWN					
Academic Institutes					
University of Liverpool (UK)	□				
University of Cranfield (UK)					
University of Glasgow (UK)	□		□	□	
TU Delft (NL)	□			□	
University of Munich (D)	□				
University of Stuttgart IAG (D)			□		
University of Roma 3 (IT)		□			
Politecnico di Milano (IT)	□	□	□	■	
National Technical Univ. of Athens (G)	□		□		
Institut Supérieur de l'Aéronautique et de l'Espace (F)				□	

□ = Member ■ = Chair

Total yearly costs of AG research programmes

	2012	2013	2014	2015	2016	2016	2018	2019	Total
Person-month	13	36.5	44.4	88.7	79.5	55	26.5	10.0	353.6
Other costs (k€)	6	13	38	103.1	102.9	54	20	27	364.0

Action Group Reports

Remark: As there were no technical activities in HC/AG-21 in 2019, this AG is not reported below.

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

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

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

Interest of the research

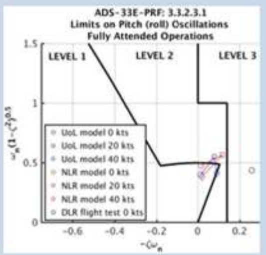
AG-23 investigates the impact of large wind turbine wakes on the flight safety of rotorcrafts.

Background

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

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

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



Programme/Objectives

Objectives

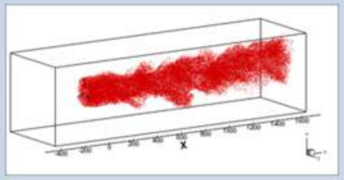
Despite the amount of literature on both wind turbine wakes and helicopter – fixed wing tip vortex encounters, not much research has been done on the interactions of wind turbine wakes and helicopter flight.
The aim of the Action Group is to set up a team of researchers from universities and research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

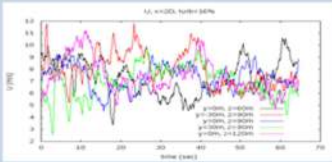
Programme

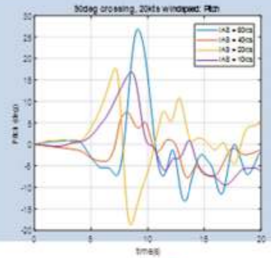
The programme consists of 5 work packages

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

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







Results

- Partners have updated their computational tools and have computed (turbulent) unsteady wind turbine wake fields
- Experimental data and calculated wind turbine wake velocity fields were shared, and have been used to harmonize the off-line simulation activities with a common wake velocity field
- Handling qualities of the UoL/DLR/NLR BO105 reference helicopter, have been compared w.r.t. stability, bandwidth, response, coupling etc. to use as a common helicopter reference model
- Piloted simulations have been performed or are being prepared
- WTN 250 Offline (Virtual Airdyn) and Piloted simulations show serious degradation of handling qualities levels. Considerable pilot effort at lower helicopter speeds with 30 knot wake
- NREL 5MW piloted simulations show rating 3 and higher for WT wake crossing (work on-going)

Members of the HC/AG-23 group are:

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

GARTEUR Responsable:
J. Hakkaart NLR

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

HC/AG-23	**"WIND TURBINE WAKE AND HELICOPTER OPERATIONS"**	
Monitoring Responsable:		J. Hakkaart NLR
Chairman:		Mr. R. Bakker NLR

- **Objectives**

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

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

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- **Activities**

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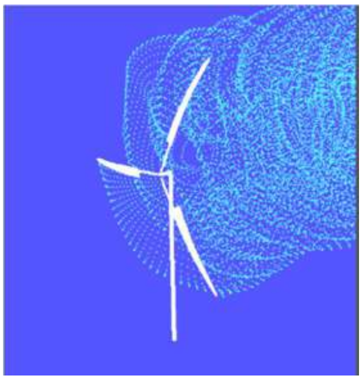
1. Wind turbine wake identification
2. Wind turbine wake experiments and computations
3. Helicopter - Wind turbine off-line simulations
4. Helicopter - Wind turbine wake piloted simulations.



- **Management issues**

The kick-off meeting was held on November the 7th, 2014. During the meeting the membership, resources and work packages were discussed and confirmed. Professor Barakos has moved to the University of Glasgow and will continue his CFD contribution there. Dr White at the University of

Liverpool will contribute to the flight simulation activities. Two teleconferences were held on 21st May and 9th December 2015. On 6 October 2016 the planned Mid-Term Meeting was combined with the 3rd Technical Meeting. Due to availability of the partners it was not possible to organise a live meeting in Glasgow. Instead a teleconference was organised. The final meeting took place at the ERF 2018 in September in Delft. The final report was delivered in Jan. 2019.

- **Results/benefits**

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

The first deliverable, a technical report on wind turbine wake characteristics, is in progress and the NREL5 model is selected as reference wind turbine for the AG23 activities. Initial CFD work and wind tunnel test preparation has commenced. The Bo105 helicopter has been chosen as the reference helicopter and a model validation exercise has been planned. The partner's contributions for both the Wind Turbine Wake survey (WP1.D1) and the Mid-Term report (WP0.D1) have been received in 2018 by all partners. The reports were deliverd. Other reports were planned at the end of the project period (month 30 and 36). The activities for these WP deliverables are successfully closed and results have been presented and communicated. Partners have been working on the generation of a representative wind turbine wake (ONERA, CIRA, NTUA, UoG, NLR) and have produced results for WT-wake and helicopter encounters (DLR, TUDelft, UoL, NLR, CIRA, NTUA). A variety of parameters have been produced: attitude response, attitude rate response, trimmed hover and forward flights, hub loads etc. To formalise and coordinate the processing of results, a selected set of test conditions has been agreed on, with the purpose of better be able to compare partners results. Other activities that were performed include the validation of wind turbine wakes with experimental data (NTUA, UoG) and validating and harmonising the BO105 flight dynamics model (UoL, DLR, NLR). All reports and deliverables were distributed in Jan. 2019.

- **HC/AG-23 membership**

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

- **Resources**

Person month resources were confirmed during the kick-off meeting and have been split tentatively in years. The following table presents the final numbers.

Resources		Year				Total
		2015	2016	2017	2018	
Person-months	Actual/ Planned	18/18	17/22	20/18	10/10,5	65,5/68
Other costs (in K€)	Actual/ Planned	1,6	1,3	11,2	0,0	14,1

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

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

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

Background

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

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

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

Programme/Objectives

Objectives

The present research work will address noise propagation in presence of the fuselage. The principal objective of HC-AG24 is then to promote activities to:

- establish unique quality database - for unsteady scattered acoustic pressure on the fuselage and in the far field as well as flow field, including flow refraction and convection effect;
- validated prediction design tools for main and tail rotor noise under influence of fuselage - including main/tail rotor interactions;
- proof of rotor noise reduction through adding acoustic absorbing liner on the part of fuselage.

The timescale for the project is three years during which the following topics are to be addressed:

- Investigate the capability and reliability of tools capable of predicting the effects of noise scattering problems;
- Perform computations of numerical benchmark cases and incorporation of the convective flow effects;
- Study the possibility to account for a surface impedance;
- Define representative test cases for generating a data base with a generic configuration, including sound pressure and flow field data

The work programme is structured in three work packages:

➢ WP 1: Simulation on the acoustic scattering effect

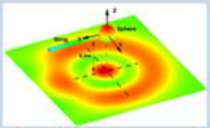
- Code adaptation & prediction
- Code validation & improvement of prediction tools
- Evaluation of noise scattering of various components using validated codes

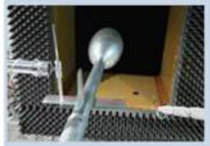
➢ WP 2: Wind Tunnel Tests & Synthesis

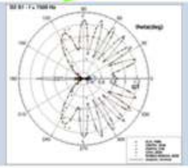
- Model preparation
- Test preparation
- Model setup and installation
- Test matrix & instrumentation
- Test conduct
- Test data compilation & distribution
- Test data analysis

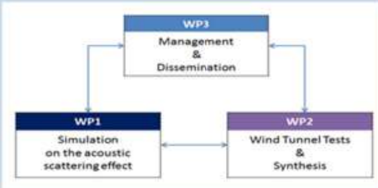
➢ WP 3: Management & Dissemination

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









Results

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

Six technical review meetings were conducted since the beginning of the action group. The following results were achieved during this period:

1. Description of available analytical, experiment test cases including database completed and distributed;
2. The common simulations for the sphere and NACA0012 wing scattering defined and the results comparied with the test. In addition the comparison results published in ERF 2016, 2017;
3. The Sphere scattering tests composed of 3 spheres, two support systems, and two noise sources were conducted and the results published in ERF 2016; Model tail rotor were manufactured, tested and published in ERF 2018;
4. Specifications on the test for the GARTEUR helicopter scattering defined. The generic helicopter were manufactured; tests for generic helicopter with three different sources has been conducted in 2019 at DLR Acoustic Wind Tunnel Braunschweig (AWB);
5. GARTEUR activities on acoustical methods and experiments is published in 2018 CEAS Aeronautical Journal;
6. 9 publications and 8 reports related to group were produced

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

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

GARTEUR Responsable:

K. Pahlke	DLR

CIRA Centro Italiano Ricerche Aerospaziali — Marine Technology Research Institute INSEAN — DLR — NLR — ONERA THE FRENCH AEROSPACE LAB — Politecnico di Milano — ROMA TRE UNIVERSITÀ DEGLI STUDI

HC/AG-24	**"HELICOPTER FUSELAGE SCATTERING EFFECTS FOR EXTERIOR/INTERIOR NOISE REDUCTION"**	
Monitoring Responsable:		**K. Pahlke** **DLR**
Chairman:		**J Yin** **DLR**

- **Objectives**

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

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

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

- **Activities**

The AG consists of 3 work packages:

1: Simulation of the acoustic scattering effect

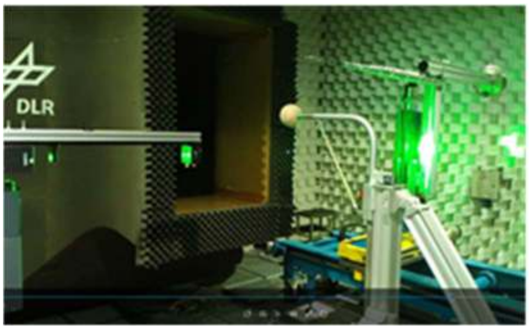
2: Wind tunnel tests and synthesis

3: Management and dissemination

A code to code comparison regarding a monopole scattering by sphere has been completed and distributed and the specification of the common simulation for NACA 0012 test arrangement has been issued; numerical simulations by all partners were carried out.

- **Management Issues**

The AG was planned to run for two years with a mid-term review to enable an extension for a third year. The kick-off meeting was held at DLR Braunschweig, Germany in Jan. 2015 and the technical review meetings were held 15-16-July, 2015, at CIRA, Napoli, 3-4 Febr. 2016 at INSEAN, Rome and at ONERA 22 Sept. 2016 in Lille. The decision to extend this AG by one year was taken during the Council March 2016. Due to technical problems with the acoustic wind tunnel at DLR Braunschweig the final tests could not be done in 2018 und HC/AG-24 had to be extended. This was accepted by the Council in April 2019. The final report was delivered in October 2019.



- **Results/benefits**

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

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

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

The following results were achieved:

1. Description of available analytical, experiment test cases including database completed and distributed;
2. Specifications on the common simulation for the sphere scattering defined and the results of sphere simulation completed and compared. In addition, the comparison results were published in ERF 2016;
3. The Sphere scattering tests composed of 3 spheres, two support systems, and two noise sources were conducted and the results published in ERF 2016;
4. The generic helicopter and model tail rotor were manufactured; tests for generic helicopter with three different sources were planned for Sep. 2017 but had partially to be postponed for technical reasons to 2018 and even 2019.
5. Specifications on the test for the GARTEUR helicopter scattering defined;
6. The abstract related to the group activities in terms of the simulations and experiments is accepted for AHS 2017;
7. 9 publications and 9 reports were produced.

- **HC/AG-24 membership**

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

- **Resources**

Person month resources were confirmed during the kick-off meeting and have been split tentatively in years. The table below provides the final numbers.

Resources		Year					Total
		2015	2016	2017	2018	2019	
Person-months	Actual/	30,0	25,0	22,0	16,0	8,0	101,0
	Planned	30,0	25,0	22,0	0,0	0,0	77,0
Other costs (in k€)	Actual/	66,0	48,0	34,0	48,0	24,0	220,0
	Planned	66,0	48,0	34,0	0,0	0,0	148,0

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

HC/AG-25: Rotor – Rotor Wakes Interactions

Action Group Chairman: Ronan Boisard (ronan.boisard@onera.fr)

Background

Almost all conventional helicopters have several rotors, from the classical helicopter with a main rotor and a tail-rotor, which has an anti-torque function, or the less classical tandem configuration with two side-by-side rotors, or the helicopters with co-axial rotors, or even tilt-rotors. In the context of the development of high speed compound helicopters, the main rotor cannot be used as an efficient propulsive device at high speed and most of the time a propeller has to be added in order to reach high advancing velocities. This multiplicity of rotors is also up-to-date in the field of UAVs, where the lifting function is more and more distributed on several rotors (sometimes more than 4).


The simultaneous use of rotating blades distributed around the airframe with planes of rotations that may differ adds a lot of aeromechanical complexity and can lead to complex unsteady interactions between the wakes emitted by the blades of the rotors or the propellers. It is legitimate to assume that such interactions, of aerodynamic nature, can have a significant impact on vibrations, on radiated noise and on aerodynamic performance, especially but probably not exclusively, in low speed conditions.

An overview of the available literature outline the fact that Rotor / Rotor and Rotor / Propeller wake interactions has been identified since the beginning of compound helicopters as extremely important for aircraft maneuverability and performances and is still an important concern for next generation of VTOL vehicles like multicopters. However, experimental databases are either extremely old or protected by the manufacturers. In such conditions it is almost impossible to improve and validate numerical tools without performing new experiments. Concerning the physical understanding of the interactions, the literature is scarce. Manufactures only focus on the overall aircraft stability, maneuverability and performances, and academic work is almost nonexistent, probably linked to the lack of freely available experiments.

Programme/Objectives

Objectives

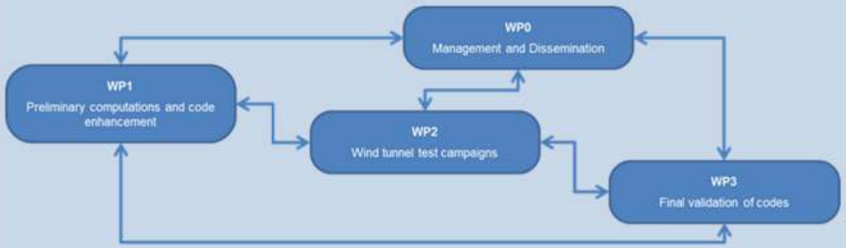
The principal objective of HC-AG25 is then to promote activities which could contribute to a better understanding and prediction of the aerodynamics of rotor / rotor wake interactions. This will be achieve by:

- Providing to the community extensive experimental databases about different kind of rotor / rotor and rotor / propeller interactions
- Validation and improvement of state of the art computational tools against experiments
- Improvement of low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes

The time frame for this program is three years during which both experiment and numerical simulations will be performed

The work programme is structured in four work packages:

- WP0 – Management & Dissemination: is aimed at the fulfilment of all the obligations concerning the project management and the dissemination of the results.
- WP1 – Preliminary Computations & Code Enhancements: deals with a preparation phase during which partners are involved in literature review and preliminary computational activities
- WP2 – Wind Tunnel Test Campaigns: concerns the performance of the different wind tunnel test campaigns:
  1. Rotor – Propeller Interactions (ONERA)
  2. Mach scaled Rotor – Propeller interactions (PoliMi)
  3. Rotor – Rotor Interactions (DLR)
- WP3 – Final Validation of Codes: is aimed at the final validation of the numerical tools proposed by partners.



Results

The action group started its activities on 1st of October 2019.

All the foreseen wind tunnel test campaigns are in a preparation phase.

The geometry of the Onera wind tunnel test was shared and all the partners involved in the numerical activities have start some pre-test computations.

Members of the HC/AG-25 group are:
(only contact persons are listed here)

R. Boisard	ONERA (Chairman)
A. Visingardi	CIRA (Vice-Chairman)
M. Kessler	IAG
G. Gibertini	PoliMi
T. Schwarz	DLR
S. Voutsinas	NTUA
G. Barakos	UoG

GARTEUR Responsable:

A. Lepape	ONERA

University of Stuttgart Institute of Aerodynamics and Gas Dynamics
Centro Italiano Ricerche Aerospaziali
POLITECNICO MILANO
DLR
University of Glasgow
ONERA THE FRENCH AEROSPACE LAB

HC/AG-25	**"ROTOR - ROTOR WAKE INTERACTIONS"**	
Monitoring Responsable:		**A. Le Pape** **ONERA**
Chairman:		**R. Boisard** **ONERA**

- **Objectives**

If rotor-rotor or rotor-propeller interactions can nowadays be numerically addressed by high order aerodynamic tools (CFD), such approaches are extremely expensive in terms of CPU time due to the difference in terms of rotating speed between the main rotor and the propeller, and also to the fact that the rotor and propeller wake have to be propagated with high accuracy on long distances. Moreover, at low speed, phenomena are highly unsteady and therefore need to be averaged over a long period of time. Therefore, there is a clear need of low order models to be used in pre-design phases of advanced rotorcraft vehicles or in comprehensive codes. Developing such low-order models requires adequate experimental databases, which are moreover mandatory to validate CFD or free-wake models. However the analysis of the previous work clearly highlights the lack of such experimental databases.

An exploratory group (EG-36) was created with the aim to promote activities which could contribute to fill these gaps. For the purpose, EG36 proposed the creation of the action group HC/AG-25 gathering a team of researcher willing to investigate, both numerically and experimentally the effect of rotor / propeller wakes interactions on high speed rotorcraft operating in low speed conditions.

The time scale for the project is three years during which the following activities:

• Application and possible improvement of computational tools for the study of rotor / propeller wakes interactions

• Setting up some cost effective wind tunnel test campaigns aiming at producing experimental database for the validation of numerical methodologies

• Final validation of the numerical methodologies.

- **Activities**

The AG consists of 4 work packages:

WP0 – Management & Dissemination:

This work package aims at the fulfilment of all the obligations concerning the project management and the dissemination of the results. Through it the project interacts with the Group of Responsables (GoR), by receiving inputs and providing the information required, and the scientific community, by collecting the results of the activities of the other three work packages and disseminating them.

WP1 – Preliminary Computations & Code Enhancements:

The main goal here is literature review and computational actions aimed at providing necessary and useful inputs to the two following work packages where experimental databases are produced (WP2) and the modelling capabilities of the applied numerical tools are validated (WP3). It also provides WP0 with all the information required for management and dissemination.

WP2 – Wind Tunnel Test Campaigns:

In this work package all the wind tunnel test campaigns that have been identified by partners as particularly meaningful for the phenomenological understanding of the wakes interactions will be performed. The resulting experimental databases will be delivered to WP3 for the final validation of the numerical tools proposed by the partners. It will also provide WP0 with all the information required for management and dissemination.

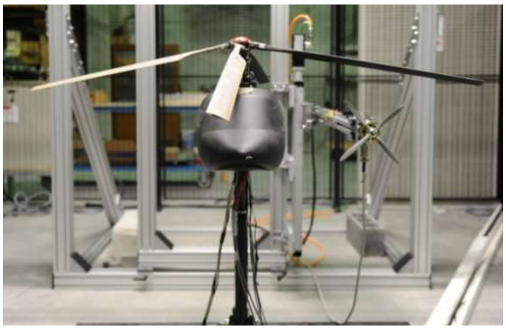
WP3 – Final Validation of Codes:

In this work package, the final validation of the numerical tools proposed by partners will be performed by comparing the numerical results of the computational activity with the experimental data produced during the wind tunnel test campaigns of the project in the framework of WP2. The work package also provides WP0 with all the information required for management and disseminationA code to code comparison regarding a monopole scattering by sphere has been completed and distributed and the specification of the common simulation for NACA 0012 test arrangement has been issued;

numerical simulations by all partners were carried out.

- **Management Issues**

This AG is planned to run for three years. The kick-off meeting was held at ONERA Lille, France in October 2019.



- **Results/benefits**

The action group started its activities on 1st of October 2019. All the foreseen wind tunnel test campaigns are in a preparation phase. The geometry of the ONERA wind tunnel test was shared and all the partners involved in the numerical activities have started some pre-test computations.

- **HC/AG-25 membership**

Member	Organisation	e-mail
R. Boisard (Chair)	ONERA	ronan.boisard@onera.fr
Q. Gallas	ONERA	quentin.gallas@onera.fr
Le Pape	ONERA	Arnaud.Lepape@onera.fr
Visingardi	CIRA	A.Visingardi@cira.it
Gardner	DLR	Tony.Gardner@dlr.de
Schwarz	DLR	Thorsten.Schwarz@dlr.de
Raffel	DLR	markus.raffel@dlr.de
Riziotis	NTUA	vasilis@fluid.mech.ntua.gr
Voutsinas	NTUA	spyros@fluid.mech.ntua.gr
Zanotti	POLIMI	alex.zanotti@polimi.it
Gibertini	POLIMI	giuseppe.gibertini@polimi.it
Barakos	UoG	George.Barakos@glasgow.ac.uk
Green	UoG	Richard.Green@glasgow.ac.uk
Kessler	IAG	kessler@iag.uni-stuttgart.de

- **Resources**

Person month resources were confirmed during the kick-off meeting and have been split tentatively in years. The table below provides these numbers and the final numbers for 2019.

Resources		Year				Total
		2019	2020	2021	2022	
Person-months	Actual/	8,3	0,0	0,0	0,0	8,3
	Planned	6,8	30,3	40,0	26,1	103,2
Other costs (in	Actual/	0,0	0,0	0,0	0,0	0,0
	Planned	9,4	64,5	43,0	28,1	145,0

ANNEX 4

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. Especially the integration of new functionalities is the key to fur ther enhance the performance of materials. Structural research is devoted to computational mechanics, loads and design methodology. Research on structural dynamics involves vibrations, response to shock and impact loading, aeroelasticity, acoustic response and adaptive vibration suppression.

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

GARTEUR

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. Past works are devoted to the following topics:

- Fatigue and damage tolerance assessment of hybrid structures;
- Damage repair in composite and metal structures.

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. The technical work in the Actions groups has been completed and the final reports are currently being prepared.

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

Although the specific topics vary over the years, the scientific basis remains largely unchanged. The work is looked upon as an upstream research intended to discover valuable areas on future activities.

Management

In 2019, a physical meeting of the GOR SM took place from May 13-14 at the ZAL in Hamburg. Five members and four IPoC's attended the meeting. Beside that exchange has taken place through bilateral meetings and telephone conferences. For the coming periods, Florence Roudolff (ONERA) will take over the chair of GoR SM and Bert Thuis (NLR) the vice chair. The measures taken last year to revitalize the Structures and Materials group were confirmed. Action Groups should be finalized quickly, preferably on the basis of the available results. Furthermore, the focus should be on the initiation of one Action Group. The greatest interest of the members is still dedicated on the topic of Additive Manufacturing, which is currently being addressed in the SM/EG 43.

Dissemination of GARTEUR activities and results

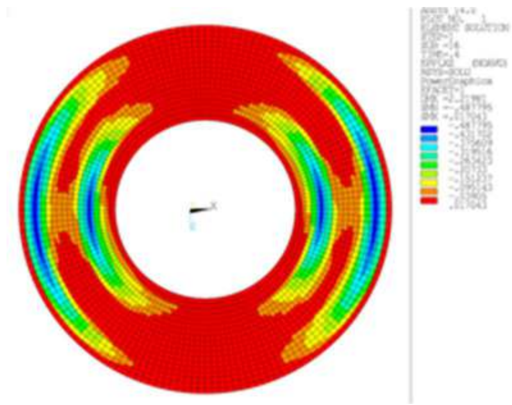
No new publications were published in the past reporting period.

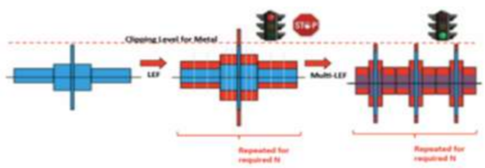
Reports issued

No new reports have been issued in 2019. The final reports for SM/AG-34 and SM/AG-35 are currently in preparation and will be issued in the next reporting period.

Status of Action Groups and Exploratory Groups

Two action groups and one exploratory group were formally active in 2019. Both action groups have finished their technical activities and are involved in writing the final report. Unfortunately, the reports in the Action Groups could not be completed as expected. Part of the reason for this is that the active work dates back some time ago and the corresponding people are no longer available from the partners involved. There are also limited resources available to carry out the work at the organizations involved. However, the Action Group Chairs strive to complete the reports.

SM/AG-34	Damage repair in composite and metal structures
	The objective of the group is the definition of effective repair techniques both for civil and military aircraft structures through the development of numerical/experimental methodologies. This will lead to minimized down-time of the aircraft for repair operation, minimized costs for repair, reduced certification costs and time for certification and will promote the repair of components instead of their substitution. The technical activities of this group have finished and the final report is currently under preparation. The chair is Dr. A. Riccio

SM/AG-35	Fatigue and Damage Tolerance Assessment of Hybrid Structures
	The objective of the group is to validate the basic assumptions for any applied spectrum manipulation techniques for fatigue test of hybrid structures, to exanimate the capabilities and benefits of a probabilistic approach, to determine the optimum way to account for thermal loads in a non-thermo test set-up with the goal to find a joint ‘best practice’ approach for testing of hybrid airframe structural components. The technical activities of this group have finished and the final report is currently under preparation. The chair is J. Laméris

SM/EG-43	Development of additive layer manufacturing for aerospace applications
	The objective of the exploratory group is to investigate the influence of powder quality on the properties of AM materials and components, to study the differences between materials and components made with e-beam AM and laser beam AM and to examine the Influence of different machine parameters for laser beam AM Material. The chair is L. 't Hoen

Rolling plans

Cat	Topic	2014	2015	2016	2017	2018	2019	2020
SM/AG 34	Damage repair in composite and metal							
SM/AG 35	Fatigue and damage tolerance assessment of hybrid structure							
SM/EG 43	Additive Layer Manufacturing							
	Active Extended Stopped Inactive							

GoR membership

Chairperson		
Peter Wierach	DLR	Germany

Members		
Domenico Tescione	CIRA	Italy
Aniello Riccio	SUN	Italy
Javier San Millan	INTA	Spain
Thomas Ireman	SAAB	Sweden
Florence Roudloff	ONERA	France
Bert Thuis	NLR	The Netherlands

Industrial Points of Contact		
Roland Lang	Airbus Defence & Space	Germany
Angel Barrio	Airbus Defence & Space	Spain
Mathias Jessrang	Airbus Operations	Germany
Hans Ansell	SAAB	Sweden
Robin Olsson	RISE/Swerea SICOMP	Sweden
Andrew Foreman	QinetiQ	United Kingdom

Table of participating organisations

	AG-34	AG-35	EG-43
Research Establishments			
CIRA	□		□
DLR		□	□
FOI	□	□	
INTA	□		
NLR	□	■	■
ONERA			□
CNR	□		
Industry			
Airbus			□
Fokker		□	
GKN			□
Leonardo Company	□		
RISE/Swerea SICOMP			

QinetiQ	☐		
SAAB	☐	☐	
Academic Institutions			
Imperial College	☐		☐
UCL University of Campania	■		☐
Lulea University of Technology	☐		☐
Norwegian University of Science and Technology NTNU	☐		☐

☐ Member ■ Chair

Total yearly costs of AG research programmes

	2012	2013	2014	2015	2016	2017	2018	2019
Man-month	7	60,5	61	10	10	-	-	-
Other costs (k€)	2	65	61	35	35	-	-	-

Action Group Reports

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

SM/AG-34: Damage Repair with Composites

Action Group Chairman: Aniello Riccio (aniello.riccio@unina2.it)

Background

Composites are much more prone to be damaged in service than metals, for example, by mechanical impact. Reparability of such damage is an important consideration in the selection of composites for aircraft applications.

In addition, metal structures can be repaired by using composite patches with great potential benefits such as costs reduction and time saving.

Repair techniques can be considered applicable to a wide range of structures both metallic and composites (laminates or sandwich).

The repair scheme used for structural restoration should be the simplest and least intrusive that can restore structural stiffness and strain capability to the required level and be implemented in the repair environment, without compromising other functions of the component or structure.

It is usually necessary to restore the capability of the structure to withstand the ultimate loads of the design and to maintain this capability (or some high percentage of it) for the full service life.

Important functions that must be restored include: aerodynamic shape, balance, clearance of moving parts and resistance to lightning strike. The requirement in military to restore the stealth properties of the component may also have to be considered and may influence the type of repair chosen.

The growing use of composite structures but also the need to reduce costs (both for metals and composites) have lead to an increasing interest in repair and especially in repair with composites and its potential applications.

However, uncertainties remain in the behavior of repaired structures that generally lead aircraft manufacturers to perform repairs only in secondary structures and to prefer bolted repair (mechanical fastened repair) over bonded repair (adhesively bonded repair) limiting the use of bonding only to moderate-size damage.

Programme/Objectives

Objectives

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

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

This objective addresses the following issue:

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

The activities have been split in Work Packages:

WP 1 REPAIR CRITERIA (WHEN UNDERTAKING REPAIR)

task 1.1) Methodologies for the assessment of residual strength in damaged composite components to decide when repair has to be undertaken

task 1.2) Crack growth analysis (static and fatigue);

WP 2 DESIGN OF PATCHES AND REPAIR STRATEGIES

WP 3 ANALYSIS OF THE REPAIR

WP 4 MANUFACTURING AND TEST

task 4.1) Manufacturing and repair procedure issues;

task 4.2) Experimental tests

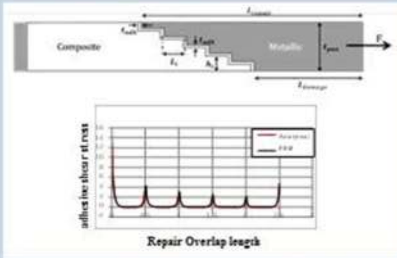
WP 5 EFFECTIVE REPAIR METHODS

task 5.1) Optimization of the patching efficiency;

task 5.2) Certification issues;

task 5.3) Technologies for repair;

task 5.4) Definition of guidelines for an effective repair of both civil and military aircraft structures.



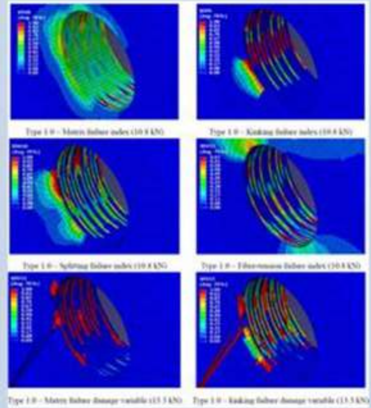
Development of an Analytical tool for Repair Design

Expected Results

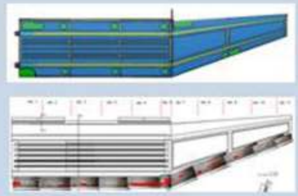
The effective outcomes can be summarized in:

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

A number of benchmarks have been selected for models validation.



Numerical Analysis - progressive Damage in composite Joint



Repair of an UAV wing

GARTEUR

SM/AG-34 Damage Repair with Composites	
Monitoring Responsable:	D. Tescione CIRA
Chairman:	Dr. A. Riccio UCL

- **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.

<u>WP 1 Repair criteria (when undertaking repair)</u>

- 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).

<u>WP 2 Design of patches and repair strategies</u>

<u>WP 3 Analysis of the repair</u>

<u>WP 4 Manufacturing and tests</u>

- Task 4.1: Manufacturing and repair procedure issues;
- Task 4.2: Experimental tests.

<u>WP 5 Effective repair methods</u>

- 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 2019

- The results of the partners were briefly presented in the last reporting period
- In the current reporting period, the aim was to compile the final report based on the results achieved
- Due to the high number of partners and the recent active work phase, the report could not be completed in the current reporting period.
- The report is expected to be finalized in the coming reporting period.

Expected results/benefits

The effective outcomes can be summarised in:

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

- **SM/AG-34 membership**

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

- Resources

Resources		Year						Total 12-16
		2012	2013	2014	2015	2016	2017	
Person-months	Act./ Plan.	-	50/36	50/30	/0	/0	/0	100/66
Other costs (in K€)	Act./ Plan.	-	49/32	20/0	/0	/0	/0	69/32

- Progress/Completion of milestone

Work package	Planned		Actual
	Initially (end of …)	Currently (updated)	
WP1 Report	Oct 2014	Oct 2014	Oct 2014
WP2 Report	Apr 2016	Apr 2017	Apr 2020
WP3 Report	Apr 2016	Apr 2017	Apr 2020
WP4 Report	Apr 2016	Apr 2017	Apr 2020
WP5 Report	Oct 2016	Oct 2017	Oct 2020
Final Report	Oct 2016	Oct 2017	Oct 2020

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

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

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

Background

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

1. Composite structure is sensitive to environmental conditions, metal parts usually are not. If it is decided not to perform fatigue- or residual strength tests under these conditions, which aspects should be taken into account via environmental factors on the applied loads?
2. Material scatter for composites is much larger than for metals; this is usually covered by a combination of a life factor and a load enhancement factor. However, to avoid non-linear behaviour of test set-up and too high stress levels in the metal parts a maximum overall load increase should be respected.
3. In general, damage growth in composite materials is most sensitive for compression-compression cycles, where metal fatigue initiation and crack growth are more sensitive to tension-compression and tension-tension cycles. A generic process for a load spectrum reduction technique covering both aspects should be discussed.
4. Spectrum truncation levels must be different for metals and composites. Where composites experience high damage from high peak loads, metals will experience crack retardation after application of a severe load condition.

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

Programme/Objectives

Objectives
The main objectives are listed below:

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

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

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

Phase 1 Benchmark definition
Phase 2 Spectrum development
Phase 3 Validation of assumptions

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

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

Phase 1 Identification of the thermal stress condition
Phase 2 Impact on fatigue life
Phase 3 Testing

Results

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

The second progress meeting was held at DLR on 19-05-2014 in Cologne and the third progress meeting was at Fokker Aerostructures at Papendrecht on 12-11-2014. SAAB hosted the fourth progress meeting on 22-09-2015 in Lynkoping. In June 2016 the fifth progress meeting was held at the NLR premises in Amsterdam. The next project meeting is planned for Jan/Feb 2017

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. The first part of the work of Fokker/NLR on 3 test approaches (application of probabilistic analyses in combination with virtual testing techniques) has been completed and reporting is almost completed. The second part concerns validation by testing and is planned for 2017

Task 2: Probabilistic approach
The DLR contribution on a probabilistic approach is ongoing. The work on hybrid joints (metal/composite) is in the testing phase. A PhD student is currently working on the completion of this task.

Task 3: Environmental influences
The work of FOI/SAAB on uni- and biaxial loading of bolted joints (SAAB simulation, FOI testing) has been finished except for the reporting which is planned for 2017.

GARTEUR

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

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

- Objectives

The main objectives are listed below:

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

- Main achievements

Tasks accomplished in 2019

The results of the partners were briefly presented in the last reporting period and summarized the major outcomes with respect to the determination of a test spectrum, the implementation of a probabilistic approach and the effect of environmental influences. All scientific work was completed and the last reporting period was dedicated to complete the final report. Detailed results will therefore be presented in the final report that is currently prepared. Unfortunately, the report could not be completed in the last reporting period. Low available resources and the leaving of central project staff have delayed completion. The aim is to finalize the report in the next reporting period.

- Expected results/benefits

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

- SM/AG-35 membership

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

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

- Planned Resources

Resources		Year						Total 12-16
		2012	2013	2014	2015	2016	2017	
Person-months	Act./ Plan.	1/1	10.5/11	11/11	/10	/0	/0	22.5/42.5
Other costs (in K€)	Act./ Plan.	1/2	16/30	41/41.5	/35	/0	/0	58/128

- Progress / Completion of milestone

Work task	Planned		Actual
	Initially (end of...)	Currently (updated)	
Task 1	April 2015	Dec 2017	Dec 2017
Task 2	June 2015	Dec 2017	Dec 2017
Task 3	June 2015	Dec 2017	Dec 2017
Report	October 2015	Dec 2017	Dec 2020

SM/EG-43 Development of ALM technologies for aerospace applications	
Monitoring Responsable:	H.P.J. de Vries NLR
Chairman:	L. ‘t Hoen NLR

- **Objectives**

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

- **Benefits**

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

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

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

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

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

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

- **Progress**

As stated in the last annual report the GoR SM continues to prioritize the topic. The EG was started in 2014. Since 2016 there has been little activity among interested partners. The topic was taken up again in 2018/19 and is now to be transferred to an Action Group. The content was further prioritized and detailed in 2019 with the expectation that an action group can be initiated in 2020.

- **EG membership**

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

GARTEUR GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

GARTEUR Organisation 2019

GARTEUR Chair Country 2018-2019: Spain
Council Chair: Mr Bartolome Marques, Spain

XC Chair: Mr. Francisco Muñoz, Spain
Secretary: Mr. Jose Garcia, Spain

Function	France	Germany	Italy	Netherlands	Spain	Sweden	United Kingdom
Head of Delegation	J. L'Ebraly	J. Bode	G. De Matteis	C. Mekes	B. Marques	A. Blom	P. Griffiths
XC Member	O. Vasseur	-	L. Paparone	K. Wijnberg	F. Muñoz Sanz	E. Bernhardsdotter	S. Gates
Other Members of Delegation	P. Beaumier	H. Hemmer M. Fischer	-	C. Beers	J.F. Reyes-Sánchez	R. Stridh N. Tooloutalaie	S. Weeks S. Pendry M. Scott

GROUPS OF RESPONSABLES									
Aerodynamics (AD)		**Aviation Security (AS)**		**Flight Mechanics, Systems & Integration (FM)**		**Helicopters (HC)**		**Structures & Materials (SM)**	
GoR AD members		**GoR AS members**		**GoR FM members**		**GoR HC members**		**GoR SM members**	
F. Monge Gómez	ES chair 2018-19	**A. Vozella**	IT chair 2017-18	**M. Hagström**	SE chair 2017	**K. Pahlke**	DE chair 2019-20	**P. Wierach**	DE chair 2016-17
H. van der Ven	NL chair 2016-17	V. Wiels	FR chair 2014-16	W. Rouwhorst	NL	M. White	UK chair 2015-16	T. Ireman	SE chair 2011-13
E. Coustols	FR	I. Ehrenpfordt	DE	B. Korn	DE	L. Notarnicola	IT chair 2013-14	D. Tescione	IT
G. Mingione	IT	B. Eberle	DE	L. Verde	IT	J. Hakkaart	NL	J. Sanmilan	ES
K. Richter	DE vice-chair 2018-19	F. Muñoz Sanz	ES	P. Mouyon	FR	A. Antifora	IT	J. Schön	SE
P. Weinerfelt	SE	A. Eriksson	SE	TBC	SP	R. Heger	DE	A. Riccio	IT (Associated member)
M. Tormalm	SE	R. Wiegers	NL			F. X. Filias	FR	B. Thuis	NL
						R.-H. Markiewicz	UK	F. Roudolff	FR
						M. Arnaud Le Pape	FR		
Industrial Points of Contacts		**Industrial Points of Contacts**		**Industrial Points of Contacts**		**Industrial Points of Contacts**		**Industrial Points of Contacts**	
T. Berens	DE			E. Cortet	FR			H. Ansell	SE
N. Ceresola	IT	AS IPoCs will be included very soon		L. Goerig	FR	HC IPoCs included above		A. Barrio Cardaba	ES
M. Mallet	FR			M. Hanel	DE			L. Hootsmans	NL
D. Pagan	FR			TBC	SE			R. Lang	DE
L. P. Ruiz-Calavera	ES							C. Petiot	FR
B. Stefes	DE							A. Foreman	UK
								M. Jessrang	DE
								R. Olsson	SE
								M. Riccio	IT

For further information about GARTEUR please contact:
secretariat@garteur.org or go to **www.garteur.org**