Contract Number AST4-CT-2005-516074

GOAHEAD

Generation of Advanced Helicopter Experimental Aerodynamic Database for CFD code validation

Specific Targeted Research Project
Priority 4: Aeronautics and Space

Publishable Final Activity Report

Document Reference	GOAHEAD / WP5 / DLR / D5.1.4 PFA / A

Period covered: From 1st Jul. 2008 to 31th Dec. 2009	Date of Preparation: 10th Feb. 2010
Start date of project: 1st July 05	Duration: 48 months + 6 months extension
Project coordinator name: Dr.-Ing. Thorsten Schwarz Project coordinator organisation name: DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V.	Revision A

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1 Overview

Today leading edge CFD (computational fluid dynamics) software systems are available which are capable of predicting the viscous flow around main rotor-fuselage configurations or even complete helicopters. The greatest shortcoming for qualifying these methods as design tools in the industrial design process was the lack of detailed experimental validation data for the aerodynamics of complete helicopters.

In order to establish a CFD validation database for helicopters, the GOAHEAD research project (Generation of Advanced Helicopter Experimental Aerodynamic Database for CFD code validation) was formed by 15 partners. Within the project a wind tunnel model of a complete helicopter consisting of fuselage, main and tail rotors was built and tested in the DNW-LLF wind tunnel. CFD codes were applied in a blind test phase before the experiment and a post test phase after the experiment.

The experimental database in combination with the validated CFD models will allow new helicopter designs to be assessed in a considerably reduced time span without the need for large corrections after flight testing.

The GOAHEAD research project was conducted under the Integrating and Strengthening the European Research Area Programme of the 6th Framework, priority theme 4 “Aeronautics and Space”. The GOAHEAD project had a duration of four and a half years (July, 1st, 2005 – December 31th, 2009). The total budget of the project is calculated to be 5.0 Million Euro including wind tunnel costs.

2 Project partners

The project has 15 partners including four European helicopter manufacturers.

Legal Name	Short Name	Ctry
Deutsches Zentrum für Luft- und Raumfahrt e.V.	DLR	DE
Office National d’Etudes et de Recherches Aérospatiale	ONERA	F
EUROCOPTER Deutschland G.m.b.H.	ECD	DE
EUROCOPTER S.A.	EC SAS	F
Agusta S.p.A.	Agusta	I
Westland Helicopters	WHL	UK
Centro Italiano Ricerche Aerospaziali S.C.P.A.	CIRA	I
Foundation for Research and Technology	FORTH	GR
Stichting Nationaal Lucht-en Ruimtevaartlaboratorium	NLR	NL
University of Glasgow	UG	UK
Cranfield University	CU	UK
Politecnico di Milano	POLIMI	I

Institut für Aerodynamik und Gasdynamik der Universität Stuttgart	USTUTT-IAG	DE
Aktiv Sensor GmbH	AS	DE
University of Liverpool	ULIV	UK

The GOAHEAD project is co-ordinated by DLR. The contact details of the coordinator are as follows

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3 Web page

A Web-page for the GOAHEAD-project is available at
http://www.dlr.de/as/en/desktopdefault.aspx/tabid-3384/5247_read-7664/

4 Background and Objectives:

During the last ten years considerable progress has been made in developing aerodynamic prediction capabilities for isolated helicopter components such as an isolated main rotor or an isolated fuselage. Today leading edge CFD software systems are available, and others are being developed, which are capable of predicting the viscous flow around main rotor-fuselage configurations or even complete helicopters. The greatest shortcoming for qualifying these methods as design tools in the industrial design process is the lack of detailed experimental validation data for the aerodynamics of complete helicopters. To overcome these shortcomings, the GOAHEAD-project is carried out with the following main objectives:

1. To enhance the aerodynamic prediction capability of Europe’s helicopter industry with respect to complete helicopter configurations.
2. To create an experimental database for the validation of 3D CFD and comprehensive aeromechanics methods for the prediction of unsteady viscous flows including rotor dynamics for complete helicopter configurations, i.e. main rotor

– fuselage – tail rotor configurations with emphasis on viscous phenomena like flow separation and transition from laminar to turbulent flow.

3. To evaluate and validate Europe's most advanced solvers of the unsteady Reynolds-averaged Navier-Stokes (URANS) equations for the prediction of viscous flow around complete helicopters including fluid-structure-coupling.
4. To establish best practice guidelines for the numerical simulation of the viscous flow around helicopter configurations.

All partners have a profound knowledge of helicopter experimental testing and CFD modelling, thus creating a unique European added value. None of the single partners or even nations could today incur the costs and the effort required to tackle this problem on their own. Only a joint approach as proposed in GOAHEAD brings the critical mass of expertise and funding together that will allow major progress.

5 Wind tunnel Model

The wind tunnel experiment planned within GOAHEAD concerned itself with the Mach scaled model of a modern transport helicopter consisting of the main rotor, the fuselage (including all control surfaces) and the tail rotor. The experimental set-up was tailored to serve the needs of the aerodynamic validation for methods based on the unsteady Reynolds-averaged Navier-Stokes equations. In order to keep the costs of the experimental campaign as low as possible, existing components of previous wind tunnel experiments were reused, i.e. the fuselage of a NH90, the instrumented 7AD main rotor and the instrumented BO105 tail rotor. The test configuration was therefore not a scaled model for an existing helicopter. This is of no importance because the aim is to produce data for CFD validation for any realistic configuration. The model has been assembled and equipped with measurement equipment within the GOAHEAD project.

6 Work performed

The project was organized in five work packages and 17 tasks as shown in Figure 1. Work package 1 dealt with the final definition of technical project details, like the final test matrix for wind tunnel testing, the final matrix of CFD test cases and common formats for data exchange. In Work package 2 CFD methods will be applied and assessed, while in work package 3 the preparation and conduct of the wind tunnel experiments including direct data post processing will be carried out. The detailed data analysis and evaluation will be done in work package 4. The project management will be done in work package 5 which will include the exploitation and Technology Implementation Plans (TIP).

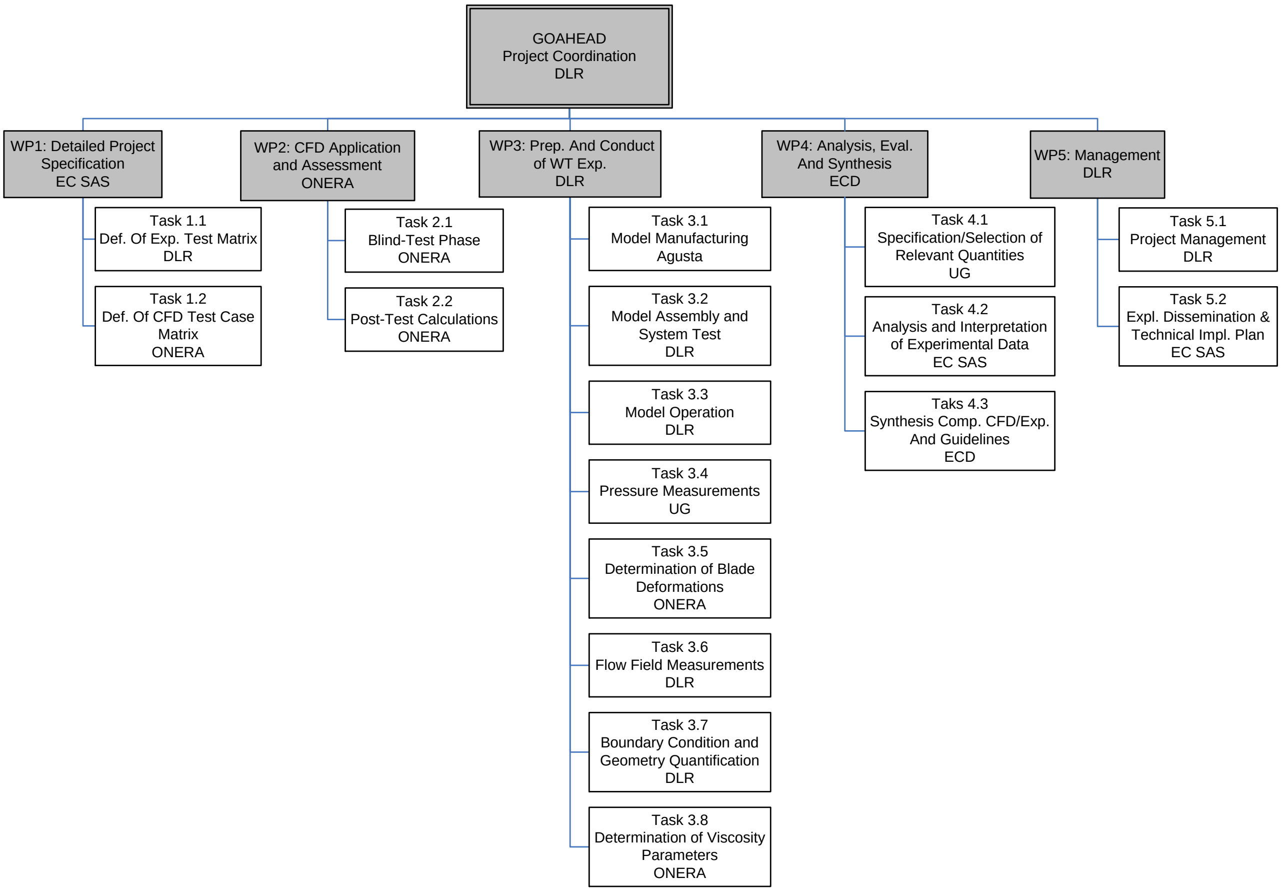


Figure 1 Organisation chart of GOAHEAD

6.1 Work package 1: Detailed Project Specification

At the beginning of the project the experimental test matrix was defined in work package 1. It was agreed to choose five relevant flight conditions only, but to plan a very intensive experimental analysis of those test cases. The selected test cases are: low speed-pitch up (TC2), cruise flight (TC3), tail-shake (TC34), dynamic stall (TC5) and high speed forward flight (TC6). After detailed analyis of the flight parameters it was decided to use identical conditions for TC4 and TC4. The rotor settings were pre-computed with the comprehensive rotor code HOST in order to check if the wind tunnel model can operate at the required power consumption and rotor settings. In addition the isolated fuselage was included for the same flight conditions like the complete helicopter in order to analyse the influence of the rotors.

Configuration	Test case	Test case ID	Inflow Mach number	Main rotor, tip Mach number	tail rotor, tip Mach number
isolated	low speed,	TC 1a	0.059	-	-

fuselage	pitch up				
	cruise/tail shake	TC 1b	0.204	-	-
	dynamic stall	TC 1c	0.259	-	-
complete helicopter	low speed, pitch up	TC2	0.059	0.617	0.563
	cruise/tail shake	TC3/4	0.204	0.617	0.563
	dynamic stall	TC5	0.259	0.617	0.563
	high speed	TC6	0.28	0.617	0.563

Table 1: selected Test cases for GOAHEAD

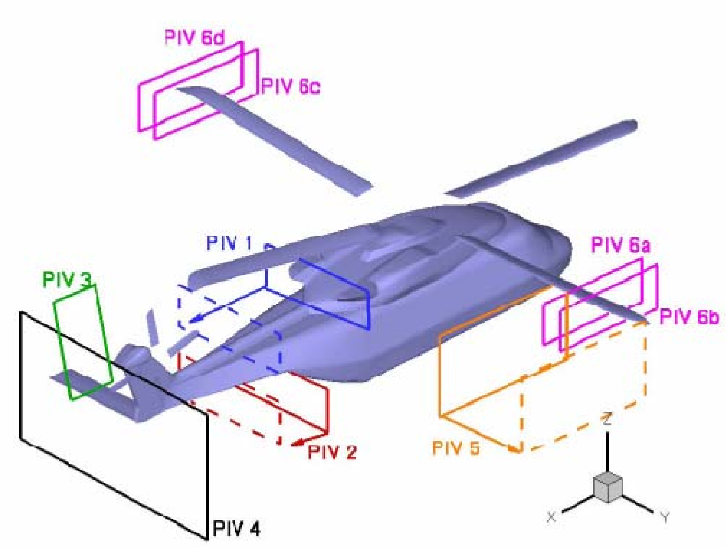


Figure 2: Locations of PIV-planes defined in WP1 (Particle Image Velocimetry)

An important aspect of the work in WP1 was the selection of the measurement techniques and to propose the placement of sensors and PIV-planes (Particle Image Velocimetry), see Figure 2.

6.2 Work package 2: CFD application and assessment

The CFD activities were performed in work package 2. Existing CFD codes were applied for complete helicopter configurations in a blind-test exercise. The test cases chosen in WP1 were distributed among the partners, such that all flight conditions were covered by a time-accurate computation of the complete helicopter with state-of-the-art methods. The blind test phase was finished in February 2008. The results were forwarded to WP4 for a later comparison with experimental data.

After the wind tunnel experiment was finished the partners started the post test computations. The grids and the computational set-up were improved based on the experiences of the blind test phase. The postprocessed CFD-results of the post test phase were forwarded to WP4 for comparison with experimental data.

The following table summarizes the investigated test cases and their distribution to the individual partners:

	test cases						
	isolated fuselage			complete helicopter			
Partner	TC1a	TC1b	TC1c	TC2 Pitch-Up	TC3/4 Cruise/Tail Shake	TC5 dynamic stall	TC6 very high speed
DLR	✓	✓	✓		✓	✓	
ONERA					✓		✓
ECD	✓	✓				✓	
EC SAS				✓	✓		
AGUSTA	no activity in WP 2						
WHL					✓		
CIRA	no activity in WP 2						
FORTH							✓
NLR	✓	✓			✓		
UG	no activity in WP 2						
CU		✓	✓				
POLIMI					✓		
USTUTT-IAG				✓			
AS	no activity in WP 2						
ULIV		✓	✓		✓	✓	

Table 2: CFD computations within GOAHEAD

Two examples of the work in WP2 are shown in Figure 3. On the left side the automatically created Cartesian overset background mesh by ONERA is shown. On the right University of Stuttgart has visualized the flow field for the low speed/pitch-up case.

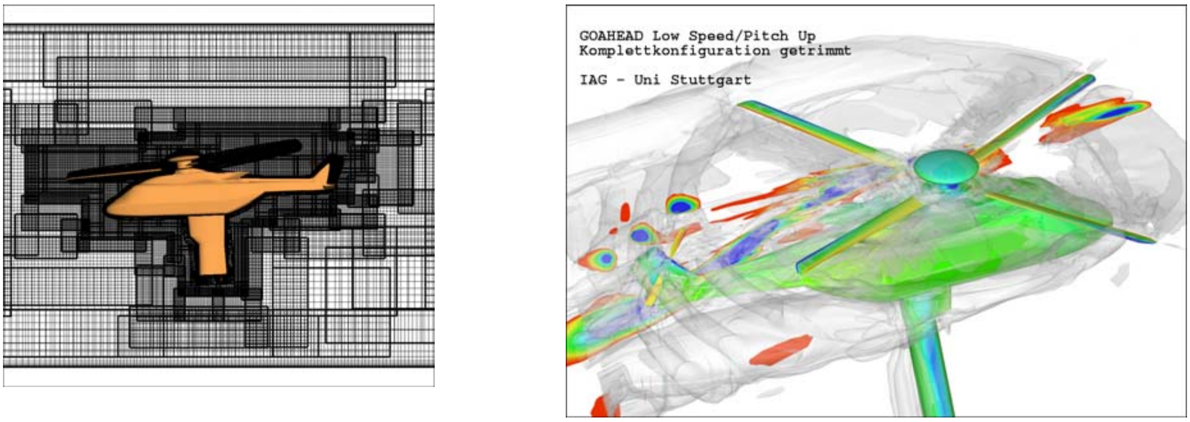


Figure 3: some results of WP2, left: automatic Cartesian background mesh applied by ONERA, right: flow field for complete helicopter in low speed/pitch up condition.

6.3 Work package 3: Preparation and Conduct of Wind Tunnel Experiment

Much effort was spent in WP3 to manufacture and assemble the wind tunnel model. The fuselage shell for a scaled model of the NH90 has been modified by Agusta for the integration of the pressure sensors and of the tail rotor whereas the 7ad-rotor blades have been overhauled by ONERA. After delivery of the fuselage and the main rotor DLR immediately started to assemble the model and to install the measurement equipment. The fuselage was connected to the modular wind tunnel model of DLR and the BO105 tail rotor was integrated into the tail unit. The displays for the rotor control room were coded. The complete model set-up was checked for correct operation. For the wind tunnel experiment the model was assembled in the test hall of DNW-LLF and all systems and measurement techniques were checked for correct operation.

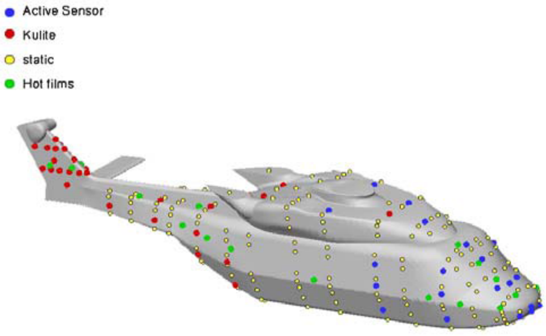
In parallel to the set-up of the model the measurement equipment was prepared: DLR, DNW, GU prepared the recording of the steady and unsteady pressure signals, ONERA and CU prepared the hot films on the fuselage and main rotor, DLR, DNW and ONERA prepared the measurement of blade deflection with SPA (strain pattern analysis) and SPR (stereo pattern recognition), CIRA and DLR prepared PIV (particle image velocimetry), PoliMi set up the hot wire inflow measurements, DLR prepared micro tuft flow visualization and infrared photography.

On March 26th the model was moved into the test section Wind tunnel experiments were performed during 16 days from March 28th to April 14th. The model was operated by DLR while the other WP3 partners were responsible for the measurement equipment. The well prepared wind tunnel campaign allowed to conduct all planned measurements at all test conditions. The measurement comprised global forces of the main rotor and the fuselage, steady and unsteady pressures, transition positions, stream lines, position of flow separation, velocity fields in the wake, vortex trajectories and elastic deformations of the main rotor blades. In addition velocity profiles and the turbulent kinetic energy were measured at the inflow plane.

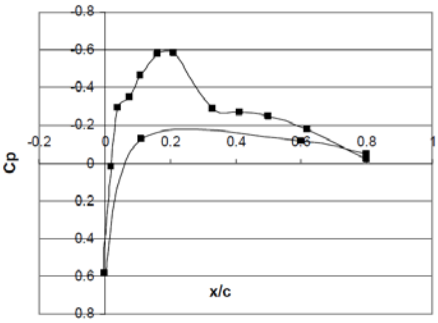
After the experiment the data were postprocessed by the partners and sent to UG for integration into the data base.

Some selected results of WP3 are displayed in Figure 4.

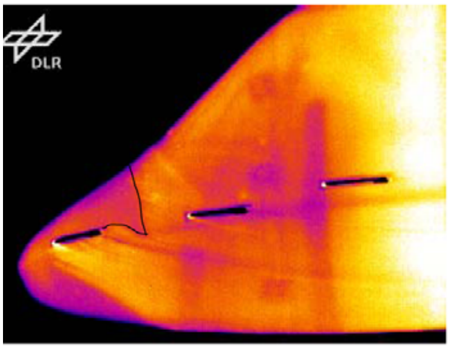
GOAHEAD-wind tunnel model in DNW-LLF



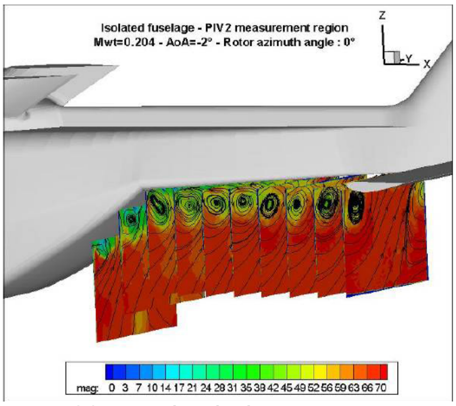
Distribution of unsteady pressure sensors (ActiveSensor, Kulites), steady pressure sensors and hot films on the fuselage



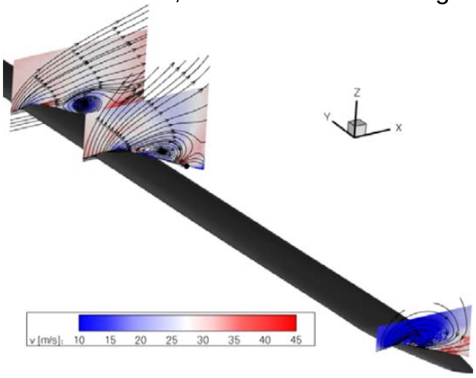
pressure distribution ar r/R=0.825%, Ψ=90°



infrared image of fuselage, regions with laminar flow at the nose are violet, turbulent flow is orange



PIV-image of flow at back-dor



PIV image of dynamic stall

Figure 4: some results of work package 3

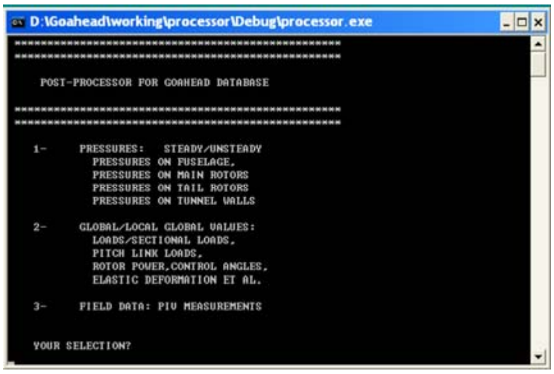
6.4 Work Package 4: Analysis, Evaluation and Synthesis

In work package 4 the experimental data were gathered by the University of Glasgow and stored in a data base. In total more than 400 GB experimental data are archived in the data base. UG also developed a data post processing tool which allows an easy access to the data base. A comprehensive documentation for the data base was written by the partners involved in the measurements. By including several measurements in the interpretation of data conclusions were drawn on transition, fluid structure interaction and blade aerodynamic response.

The data base contains the following data:

- Balance loads for fuselage, main rotor, horizontal stabilizer and tail rotor
- Steady pressures fuselage (292 sensors)
- Unsteady pressure fuselage (128 Sensors), main rotor (97 sensors), tail rotor (31 sensors)
- Boundary layer data (hot films) → fuselage (38 sensors), main rotor (8 sensors)
- Blade deformation with SPA (strain pattern analysis) and SPR (stereo pattern analysis)
- Flow visualization on fuselage (micro tufts)
- Flow velocities with PIV (particle image velocimitry) (7 regions, some of them with varying streamwise positions, e.g. behind the back dor)
- Inflow velocities and turbulence (hot wire)
- transition detection by infrared photography

The partners involved in the blind and post test CFD computations compared their results with experimental data in order to assess the accuracy of the CFD solutions. Based on the findings ECD prepared guidelines for URANS application to complete helicopters.



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   POST-PROCESSOR FOR GOAHEAD DATABASE

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   1-     PRESSURES:   STEADY/UNSTEADY
            PRESSURES ON FUSELAGE,
            PRESSURES ON MAIN ROTORS
            PRESSURES ON TAIL ROTORS
            PRESSURES ON TUNNEL WALLS

   2-     GLOBAL/LOCAL GLOBAL VALUES:
            LOADS/SECTIONAL LOADS,
            PITCH LINK LOADS,
            ROTOR POWER,CONTROL ANGLES,
            ELASTIC DEFORMATION ET AL.

   3-     FIELD DATA: PIV MEASUREMENTS


   YOUR SELECTION?
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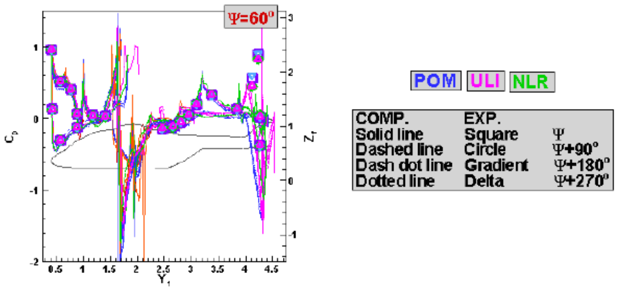
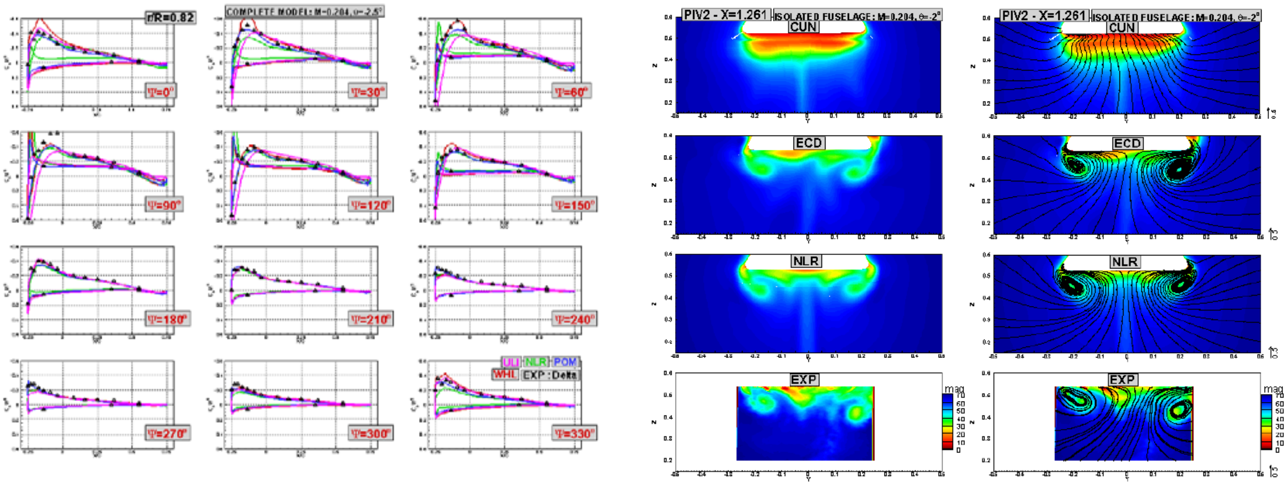
data postprocessor



pressure distribution on fuselage predicted by CFD compared to experiment



comparison of numerical and experimental results on main rotor pressure distributions

comparison of numerical and experimental flow field behind back door

Figure 5: some results of WP4

6.5 Work Package 5: Management

In WP5.1 the project co-ordinator DLR managed the project, i.e. negotiation of subcontracts, financial status, monitoring of WP1-4.

In WP5.2 a mid term report and a final report on the “Exploitation, dissemination and technology implementation plan” has been prepared.

7 Outcome of the GOAHEAD project:

Main deliverables are the deeply analyzed experimental database for the complete helicopter, the report on the evaluation of the existing CFD URANS methods for complete helicopters, the report on the post-test computations including the explanations of the deviations between the blind-test results and the experimental data and the best practice guidelines for the application of URANS methods to complete helicopters.

7.1 Outcome rated against objectives

The following was achieved compared to the objectives of GOAHEAD:

1. To enhance the aerodynamic prediction capability of Europe’s helicopter industry with respect to complete helicopter configurations.
    - All CFD-solvers applied within the project are capable to simulate the unsteady flow about complete helicopters with good accuracy for certain features. Interaction phenomena are partly captured. This is a big step

forward having in mind that the first successful RANS helicopter simulations in Europe have been published in 2002.
    - *Remark: Due to the complexity and instationarity of the flow the solution accuracy has not reached the same level like for fixed wing applications.*
    - *Remark: Further CFD developments and validation is required in order to further improve the CFD software, e.g. turbulence and transition modelling, coupling of CFD methods to structural mechanics and flight mechanics, CPU time reduction.*
2. To create an experimental database for the validation of 3D CFD and comprehensive aeromechanics methods for the prediction of unsteady viscous flows including rotor dynamics for complete helicopter configurations, i.e. main rotor – fuselage – tail rotor configurations with emphasis on viscous phenomena like flow separation and transition from laminar to turbulent flow
    - Within the GOAHEAD project a comprehensive data base with high quality data for complete helicopters has been generated.
    - Almost all data as originally planned were gathered during the experiment.
    - *Remark: a full understanding of the data base will require many more years of research and data analysis like for any other experimental data base.*
3. To evaluate and validate Europe's most advanced solvers of the unsteady Reynolds-averaged Navier-Stokes (URANS) equations for the prediction of viscous flow around complete helicopters including fluid-structure-coupling.
    - CFD solvers for helicopter industry were improved and validated for complete helicopters. Industry extended range of applications for in-house simulations.
      Remark: due to the large computational effort complete helicopter simulations will not be routinely run in near future in industry.
4. To establish best practice guidelines for the numerical simulation of the viscous flow around helicopter configurations.
    - Experience of partners obtained during GOAHEAD was gathered and documented in best practice guidelines

7.2 Impact on industry and research

The specific results were exploited as the programme proceeds. Since all European helicopter manufacturers apply CFD methods that have been and are being developed by one of the research centres or universities of the GOAHEAD consortium the validation of these URANS methods will directly improve the industrial design processes because of improved accuracy and reliability.

In detail the GOAHEAD RTD work will produce the following economic benefits

- Cost reduction for single partners in developing and validating new CFD methods
- Increase of competitiveness of helicopters produced in Europe through increased aerodynamic performance and efficiency
- Reduction of development costs, by shorter design cycles for main, tail rotors and fuselages leading to higher aerodynamic performance (e.g. by improved mast fairing, control surfaces, etc.). Less uncertainty, especially when assessing novel

vertical take off configurations in the early design phase, fewer delays in development

- Improved experimental and theoretical knowledge will also reduce development risks and ease certification.

Overall this will improve the competitiveness and economic prospects of the European helicopter manufacturers especially in the face of strong competition from the US. Higher aerodynamic performance will reduce the specific fuel consumption and so reduce pollution, this is a benefit for the community in its quest for a clean and healthy environment.

Many partners in the consortium educate and train scientists and engineers (all universities and also the research establishments). The GOAHEAD findings, basic and fundamental aerodynamic phenomena and algorithmic approaches and RTD progress will thus directly be translated into the respective technical community and into higher education.

8 Work envisaged after the end of the project

_Although the GOAHEAD-project is finished and no further funding is available the GOAHEAD-partners have agreed to publish the results of the GOAHEAD-project in a book and on a conference.

- The book will be available in autumn 2010 in the Springer series “Notes on Numerical Fluid Mechanics and Multidisciplinary Design”.
- It is planned to organize a dedicated session on GOAHEAD during the next European Rotorcraft Forum in Paris, France (September 7-9, 2010).

The experimental data base is already used within other European projects, for example in JTI GRC1. Since the data base is unique in Europe it is assumed that it will be used in many other projects.

9 Exploitable Knowledge and its Use

Exploitable Knowledge	Exploitable Product(s) or measure(s)	Sector of application	Timetable for commercial use	Patents or other IPR protection	Owner & other Partner(s) involved
Improved Understanding of helicopter flow phenomena	Training courses for students and engineers	Aeronautics, automotive industry	2009		all GOAHEAD partners
Additional experience gained through wind tunnel test for unsteady pressure sensors	Unsteady pressare sensors	Aeronautics, automotive industry, medical industry, computer industry	2008 based on WT experience the sensors were optimized		AS
Improved understanding of CFD methods because of new exp. data base	CFD solvers like FLOWer, elsA, TAU, ROSITA, HMB and others.	Fluid mechanics (aeronautics, automotive industry, etc.)	2009	Licence agreements are foreseen	all GOAHEAD partners
Validated CFD methods with improved accuracy	New designs of aircraft components	Aeronautics	2010		al GOAHEAD partners
Validated CFD methods with improved accuracy	Newly designed rotor blades and/or fuselages for helicopters	Aeronautics, especially the helicopter field	2012		ECD, EC SAS, WHL, Agusta
Improved understanding and enlarged experience in large scale wind tunnel testing	Wind tunnel measurements for complex wind tunnel models	Aeronautical industry	2009, DLR will exploit experiences in forthcoming STAR (HART III) campaign		DLR, ONERA, CIRA
Improved understanding how to apply RANS solvers to complete helicopter flows	Guidelines	CFD community	2009		all GOAHEAD partners

10 Dissemination of Knowledge

Planned/ actual Dates	Type	Type of Audience	Contries addressed	Size of Audience	Partner responsible/ involved
Feb. 2007	GOAHEAD web page	Internet users	World wide	Unkown	DLR
Sep. 2007	three technical papers presented	European Rotorcraft Forum	Europe, USA, Korea, Japan	40 per paper	DLR, NLR, USTUTT-IAG
Oct. 2007	one technical paper presented	Workshop on high performance computing	Germany, citable publication	40	USTUTT-IAG
Jan. 2008	one technical paper presented	AIAA-Aerospace Meeting and Exhibition	USA, Europe, Korea, Japan	50	DLR, USTUTT-IAG,
Jun. 2008	journal publication	International Journal for Numerical Methond in Fluids	world wide	unknown	ULIV
Sept 2008	one technical papers	ERCOFTAC	Europe, USA, Korea, Japan	40	CU
Sept 2008	two technical papers	European Rotorcraft Forum	Europe, USA, Korea, Japan	40	NLR, ULIV
Oct. 2008	paper	newsletter	UK	unknown	CU
Sept 2009	Technical Papers	European Rotorcraft Forum	Europe, USA, Korea, Japan	40	DLR,
Sep 2010	Technical Papers, dedicated session for GOAHEAD	European rotorcraft forum	Europe, USA, Korea, Japan	50	DLR, ONERA, ECD, EC SAS, WHL, CIRA, FORTH, NLR, UG, CU, PoliMi, USTUTT-IAG, AS, ULIV
Nov. 2010	technical papers	book on GOAHEAD at Springer in the series “Notes on Numerical Fluid Mechanics and Multidisciplinary Design”	world wide	unknown	DLR, ONERA, ECD, EC SAS, WHL, CIRA, FORTH, NLR, UG, CU, PoliMi, USTUTT-IAG, AS, ULIV

11 Publishable Results

The GOAHEAD data base and all related documentation are restricted to the GOAHEAD partners.

A number of papers have been published in the course of GOAHEAD:

11.1 Papers published in 2007

M. Dietz, M. Kessler and E. Krämer: „Trimmed Simulation of a Complete Helicopter Configuration Using Fluid-Structure Coupling", In E. W. Nagel, D. B. Kröner, M. Resch (eds): "High Performance Computing in Science and Engineering '07: Transactions of the High Performance Computing Center, Stuttgart (HLRS) 2007", Springer- Verlag Berlin Heidelberg, 2008

K. G. Pahlke: "The GOAHEAD Project", 33rd European Rotorcraft Forum, Kazan, Russia, September 11th-13th, 2007

O.J. Boelens, G. Barakos, M. Biava, A. Brocklehurst, M. Costes, A. D'Alascio, M. Dietz, D. Drikakis, J. Ekaterinaris, I. Humby, W. Khier, B. Knutzen, J. Kok, F. LeChuiton, K. Pahlke, T. Renaud, T. Schwarz, R. Steijl, L. Sudre, H. van der Ven, L. Vigevano and B. Zhong: "The blind-test activity of the GOAHEAD project", 33rd European Rotorcraft Forum, Kazan, Russia, September 11th-13th, 2007

W. Khier, M. Dietz, T. Schwarz, S. Wagner: „Trimmed CFD Simulation of a Complete Helicopter Configuration", 33rd European Rotorcraft Forum, Kazan, Russia, September 11th-13th, 2007

M. Poinot, M. Costes: "Large and heterogeneous data handling for helicopter CFD", 8th. World Congress on Computational Mechanics (WCCM8), 5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008), Venice, Italy, June 30 – July 5, 2008

11.2 Papers published in 2008

M. Dietz, W. Khier, B. Knutzen, S. Wagner, E. Krämer: „Numerical Simulation of a Full Helicopter Configuration Using Weak Fluid-Structure Coupling", 46th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, 7-10 January 2008

R. Steijl and G. Barakos: "Sliding Mesh Algorithm for CFD Analysis of Helicopter Rotor-Fuselage Aerodynamics", AHS Specialists' Conference on Aeromechanics, San Francisco, CA, January 23 – 25, 2008

R. Steijl and G. Barakos: "Computational Analysis of Rotor-Fuselage Interactional Aerodynamics using Sliding-Plane CFD Method", 34th European Rotorcraft Forum, Liverpool, UK, September 16th-19th, 2008

R. Steijl and G. Barakos: "Sliding mesh algorithm for CFD analysis of helicopter rotor-fuselage Aerodynamics", International Journal for Numerical Methods in Fluids, Vol. 58, 2008, pp. 527-549

O.J. Boelens, H. van der Ven, J.C. Kok and B.B. Prananta: "Rotorcraft simulations using a sliding-grid approach", 34th European Rotorcraft Forum, Liverpool, UK, September 16th-19th, 2008

B. Zhong, S. K. Yadav and D. Drikakis: "Turbulent Flow Simulations Around An Airfoil At High Incidences Using URANS, DES And ILES Approaches", ERCOFTAC workshop "Direct and Large-Eddy Simulations 7" (DLES7), Trieste, Italy, September 8-10, 2008

B. Zhong, D. Drikakis, F. Le Chuiton, T. Schwarz, J Raddatz: "URANS, DES and ILES approaches for a complete helicopter fuselage flow simulations with, and without, actuator disks modelling", Capability Conmputing, Issue 12, Autumn 2008

11.3 Papers published in 2009

R. Steijl_and G.N. Barakos: "Computational Study of Helicopter Rotor-Fuselage Aerodynamic Interactions", AIAA-Journal, Vol. 47, No. 9, September 2009, pp. 2143 – 2157

M. Raffel, F. de Gregorio, W. Sheng, G. Gibertini, A. Seraudie, K. de Groot, B. van der Wall: "Generation of an advanced helicopter experimental aerodynamic database", 35th European Rotorcraft Forum, Hamburg, Germany, September 22nd - 25th, 2009

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11.4 Papers under preparation for 2010

The GOAHEAD partners plan to organize a dedicated session on GOAHEAD at the European rotorcraft forum 2010 in Paris.

Book on GOAHEAD: all partners have agreed to publish a book on GOAHEAD at the publishing company "Springer". The book will be available in autumn 2010 in the series "Notes on Numerical Fluid Mechanics and Multidisciplinary Design".