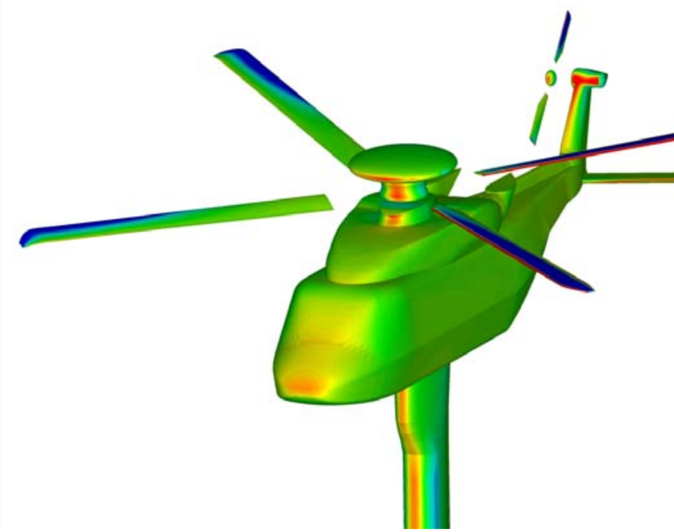

# Generation of an Advanced Helicopter Experimen Aerodynamic Database for CFD Code Validation (GOAHEAD)

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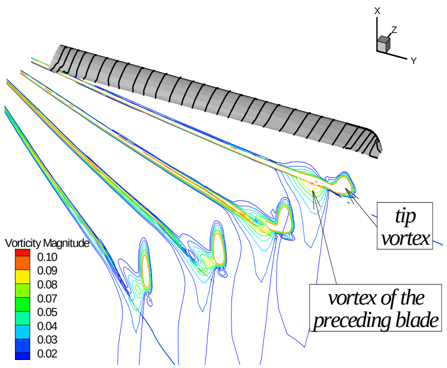
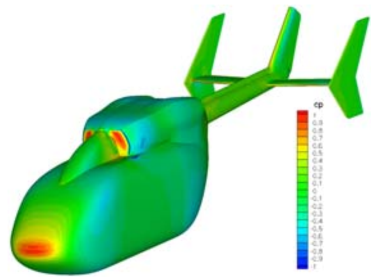
# Outline

- Motivation
- The GOAHEAD project
- Wind tunnel experiment
- CFD activities
- Conclusions

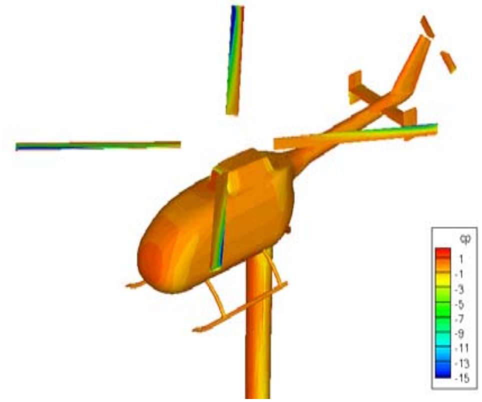
# State of the art in CFD in Europe 2005




Isolated rotors
hover/forw. flight



Isolated fuselages




Complete helicopter
first demonstration in Europe 2002

- before 2005 two RANS flow solvers have been applied to complete helicopters → elsA (ONERA) and FLOWer (DLR)
    - Demonstration of capability, not a careful validation
    - Considered was one test case only
    - Challenging because of high computational costs
- A lack of experimental validation data was observed. Previous wind tunnel experiments focussed on isolated rotors or fuselages, or complete helicopter experiments with focus on vibrations or acoustics.

⇒ set-up of the European „GOAHEAD“-Project

# Objectives of GOAHEAD

- GOAHEAD = Generation Of Advanced Helicopter Experimental Aerodynamic Database for CFD code validation
- STREP, 6th Framework Program, total budget 5M€, EU-funding 3M€

Objectives of GOAHEAD

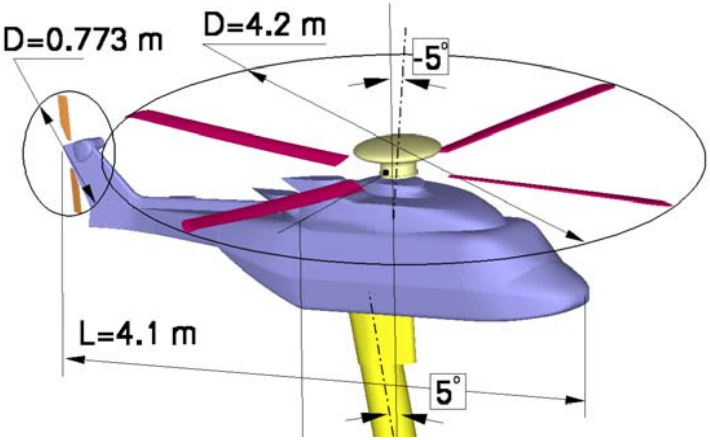
- To enhance the aerodynamic prediction capability with respect to complete helicopter configurations.
  - create an experimental database for the CFD-validation
  - evaluate and validate Europe's most advanced URANS solvers

# GOAHEAD consortium

Project leader: DLR

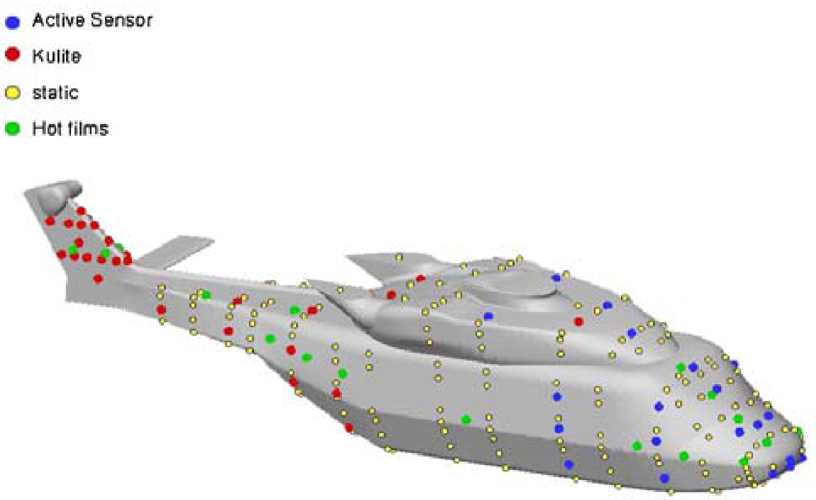
# Configuration

- Generic Mach scaled model,
  similar to modern transport helicopter
- existing components are reused, in order to put high effort into measurements,
  - fuselage: slightly modified NH90
  - instrumented 4-bl. main rotor (7AD geometry)
  - instrumented 2-bl. tail rotor (BO 105)
- main rotor diameter 4.2 m: 1/3.9 scale
- model prepared by
  Agusta (fuselage shell),
  ONERA (rotor blades),
  DLR (assembly and testing)




# Model Instrumentation

- Fuselage:
  - balances for the fuselage and the horizontal stabilizer
  - 130 unsteady pressure sensors, 292 steady transducers
  - 38 hot wires for detection of transition and flow separations
- Main rotor
  - rotor balance
  - 125 unsteady pressure sensors
  - 40 hot wires
  - 29 strain gauges for blade deformation measurements




- Tail rotor
  - 38 unsteady pressure sensors
  - 4 strain gauges for thrust measurement
  - Torque meter
- CAD data of configuration based on model scan with structured-light 3D scanner

# Wind tunnel experiment

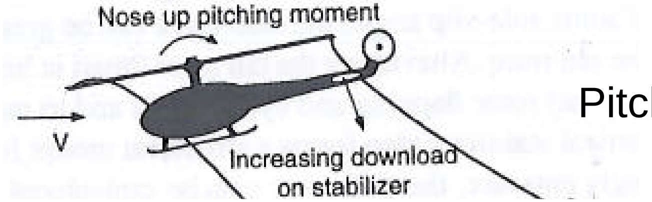
- Wind tunnel experiment in the DNW-LLF, Marknesse, The Netherlands
- Test were performed in the 6m * 8m closed test section
- Duration: 14 days from March 28th to April 14th, 2008
- Model was operated by DLR
- Seven Partners involved in measurements
- Almost all data as originally planned were gathered during the experiment.

- Challenging wind tunnel experiment
  - Model could only be tested in lab conditions before
  - Model must be operated like a real helicopter based on measured loads

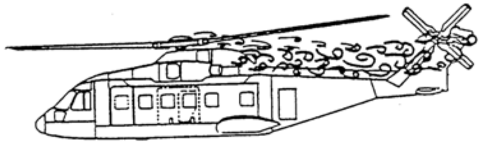
# Experimental results

Executed Test matrix

- Only four flight states were considered to allow detailed experimental analysis
    - Low speed, pitch up (M=0.059)
    - Cruise / tail shake (M=0.204)
    - Dynamic stall (M=0.259)
    - High speed (M=0.28)
- Tests with and without rotors ($\rightarrow$ isolated fuselage and complete helicopter)




Pitch-up



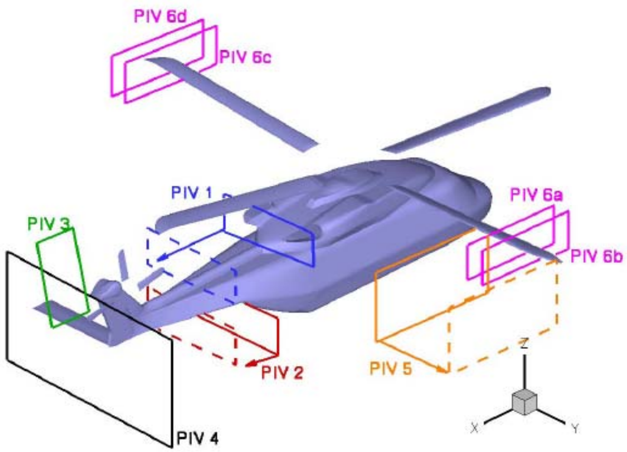
Tail shake

Experimental data base

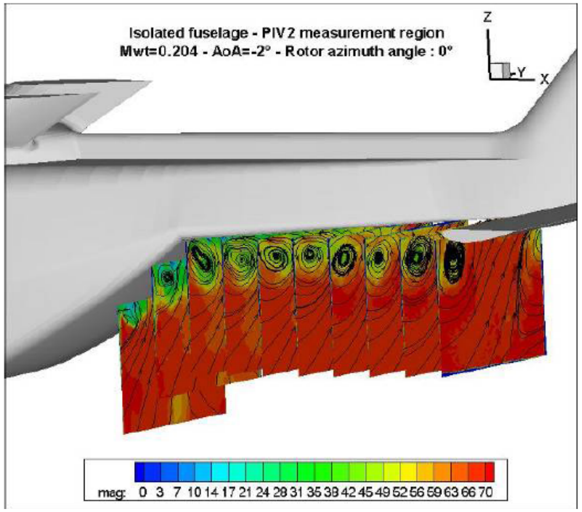
- data base with more than 400 GB data
- data postprocessor developed by Glasgow University
- comprehensive documentation available

M. Raffel et al.: “Generation of an advanced helicopter experimental aerodynamic database”, ERF 2009

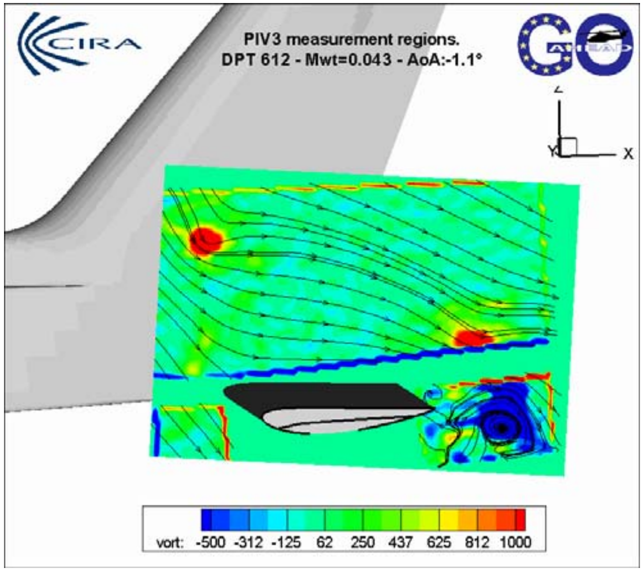
# Experimental results - PIV



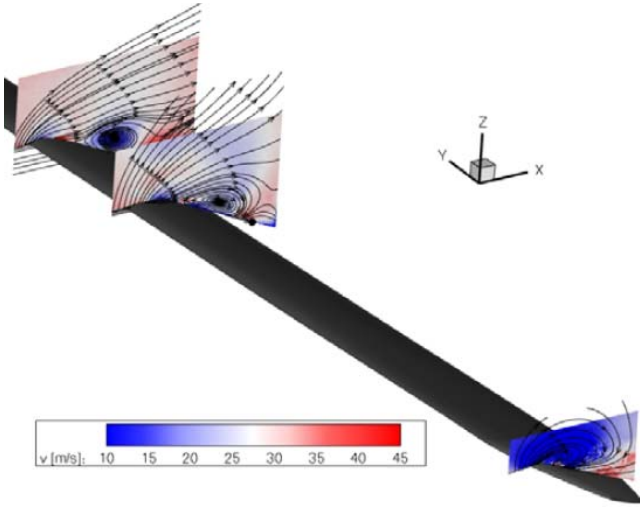

Detailed flow field analysis with particle image velocimetry (3C PIV)




Isolated fuselage, Vortices behind back door

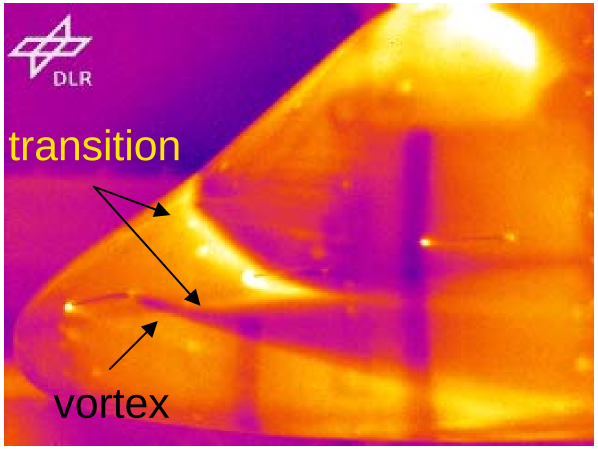


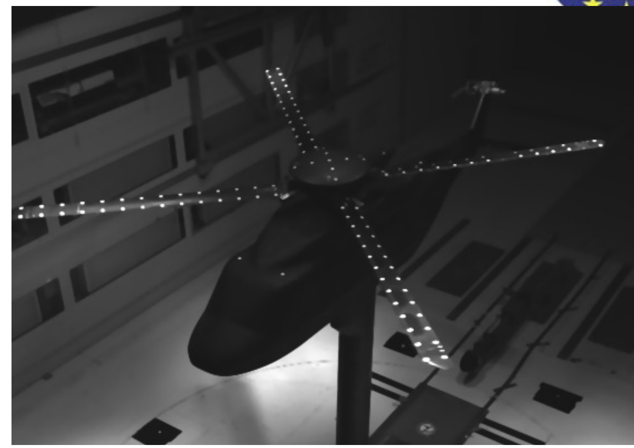

pitch up-condition

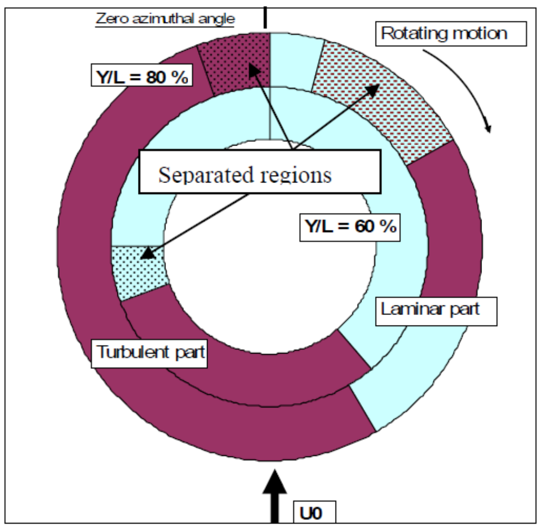


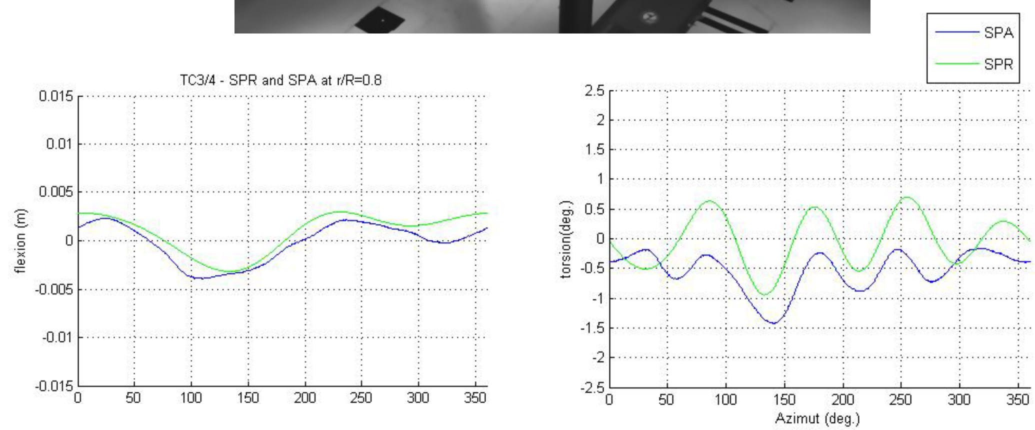

Dyn. Stall on highly loaded rotor

# Experimental results





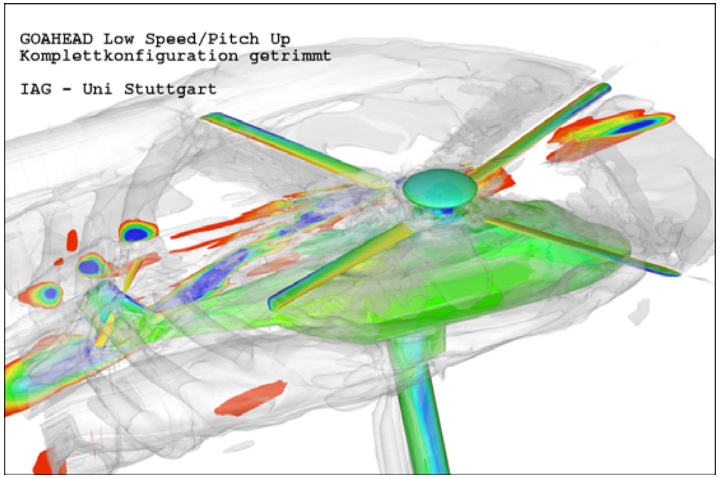




- Transition detection, top: IR, bottom: hot films on main rotor

- Blade deformation measurements with Strain Pattern Analysis (SPA) and Stereo Pattern recognition (SPR)
- Top : SPR markers, bottom: bending and torsion (r/R = 0.8, cruise condition)

# CFD codes applied in GOAHEAD

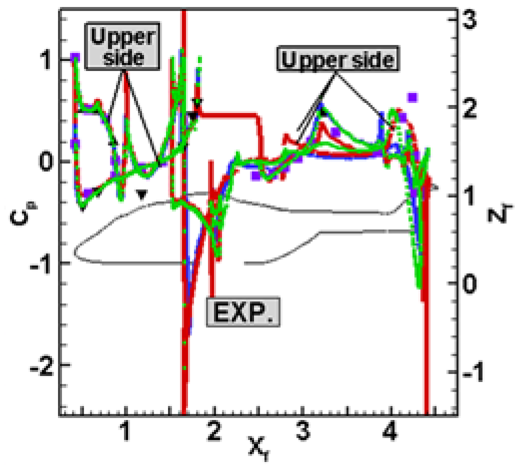
| CFD Code | Research organisations | Helicopter industry |
|---|---|---|
| elsA | ONERA | EC SAS |
| FLOWer | DLR, CU, USTUTT-IAG, | ECD |
| HMB | ULIV | WHL |
| ROSITA | PoliMi | Agusta |
| ENSOLV | NLR | |
| FORTH in house | FORTH | |



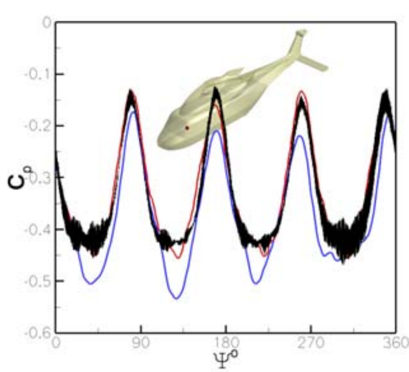

- Codes were applied in a blind test phase in order to assess the prediction capabilities and a post test phase to refine CFD results
- At the end of the project with all codes complete helicopter simulations were performed
- Budget in GOAHEAD for CFD-validation only, significant activities for code improvement paid by internal funding of partners

# CFD validation, cross plots

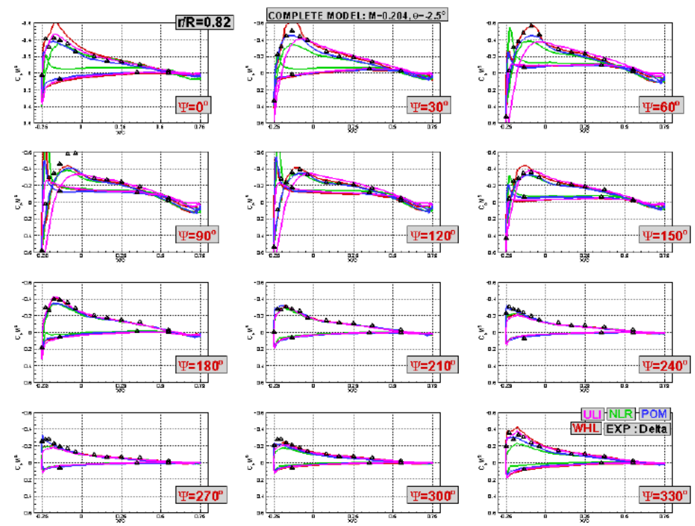
- Application of several codes to same test cases allowed to assess different solution approaches
  e.g. Chimera / sliding meshes, rigid / elastic blades, turbulence models, …
- Best practice guidelines have been established




top: pressures in symmetry plane, isolated fuselage (ECD, NLR, CUN)




Unsteady pressures on fuselage (cruise condition, DLR, POM)




main rotor pressures at r/R = 0.82, (cruise condition, ULI, NLR, POM, WHL)

Boelens et al.: "The blind test activity of the GOAHEAD project", ERF 2007

Antoniadis et al.: Assessment of CFD methods against experimental flow measurements for helicopter flows", ERF 2010

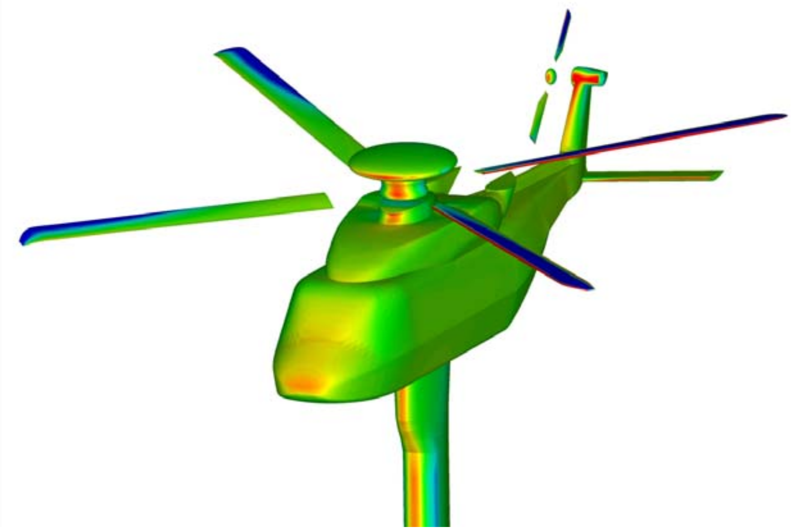
# Conclusions (1/2)

- Within the GOAHEAD project a comprehensive data base with high quality data and documentation for complete helicopters has been generated.
  - A full understanding of the data base will require many more years of research and data analysis like for any other experimental data base.
- All CFD-solvers 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.
  - due to the complexity and instationarity of the flow the solution accuracy has not reached the same level like for fixed wing applications. Further CFD developments and validation is required in order to further improve the CFD software, e.g. coupling of CFD methods to structural mechanics and flight mechanics, turbulence and transition modelling, and CPU time reduction.
  - CFD-simulations for complete helicopters are still a challenge
  - Access to modern supercomputers is crucial

# Conclusions (2/2)

- The European helicopter industry took advantage from the improvements and validation of their URANS-CFD tools. By working jointly with research centers industry extended the range of applications for in-house simulations.
  - However, due to the large computational effort complete helicopter simulations will not be routinely run in near future in industry.

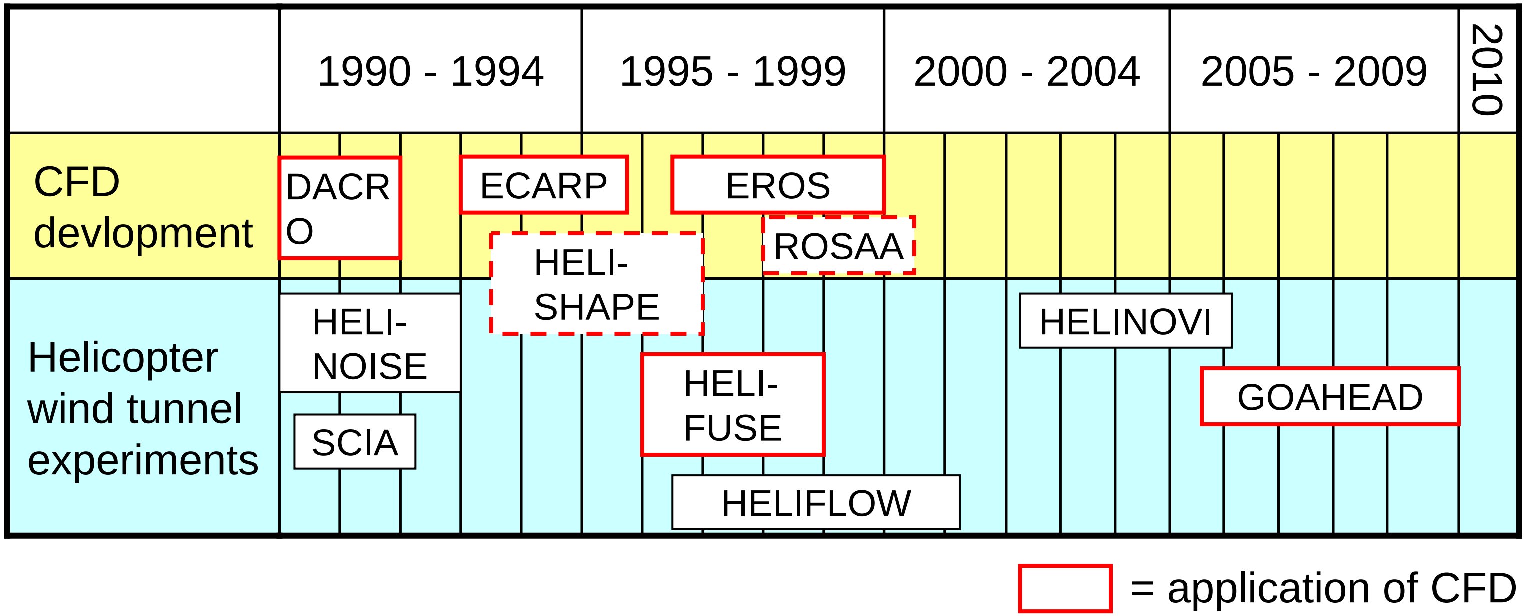
# Thank you



GOAHEAD

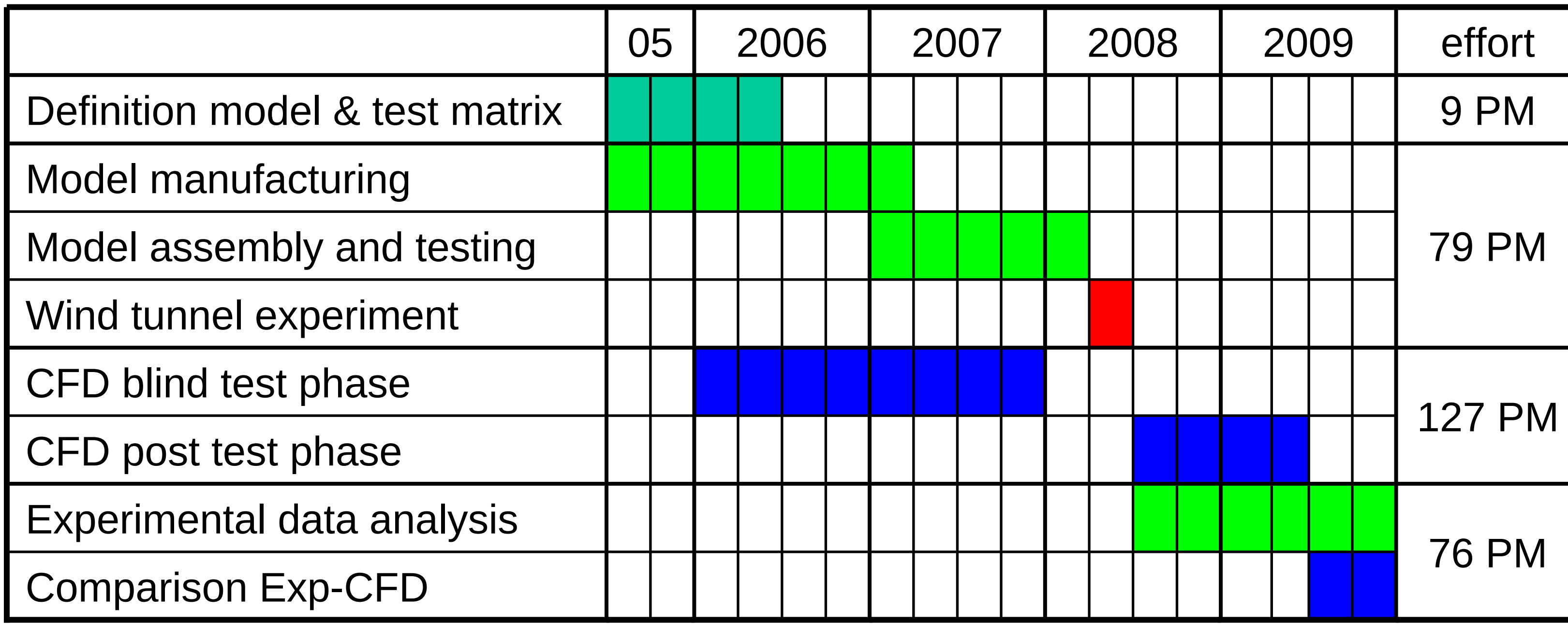
Generation Of Advanced Helicopter Experimental Aerodynamic Database for CFD code validation

# Background from European R&D projects




- long history of CFD applications to helicopters in European projects
- EROS: development of a mesh generator and Euler solver for rotors
- HELIFUSE: validation of RANS methods for fuselages
- Development of RANS solvers for rotors with national funding
- GOAHEAD: validation of CFD for complete helicopters

# Work plan of GOAHEAD




- Total planned effort (including project management 14PM): 305 PM = 25.4 PY
- Real effort significantly higher (many partners used internal funding)

# Partners in GOAHEAD

| Short Name | Legal Name | Country |
|---|---|---|
| DLR | Deutsches Zentrum für Luft- und Raumfahrt e.V. | Germany |
| ONERA | Office National d’Etudes et de Recherches Aérospatiales | France |
| CIRA | Centro Italiano Ricerche Aerospaziali S.C.P.A. | Italy |
| FORTH | Foundation for Research and Technology | Greece |
| NLR | Stichting Nationaal Lucht-en Ruimtevaartlaboratorium | NL |
| ECD | EUROCOPTER Deutschland G.m.b.H. | Germany |
| EC SAS | EUROCOPTER S.A. | France |
| Agusta | Agusta S.p.A. | Italy |
| WHL | Westland Helicopters | UK |
| UG | University of Glasgow | UK |
| CU | Cranfield University | UK |
| PoliMi | Politecnico di Milano | Italy |
| USTUTT-IAG | Institut für Aerodynamik und Gasdynamik Uni Stuttgart | Germany |
| ULIV | University of Liverpool | UK |
| AS | Aktiv Sensor GmbH | Germany |

# Thank you

GOAHEAD

Generation Of Advanced Helicopter Experimental Aerodynamic Database for CFD code validation

Preparation for 3D surface scan