EUROLIFT II
European High Lift Program

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Project title :	**European High Lift Programme II**
Instrument :	**STREP**
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Final Publishable REPORT

Start date of project:	**01/01/2004**
Duration:	**42 months (36 months plus 6 months extension)**
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Summary

The European High-Lift Project EUROLIFT II started in January 2004 under the co-ordination of DLR as a Specific Targeted Research Project (STReP) of the 6th EU framework program. The project continues the successful work of the predecessor project EUROLIFT under the leadership of Airbus-Deutschland. In view of the realization of the demanding ecological targets of the European vision 2020, high lift systems have the potential to deliver a substantial contribution for more efficient and environmentally friendly aircraft. Corresponding potentials of the high-lift system are the aerodynamically improved high lift systems with reduced maintenance effort, the development of more efficient and accurate theoretical and experimental methods for the industrial design process, and the reduction of the noise emission in the start and landing phase by advanced high-lift concepts. This can only be achieved, when modern validated numerical and experimental methods are available, which can be used for the analysis of the dominant aerodynamic phenomena as well as for the high-lift design and optimization under real flight conditions.

With the EC-project EUROLIFT II, these methods and the physical understanding of the dominant aerodynamic phenomena should be brought to a level, which guarantees the solution of the envisaged tasks.

The general objectives are the validation of numerical and theoretical methods for the exact prediction of the aerodynamics of a complete aircraft in high-lift configuration at flight Re-numbers, and an numerical and experimental analysis of the physical interaction of the different vortex dominated aerodynamic effects, as well as their impact on the aerodynamic performance. This will be accomplished by using state-of-the art RANS-methods (Reynolds-averaged Navier-Stokes) and also the wind tunnels ETW (European Transonic Wind Tunnel) and LSWT (Low Speed wind tunnel) of Airbus-Deutschland. Furthermore, an assessment of progressive high-lift systems including numerical has been conducted as well asits experimental demonstration.

The DLR Institute of Aerodynamics and Flow Technology coordinates the project EUROLIFT II. The project consortium of 13 partners includes the European Airframe industry and the European research institutions as well as one SME:

- DLR, Deutsches Zentrum für Luft- und Raumfahrt e.V., Germany
- Airbus Germany, Airbus France, Airbus United Kingdom
- Alenia Aeronautica S.p.A., Italy
- Dassault Aviation, France
- ETW, European Transonic Wind Tunnel, Germany
- CIRA, Centro Italiano Ricerche Aerospaziali S.C.p.A., Italy
- FOI, Swedish Defense Research Agency, Sweden
- INTA, Instituto National de Tecnica Aerospacial, Spain
- NLR, Stichting Nationaal Lucht- en Ruimtevaart Laboratorium, Netherlands
- ONERA, Office National d'Etudes et de Recherces Aerospatiales, France
- Engineering Office Dr. Kretzschmar, Germany

The research activities focus on a commercial transport aircraft configuration in various high lift settings designated as DLR F11 as shown in Figure 1.

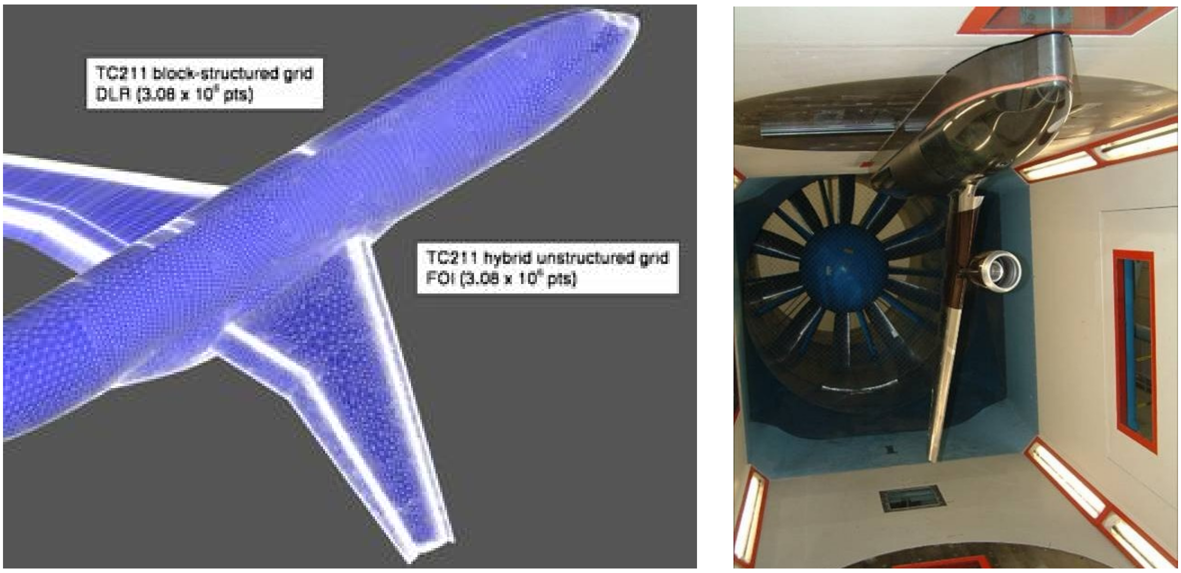

Figure 1. Numerical and experimental investigations on the DLR-F11 model being the baseline configuration for EUROLIFT II.

The complexity of the DLR F11 will be increased in three stages towards a realistic high lift aircraft configuration as sketched in the following figure.

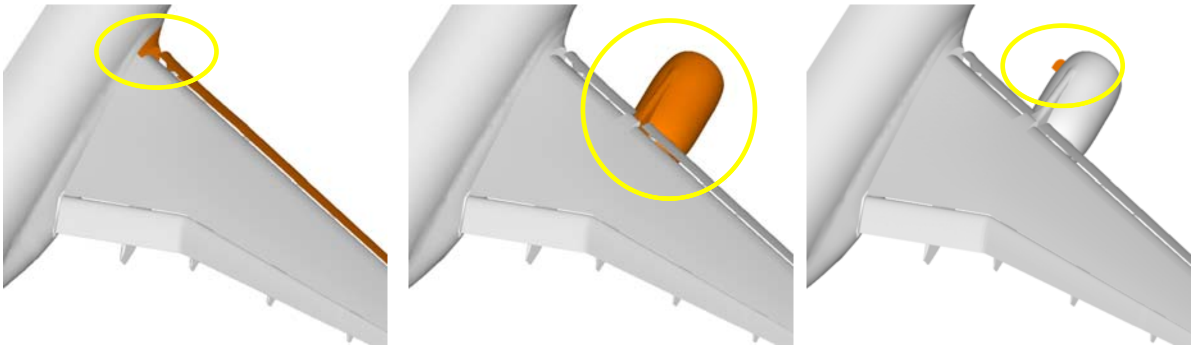

Figure 2. The three stages of the modified KH3Y towards a realistic high lift AC. The modifications with respect to the previous stage are marked in yellow.

The run time of EUROLIFT II has been scheduled for 36 months and is extended for another 6 months.

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Background

The design of high lift systems for commercial aircraft has a considerable potential to contribute to the achievement of the demanding goals formulated in the European Vision for 2020 [1]. Basically, efficient innovative high lift devices are a pre-requisite for improvements in two fields: the first is the reduction of the perceived aircraft noise, as for nowadays efficient low noise high bypass ration engines the airframe, more precisely the slat, is becoming the main source of noise during the landing phase. The second field is the strong reduction of CO_2 emissions. Although this goal is primarily related to improved aerodynamic cruise performance, there is a close relation to the high lift system. As outlined in [2] improvements in the maximum lift coefficient for the landing configuration as well as those in L/D for the take-off configuration directly translate into substantial increases in payload or efficiency for the overall aircraft mission. In addition, promising low emission technologies as e.g. the laminar wing technology require smooth wing leading edge designs with specific nose shapes, which directly have implications on the leading edge high lift system.

With respect to lower the noise emissions there are two principle conceptual directions: (I) Special novel low noise high lift systems; they will have to sustain a comparable level of high lift performance in order not to spoil the lower source noise by reduced distances to the airport and its residents. (II) High lift systems with improved aerodynamic performance e.g. by means of optimized shape and setting and/or by means of flow control to allow finally a reduced perceived noise by an extended overflight distance. The prerequisite to investigate and design such future high lift system is twofold. Given the complexity of the high lift system and the interrelation between aerodynamics and aeroacoustics it is evident that efficient validated high fidelity numerical tools as well as advanced experimental methods are required in the design process. In addition, a deep understanding of the high lift aerodynamics and its scale effects is essential [3]. Although comprehensive high lift research activities have been carried out in the past [4], [5], novel configurations and high lift systems may allow only a limited transfer of existing knowledge and require new design studies.

The challenge to reliably simulate the aerodynamic characteristics of commercial aircraft high lift configurations, either in the wind tunnel or using numerical methods, is based on the presence of a variety of different flow phenomena on such configurations, and the geometric complexity of the deployed high lift devices at the wing leading and trailing edges. Important flow phenomena are pressure and geometry induced flow separations, interactions of wall bounded and free shear layers, strong pressure gradients due to a large velocity disparity from low speed to moderate compressible flows, and strong flow curvature. The assessment and eventually improvement of the high lift properties of a configuration requires the identification, localization, and understanding of the effects and features that determine the maximum attainable lift. For high aspect ratio wings and configurations maximum lift is directly related to the occurrence of flow separation that is strong enough to cover a sufficiently large portion of the wing to over-compensate the lift gain in portions of the wing with attached flow. For the complete aircraft configuration with underwing mounted podded engines the trailing edge area at the wing root and the leading edge area at the nacelle position are the most critical areas with respect to the determination of maximum lift. The vortex which is shed by the slat end at the wing root together with the large local Reynolds-number may provoke trailing edge separation. The maximum lift behavior can be improved by modifications of the slat end, like slat horns. Concerning the nacelle mounting modern commercial aircraft are equipped with high to very high bypass ratio engines mounted closely coupled to the wing. The close coupling requires a cut-out in the leading edge high lift device. The shaping of the cut-out edges and the pylon/wing junction is essential to improve the high lift capabilities in this area. So-called nacelle strakes are often mounted at the forward upper part of the nacelle to improve the local maximum lift behavior. In both areas, at the wing/fuselage junction and at the wing/pylon junction vortices are generated, that interact with the local wing boundary layer by inducing additional velocities. This scenario forms the basis to assess and improve the simulation tools in the framework of the EUROLIFT projects.

Objectives

The predecessor project, EUROLIFT (I), has been launched as part of the 5th European framework program in 1999 under the co-ordination of Airbus-Deutschland [6] with two major objectives:

- to generate a suitable experimental and numerical database for state-of-the-art CFD methods [7] together with a deeper understanding of the related flow phenomena and scale effects.

- to study advanced high lift concepts under cryogenic conditions.

Being the first cooperative attempt of that kind the geometric complexity has been limited to a wing/fuselage configuration with intersecting slat/flap-fuselage junctions. While most of the activities in EUROLIFT (I) concentrate on the wing/fuselage configuration, the follow-on project EUROLIFT (II), launched in 2004 within the 6th European Framework Program under the co-ordination of DLR, extends the studies to complete high lift aircraft configurations including effects of engine/airframe integration [8]. As for EUROLIFT (I) the focus of EUROLIFT II is twofold. On the one hand side the activities are devoted to validation and application of improved CFD methods. The emphasis is laid on the extension of the validation database towards more complex configurations. In addition to the numerical analysis, also a common optimization study is introduced in EUROLIFT II. Moreover, advanced transition detection techniques for cryogenic testing are investigated to accompany and support corresponding transition prediction studies. Inline with these studies also techniques for deformation measurement in cryogenic testing conditions are investigated to support numerical simulations in order to reveal and separate effects of model deformation and in-tunnel mounting. A further focus is laid on novel leading edge devices using passive and active flow control to suppress separation. The present contribution outlines the activities and the approach of the high lift research carried out in EUROLIFT II from a conceptual point of view. Both projects, EUROLIFT(I) and EUROLIFT II, have been set-up to generate a comprehensive validation database for CFD codes covering the Reynolds-number range representative of atmospheric facilities up to high Reynolds-numbers representative for flight conditions, that is the range from Re = 1.5 x 10^6 up to 25 x 10^6. The project covers experimental as well as extensive numerical activities for the validation and improvement of state-of-the-art CFD codes in order to pave the way for a routine prediction of the flow around commercial aircraft high lift configurations and to elaborate best practice approaches. In order to be able to separate the different maximum lift determining effects present on typical commercial aircraft configurations and their Reynolds-number dependency, the investigations have been carried out starting with the reference KH3Y wing/fuselage configuration and a simplified high lift system and then increasing the complexity up to a configuration with pylon mounted nacelles and strakes, see Figure 3.

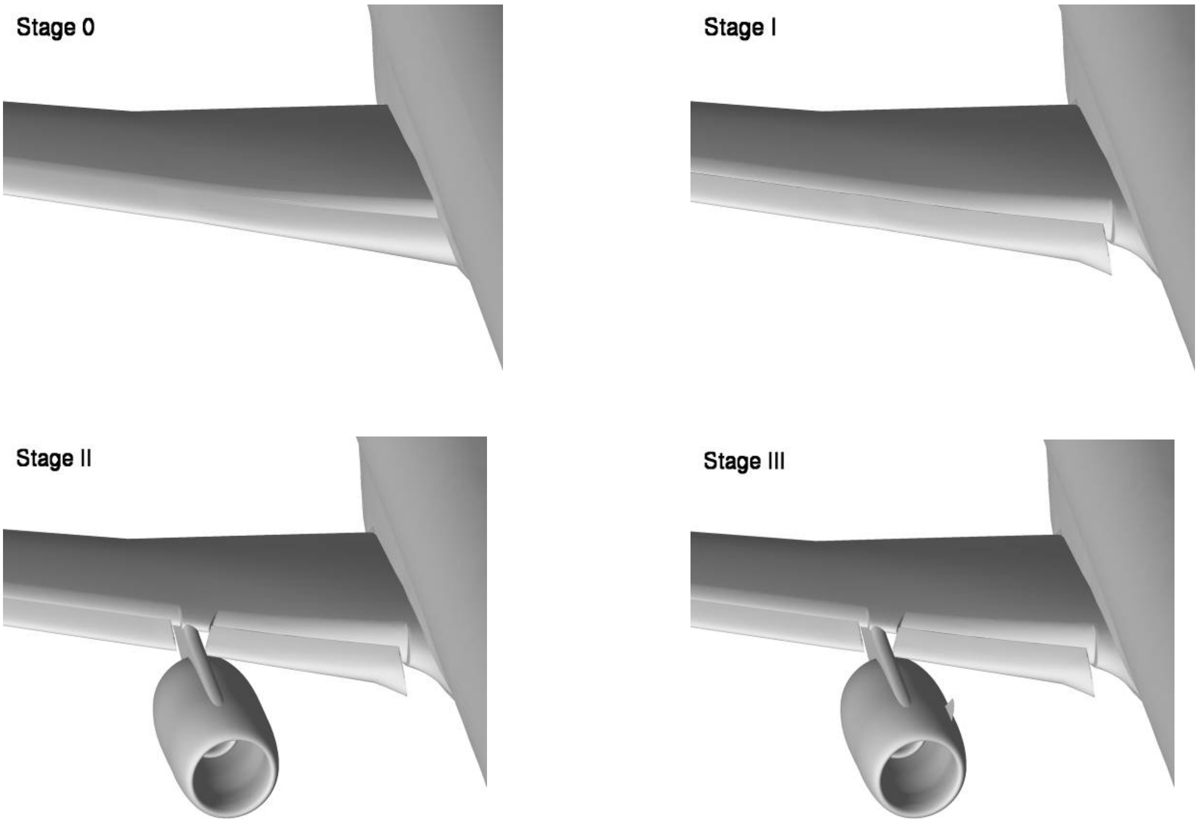


Figure 3. Complexity stages of KH3Y high lift configurations

In addition to the KH3Y commercial aircraft configuration the constant chord swept 3-element AFV wing forms the basis for studies on the analyses and prediction of transition phenomena as well as flow control applications. Details of the different tasks are outlined when describing the project structure in the next section.

Configurations and Facilities

The baseline model for the present studies is representative for a commercial wide-body twin-jet high lift configuration. The layout and geometry has been defined by Airbus-Deutschland, denoted as KH3Y geometry. The model is constructed and manufactured by DLR and denominated as the DLR-F11 model. The extension for the high lift configuration and the construction and manufacture of the high lift devices and nacelle has been done as part of the EUROLIFT projects. The configuration is available as a cruise model with baseline and a modified slightly drooped leading edge. The droop nose design forms the geometrical basis for all configurations of the KH3Y configuration with deployed high lift devices.

The main dimensions of the model are listed in Table 1:

half span, s	[m]	1.4
wing reference area, A/2	[m^2]	0.419
reference chord, c_{ref}	[m]	0.347
aspect ratio, Λ	[-]	9.353
taper ratio, λ	[-]	0.3
¼ chord sweep, φ_{25}	[^{o}]	30
fuselage length, l_{Fu}	[m	3.077

Table 1: Main dimensions of KH3Y model

The high lift system consists of a leading edge slat and a trailing edge Fowler flap. The slat is subdivided into three parts. The elements are interconnected laterally by latches. The slat is continuously extending up to the wing tip. The local relative chord ranges from about 10 % at the inboard pressure section (DV1) to nearly 24% chord at the most outboard pressure section (DV11). The Fowler flap also consists of three parts. The first one extends up to the wing kink, and the second one up to 71% half span. The third element extends up to the wing tip. It can be interchanged against a flaperon. For 2D investigations a representative wing section at 68% half span is selected. At this station the slat has a local chord length of 17.7% and the flap of 27.6%, respectively. The high lift system can be mounted in two take-off settings and one landing setting. For the experimental investigations with respect to maximum lift analysis in EUROLIFT II, only the landing setting is considered. The flap can be mounted in several fixed window positions. The reference setting for the landing configuration is denoted as WP 9. The device rigging specifications in terms of deflection, gap, and overlap for WP 9 are listed in Table 2.

slat deflection angle, δ_s	[^{o}]	26.5
slat gap, g_s / c_{ref}	[-]	0.014
slat overlap, o_s / c_{ref}	[-]	-0.008
flap deflection angle, δ_f	[^{o}]	32.0
flap gap, g_f /c_{ref}	[-]	0.010
flap overlap, o_f /c_{ref}	[-]	0.006

Table 2: Specification of KH3Y model in landing configuration, WP 9

A baseline experimental investigation of the high lift performance of the KH3Y configuration featuring detailed flow field measurements is carried out in the low speed tunnel of Airbus-Deutschland in Bremen, B-LSWT for Re = 1,4 x 10^6. The B-LSWT is a continuous low speed facility for atmospheric testing. The facility has an open Eiffel-type circuit with a closed test section. The operating speed range is from 5 m/s to 80 m/s. The test section is 4.45 m in length, with a cross section measuring 2.1 m x 2.1 m. The Reynolds-number variations have subsequently been carried out with the same model in the European Transonic Windtunnel (ETW) facility in Cologne, Germany. The ETW is a high Reynolds number transonic wind tunnel using nitrogen as the test gas. High Reynolds numbers are achieved under the combined effects of low temperatures and moderately high pressures. ETW has a closed aerodynamic circuit with a Mach number range from M = 0.15 to 1.3. The test section is 2.00 m high, 2.40 m wide, and 8.73 m long.

In parallel to the analysis part of the studies, a flap shape and setting optimization is carried out in the EUROLIFT II. According to the results of the numerical optimization a new trailing edge flap is manufactured and wind tunnel tested in the ETW. The optimization studies have been carried out for the KH3Y configuration in take-off setting.

All experiments of the EUROLIFT projects make use of the half model test technique to benefit from the larger scale compared to full model tests. The model is mounted on a peniche. Both, fuselage as well as the peniche, incorporate labyrinth seals adjacent to each other. The effective height of the peniche and the seals in the wind tunnel amounts to 0,101m. The high lift devices have been manufactured to fit gapless in spanwise direction for the take-off setting 2. Consequently, also the pressure sections of slat and flap are in-line with the fixed wing pressure sections for this setting. A roughness band of 5 mm width is attached to the fuselage 30 mm downstream of the fuselage. All other components are testes without any transition fixing.

The high lift wing is equipped with 487 pressure taps in 10 pressure sections (DV). For the EUROLIFT II project the wind tunnel model is modified towards a more realistic high lift configuration. Therefore a slat cut-out is introduced at the fuselage and a nacelle is added. At the inner slat-end an onglet serves as a fairing between wing leading edge and fuselage. The inner slat side edge is equipped with a slat-horn. For the wing/fuselage/nacelle configuration the slat has a cut-out at the pylon position. A through-flow-nacelle is mounted at 34% half span. It is representative of a modern VHBR-engine with a bypass ratio of about 10 with external mixing. The nacelle diameter is 0.155 m, the overall length amounts to 0.33 m. It is closely coupled to the wing. The through-flow-nacelle has an internal core-body nacelle and internal pylon. A nacelle strake is mounted inboard on the nacelle. 4 shows the complete EUROLIFT II half model configuration mounted on the peniche at the top wall of the ETW.

Figure 4. Complexity stages of KH3Y high lift configurations

The second configuration used in the EUROLIFT projects is the constant chord swept wing model AVF (Aile à Flèche Variable) of ONERA. The metal panel wing is based on a constant RA16SC airfoil section with no twist. The baseline configuration is build-up of a full span slat and Fowler flap attached on five tracks. The tracks are in line of flight for 40^o sweep angle. The geometric specification of the wing is given in table 3. The high lift wing is equipped with 8 spanwise pressure stations with each station having 93 taps available. The wing is mounted directly on the turntable. The model is used for the analysis of transition phenomena as well as for studies on active and passive leading edge flow control. The experimental studies for the transition investigations have been carried out in EUROLIFT (I) in the ONERA F1 low speed wind tunnel in Fauga Mauzac, France. This facility represents a continuous pressurized wind tunnel with wind speeds up to 130 m/s. The closed test section has a dimension of 4.5m x 3.5 m. Results for a range from Re = 3.0×10^6 up to 9.0×10^6 have been gathered.

half span, s	[m]	2.0
wing reference area, A/2	[m^2]	1.3054
reference chord, c_{ref}	[m]	0.500
aspect ratio, Λ	[-]	6.128
taper ratio, λ	[-]	1.0
Leading edge sweep, φ_{le}	[^{o}]	40 (variable)
slat deflection angle, δ_s	[^{o}]	26.
flap deflection angle, δ_f	[^{o}]	20.0, 40.0

Table 3: Main dimensions of AFV model

A picture of the model in the ONERA F1 tunnel is shown in Figure 5.

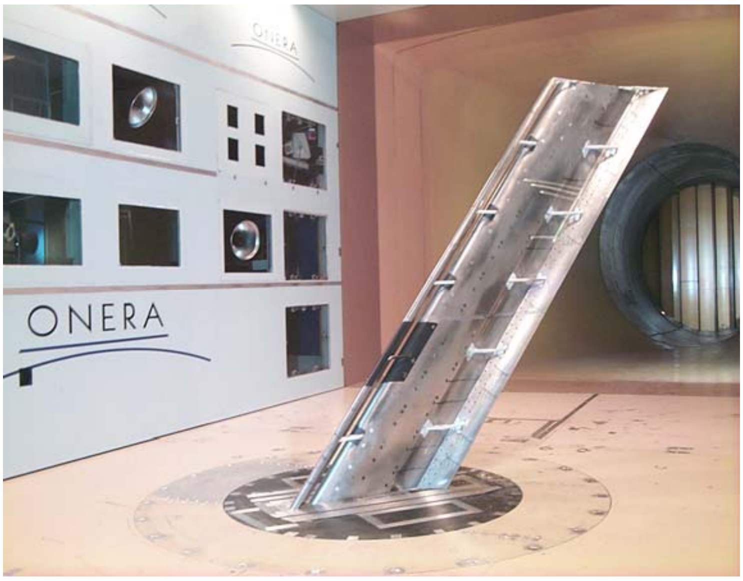


Figure 5. AFV 3-element configuration for transition studies in the ONERA F1

No transition fixing is applied for these studies. Transition phenomena are detected via hot films as well as with an infrared camera. The experiments with the AFV model in EUROLIFT II have been carried out to determine the potential of active flow control to recover the slat performance. For this purpose the model is modified to end up with a two element configuration with a retracted slat. Therefore a new clean leading edge system consisting of six leading edge boxes incorporating a full length slot on the top surface has been designed. The slot extends parallel to the leading edge and allows constant blowing in the chord direction. The leading edge has been manufactures by Airbus-UK. The tests have been carried out in the low speed tunnel of Airbus-UK in Filton, United Kingdom. The F-LSWT is a continuous atmospheric wind tunnel with wind speeds up to 97 m/s. The closed test section has a dimension of 3.66 m x 3.05 m. Compressed air is supplied to the model utilizing the high-pressure air feed system on to the F-LSWT under-floor balance. In order to ensure that the flow control effects are not corrupted by transitional phenomena transition fixing is applied to the upper and lower surface of the clean wing leading edge. Boundary layer measurements using a boundary layer traverse to measure boundary layer thickness downstream of the blowing slot, as well as Hot-Film measurements have been carried out in addition to balance and surface pressure measurements. The modified 2-element AFV configuration with the blowing device is depicted in Figure 6. The test have been carried out at Re = 3.1 x 10^6.

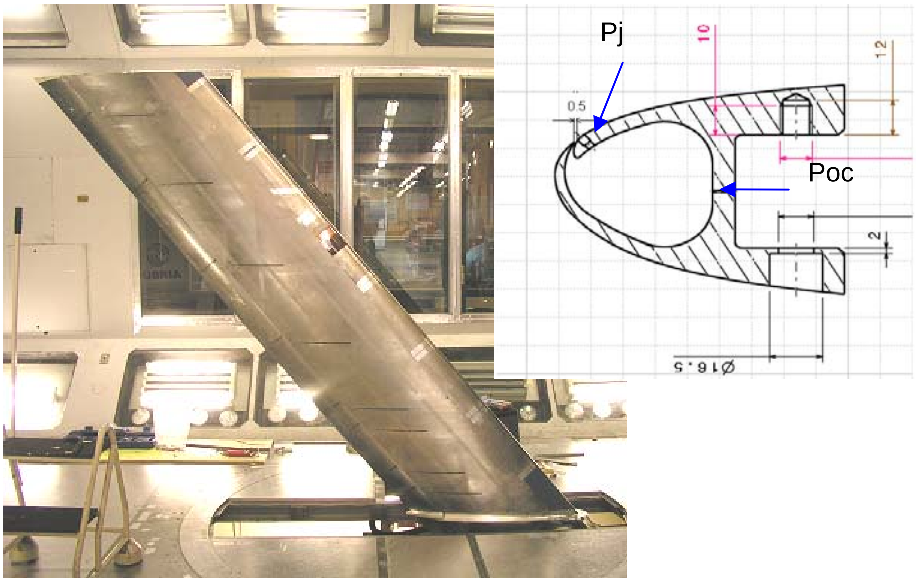


Figure 6. AFV 2-element configuration for investigations of active flow control

Consortium, Numerical Methods, and Test Cases

The consortium of the EUROLIFT II project consists of 13 partners. Among these are five airframe companies (three Airbus sites are involved) and six research establishments. The consortium is completed by IBK as an SME and the ETW. In total, 7 European countries are involved in EUROLIFT II. The DLR Institute of Aerodynamics and Flow Technology acts as the coordinator of the project. The numerical methods used by the partner are listed in Table 4. In contrast to EUROLIFT (I) RANS methods have been used exclusively for the analysis studies on the complex high lift configuration. A fair balance of hybrid unstructured, purely unstructured codes (AETHER of Dassault Aviation), as well as block-structured RANS codes are used. The physical modeling of turbulence effects is done for the standard analysis using one and two-equation eddy viscosity models including explicit algebraic stress extensions (EARSM). Within the code improvement task also implicit Reynolds-Stress models are used. A pilot application is done based on Detached Eddy Simulation (DES). In general, common meshes are used wherever feasible. According to the codes, the mesh generation is based on different approaches ranging from purely unstructured meshes, hybrid unstructured meshes to block-structured meshes. The hybrid unstructured meshes are generated using a mix of tetrahedral, hexahedral, and prismatic elements. For the block-structured approach also the Chimera technique is used.

Partner			Approach	Flow Solver
ALENIA Aeronautica	Italy	Ind.*	RANS, unstruct.	UNS3D
Airbus-D	Germany	Ind.	RANS, unstruct.	TAU
Airbus-F	France	Ind.	RANS, struct.	elsA
Airbus-UK	United Kingdom	Ind.	Exp.	/
Dassault Aviation	France	Ind.	RANS, unstruct.	AETHER
ETW	Germany	Fac.	Exp.	/
CIRA	Italy	R.E.	RANS, struct.	ZEN
DLR	Germany	R.E.	RANS, unstruct./struct.	TAU/FLOWer
FOI	Sweden	R.E.	RANS, unstruct.	EDGE
INTA	Spain	R.E.	RANS, struct.	EMENS
NLR	Netherlands	R.E.	RANS, unstruct.	FASTFLO/TAU
ONERA	France	R.E.	RANS, struct.	elsA
IBK	Germany	SME	RANS, unstruct.	TAU

Table 4: Project partner and numerical methods

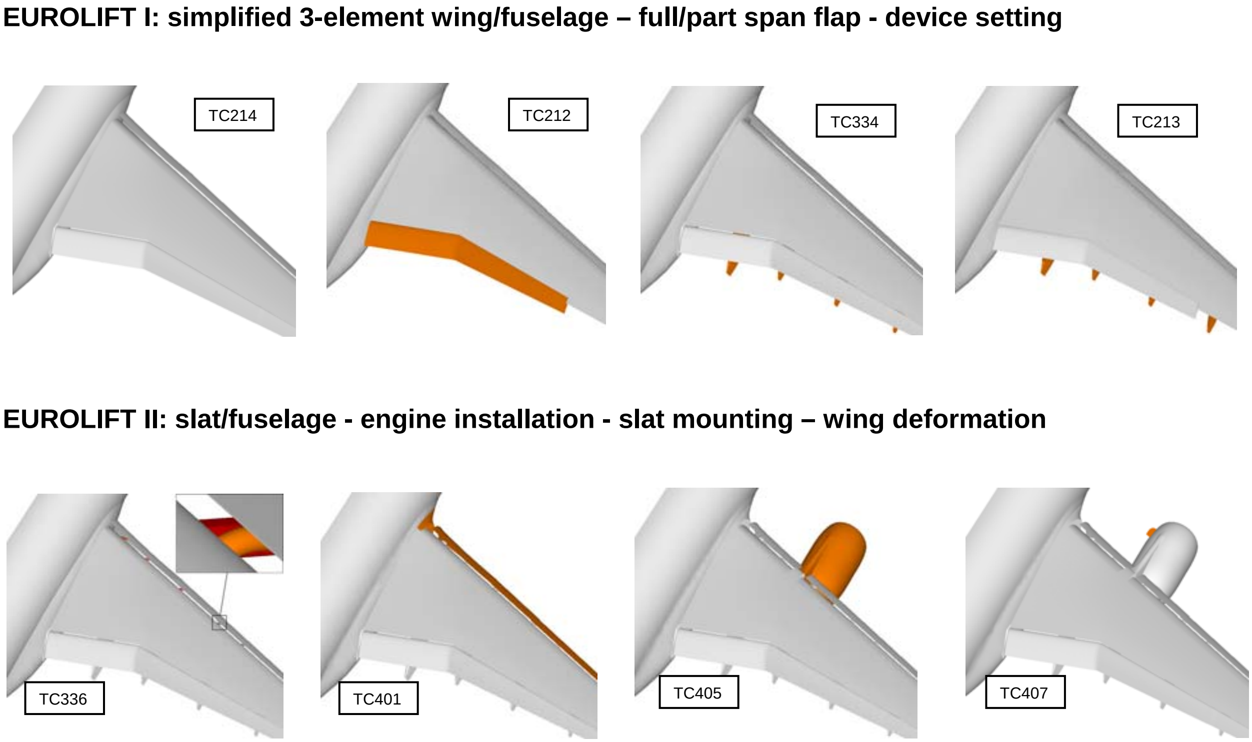
A large variety of different configurations and onflow parameters are considered for the experimental as well as the numerical investigations. They are identified by a specific project test case assignment to allow for a simple and at the same time unambiguous identification and handling of the data a test case designation is introduced within EUROLIFT. A test case, denoted as TC, is defined by a combination of a specific geometry and a corresponding set of onflow parameters. The specification of the onflow parameters is given as a combination of Mach number and Reynolds-number for a specific facility.

Thus, a test case describes a certain polar run, not to be mixed up with a specific angle of attack. As an example TC 336 refers to:

- KH3Y wing fuselage configuration (no engines or pylon)
- full san slat and flap system
- landing setting
- low Re-No conditions corresponding to an B-LSWT wind tunnel test (M = 0.178, Re = 1,34 x 10^6)

About 75 test cases are listed, but of course not all are studied in detail in the framework of the present project.

As an example for the numerical investigations a set of configurations with increasing complexity is shown in Figure 7. It becomes obvious, that some of the variations, e.g. neglecting the flap tracks and their fairing can only be studied be numerical means.



EUROLIFT I: simplified 3-element wing/fuselage – full/part span flap - device setting

EUROLIFT II: slat/fuselage - engine installation - slat mounting – wing deformation

Figure 7. Subsequent complexity increase for the numerical investigations on the KH3Y configuration

Project Structure, Approach, and Activites

The project is subdivided into three major Workpackages (WPs). Each WP has three tasks, as outlined in Figure 8. Some tasks are subdivided into subtasks. The subtask structure is generally omitted here for the sake of clarity.

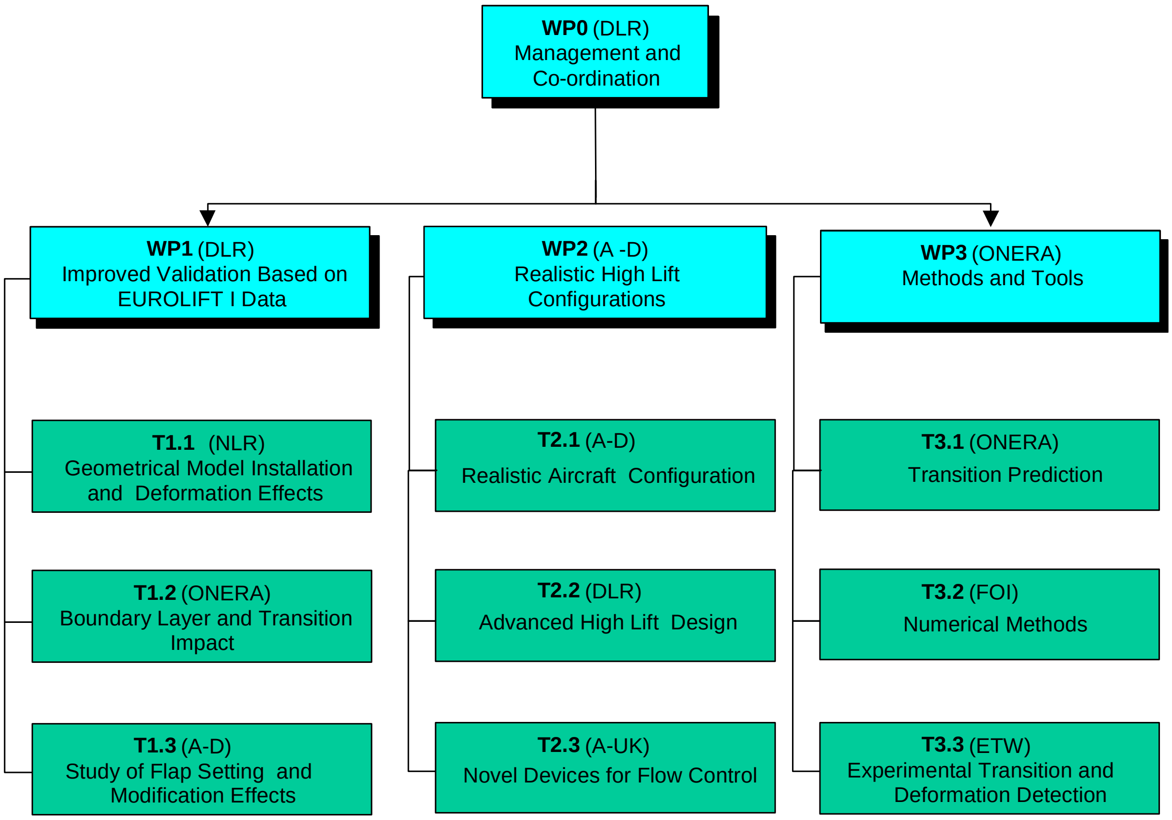


Figure 8. Workpackage and Task Structure of the EUROLIFT II project

WP1, lead by DLR, covers numerical investigations which are based exclusively on existing experimental data from EUROLIFT (I).

Task 1.1 is coordinated by NLR. The objective is to determine wind tunnel and model installation effects. In this context in-tunnel simulations are carried out with the KH3Y in Stage 0 configuration for low and high Reynolds-number tests in the B-LSWT and the ETW. Figure 9 shows as an example the unstructured surface grids of the KH3Y configuration in the ETW. In addition to the assessment of wind tunnel wall and peniche effects the influence of model deformation is investigated in this task based on coupled CFD-CSM computations. For this purpose three Finite Element models have been generated with different representation of the degree of details. To calibrate the models a static deformation test has been carried out with the KH3Y model at DLR. The technical results of Task 1.1 are discussed in detail in [9], [10], [11].

Task 1.2, coordinated by ONERA, deals with the analysis of transition phenomena based on experimental data of the EUROLIFT (I) project. The analysis of experimental data as well as CFD simulations comparing prescribed and predicted transition locations are studied. Transitional phenomena such as laminar separation, Tollmien-Schlichting instability, crossflow instability, contamination, and relaminarisation are investigated based on a range of approaches and methods from simple criteria to e^N transition prediction methods. Technical results are described in [12], [13],

Task 1.3 is concerned with the simulation of setting effects of the high lift devices. The task is coordinated by Airbus-Deutschland. The objective is to show the potential of CFD methods to predict 3D flap setting effects on lift and drag for model and full scale Reynolds numbers. In addition, Mach and Re-Number effects on the maximum lift performance of the KH3Y wing/fuselage configuration with retracted high lift devices are studied

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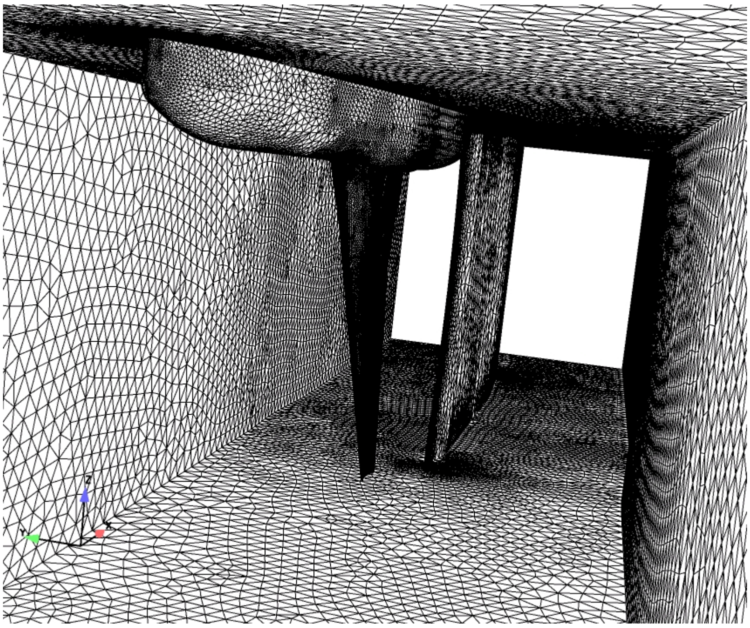


Figure 9. Surface grid of the KH3Y model inside the ETW (FOI)

WP2, coordinated by Airbus-Deutschland, is devoted to detailed analysis and optimization of high lift configurations.

Due to its importance Task 2.1, which is also lead by Airbus-Deutschland, is subdivided into three subtasks. The first one is coordinated by Airbus-Deutschland and covers detailed flowfield analysis on the three complexity stages of the KH3Y high lift configuration in the B-LSWT for low Re-number conditions. During the test campaign in 2005 3-component PIV measurements as well as oilflow visualization, infrared pictures, and boundary layer rake measurements have been carried out in addition to the standard force, moment and pressure measurements. The objective has been to get a detailed insight into the vortex dominated interaction of engine and airframe for the complete configuration. Figure 10 shows an example of the PIV measurements above the high lift wing for two different model configurations.

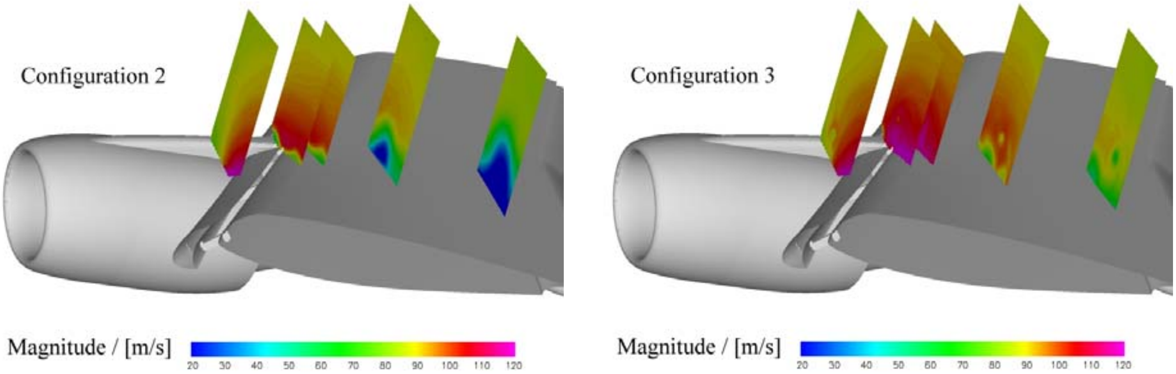


Figure 10. Vortex interaction between the nacelle vortex, the strake vortex and the wing boundary layer for the case without (left) and with nacelle strake (right) (DLR, A-D)

A detailed description of the test results in the B-LSWT is found in [14]

The Reynolds--number variation on the same configuration stages are then done in the ETW in the second subtask, coordinated by ETW. In this context a range from Re = 1.5 x 10^6 up to 25 x 10^6 is tested under cryogenic conditions to determine the Re-number dependency of maximum lift on such type of configurations. The technical results are described in [15], [16]. The accompanying numerical investigations for selected Reynolds-numbers are carried out in the third subtask, led by DLR. As this has been the first systematic geometric and Reynolds-number variation in a cooperative framework the computations have been done in a standard set-up for CFD simulations, assuming free air conditions and fully turbulent flow. Moreover, model deformation due to static aero-elastic effects is neglected in the RANS computations. Based on the fact, that the wakes of the slat tracks leave a strong pattern on the upper wing surface, these devices have been included in the numerical simulations in order to be able to better compare the experimental oilflow patterns to the friction lines in the computations. Figure 11 shows the simulations of the configuration without (Stage II) and with the nacelle strake (Stage III). The technical results are summarized in [17]

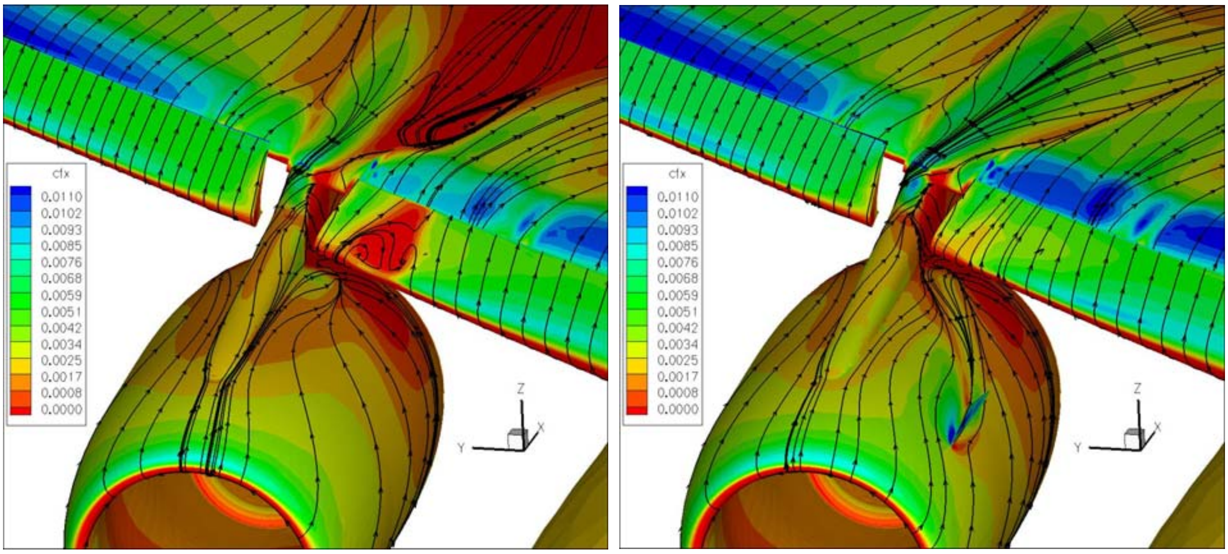
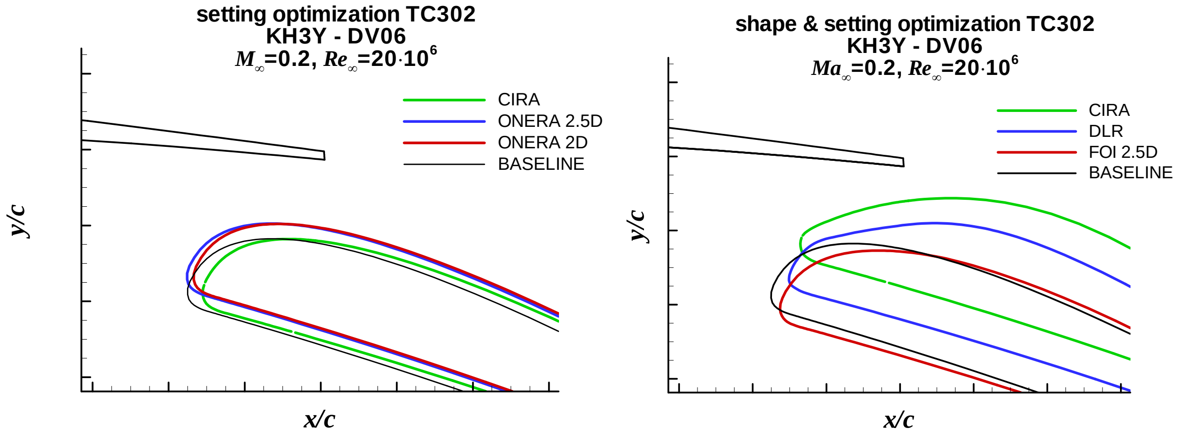


Figure 11. Simulated friction lines of the surface of the KH3Y configuration for the case without (left) and with nacelle strake (right) (DLR)

Complementary to the experimental and numerical analysis activities in Task 2.1, Task 2.2 addresses the topic of numerical optimization of high lift configurations. The common activity, which is coordinated by DLR, focuses on the setting and shape optimization of a 2D section of the KH3Y wing/fuselage configuration without engines. Based on a benchmark of the optimization codes it has been decided to base the optimization on the take-off performance and configuration in order to avoid strong deviations in the prediction of the amount of separation, which typically occurs for a landing setting.



setting optimization TC302
KH3Y - DV06
M_∞=0.2, Re_∞=$20\cdot10^6$

shape & setting optimization TC302
KH3Y - DV06
Ma_∞=0.2, Re_∞=$20\cdot10^6$

Figure 12. Optimized flap geometry and setting for Task 2.2

The resulting flap shapes and different settings as determined by the task partner are depicted in Figure 12. The flap with the highest performance is manufactured and being wind tunnel tested in ETW to verify the potential of the numerical optimization and the chosen 2D approach for flight representative Reynolds-numbers. A detailed description of the optimization approaches of the partners is given in [18], [19], [20], [21], [22], [23], and [24].

Task 2.3, coordinated by Airbus-UK, has been introduced to assess the potential of an active flow control concept on a multi-element wing configuration when replacing the slat. The task consists of preparatory numerical investigations and a demonstration test using the accordingly modified AFV configuration in the F-LSWT. An evaluation of the amount of required bleed air compared to the performance gain has been carried out to assess the feasibility of this flow control approach based on constant blowing. The concept of constant wall tangential blowing is compared to an approach using fixed sub-boundary layer vortex generators (SBVGs) at the wing leading edge. An oilflow picture of the AFV wing with and without SBVG is shown in Figure 13.

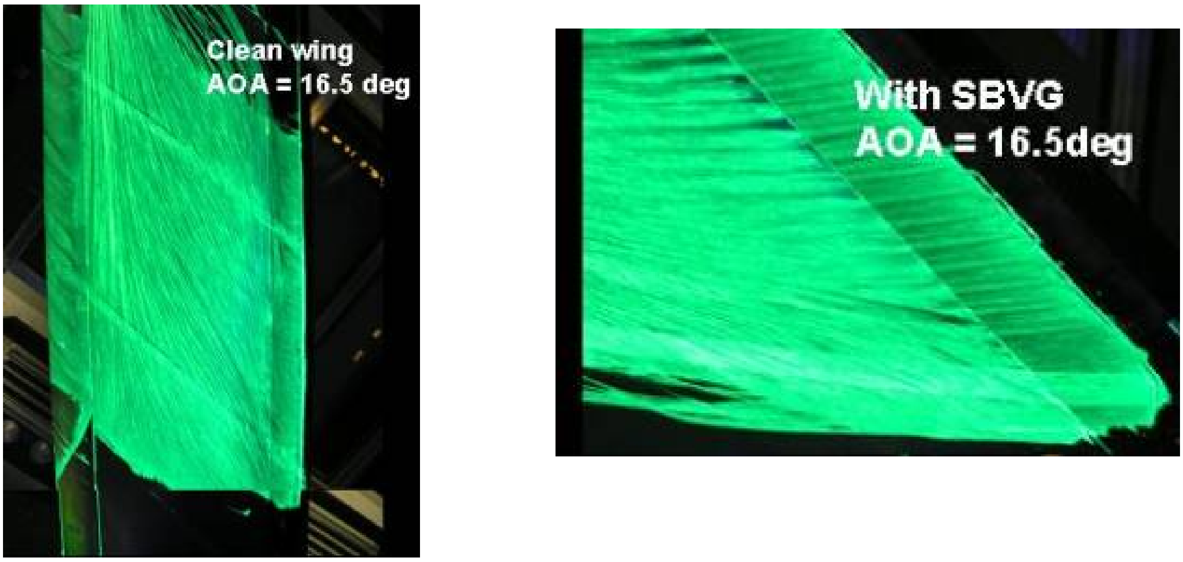


Figure 13. Oilflow picture of the AFV wing with and without SBVGs in the F-LSWT

After these configurative studies WP3, coordinated by ONERA, addresses the aspect of further developing numerical as well as experimental tools for high lift simulations. Task 3.1, also led by ONERA, is closely linked to the Task 1.2 activities. It focuses on the extension of methods for transition prediction from 2.5D (EUROLIFT (I) activity) to 3D flowfields based on database methods and on local theory approaches. Furthermore, the introduction and extension of internal transition prediction approaches based on RANS analysis codes and exact stability methods is investigated. The improvement of the physical understanding of specific 3D transition mechanisms is a topic of this task as well as the effects of transition in laminar separation bubbles. A result of an analysis of the boundary layer status on the AFV wing is presented in Figure 14. The results of Task 3.1 are described in [25], [26], [27], and [28].

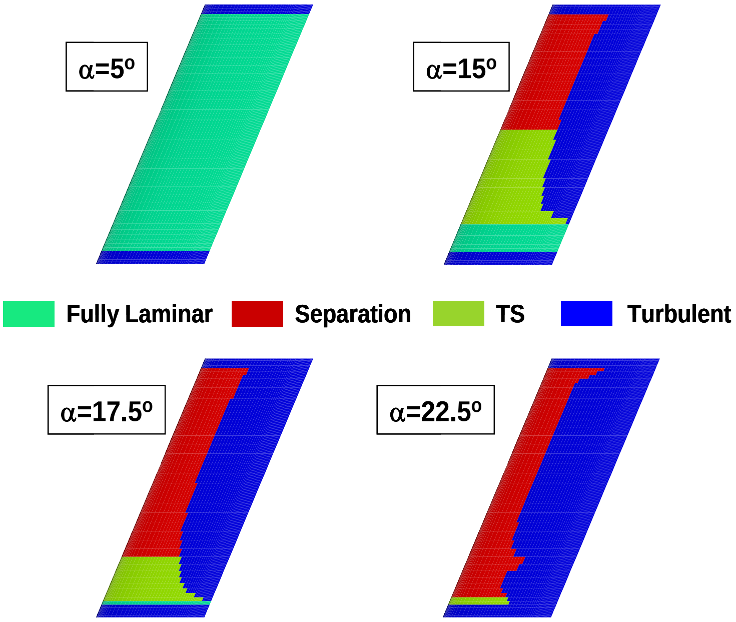


Figure 14. Areas with different boundary layer status on the of the AFV wing (INTA)

Task 3.2 intends to improve areas in the numerical simulation, that have been identified as the most promising for accuracy and efficiency improvement within the RANS codes applied. These areas are turbulence modeling and mesh generation. With respect to turbulence, modeling approaches beyond the steady state eddy viscosity concept are studied, such as e.g. differential Reynolds-Stress modeling and unsteady RANS simulations (URANS). The activities for mesh generation concentrate on highly anisotropic grids, the use of the Chimera technique and incorporation of hexahedral elements in areas of hybrid unstructured meshes to improve the mesh quality. An overview of the investigation is given in [29].

The focus of Task 3.3 is finally on improved experimental techniques for transition and deformation detection for cryogenic test conditions. The task is coordinated by ETW. Transition detection is accomplished using and assessing hot wire and hot film arrays in the ETW pilot facility, while the detection of wing deformation is done by using the Enhanced Stereo Pattern Technique (ESPT) for the tests with the KH3Y model in the ETW. Figure 15 shows a typical time trace of the wire sensor on the KH3Y model equipped with arrays. An overview of the results is also given in [16].

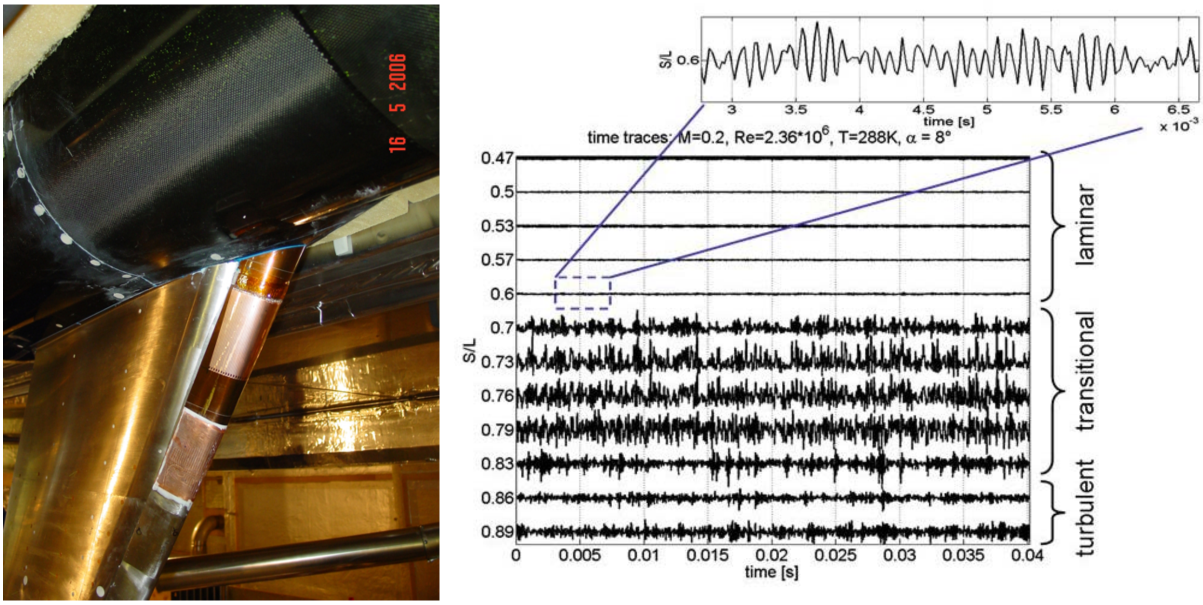


Figure 15. Time trace of the wire sensor on the KH3Y Model (ETW)

Conclusion

The EUROLIFT II project has addressed a variety of issues considered essential for the successful experimental and numerical simulation of high lift commercial aircraft configurations. One of the most important issues is the capability of RANS methods to predict maximum lift determining effects and their Reynolds-number dependency on complex configurations with deployed high lift devices. A comprehensive validation database for high lift commercial aircraft configurations has been generated covering low as well as flight representative Reynolds-numbers. Maximum lift determining effects could be isolated by investigating configurations of different complexity levels. The experimental studies are accompanied by extensive CFD studies making use of various hybrid-unstructured as well as structured grid codes. Whereas these studies have been carried out assuming fully turbulent free air flow, dedicated investigations are devoted to identify the influence of wind tunnel walls and model mounting effects deemed necessary to assess the impact of these effects for the reliable validation of the RANS codes. Numerical optimization of the shape and setting of a trailing edge flap is also addresses in the project. The resulting optimized flap shape has been tested under cryogenic conditions in order to verify the aerodynamic potential of the numerical optimization. Studies on transition phenomena, transition location prediction, as well as investigations on physical modeling and grid generation approaches complete the range of topics, which is covered by the EUROLIFT II project. The experimental database and the numerical results and experience gathered in the project including the areas of code improvement will be the basis to approach the final target of the predicting maximum lift on a complex high lift configuration with a pre-defined high accuracy.

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