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Midterm Assessment Report

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11	Dassault Aviation SA	DASSAV	F
12	Stichting Duits-Nederlandse Windtunnels	DNW	NL

Content

List of Figures

List of Tables

Abbreviations

A/C	aircraft
AoA	Angle of Attack
CAD	Computer Aided Design
CDR	Critical Design Review
CFD	Computational Fluid Dynamics
CM	Coordination Memorandum
CPU	Computer Processing Unit
CSM	Computational Structure Mechanics
D##.#	Deliverable
DoA	Description of Action
DDES	Delayed Dettached Eddy Simulation
DFEM	Dynamic FEM
DLR-F15	DLR research configuration #15
FE	Finite Elements
FEM	FE Method
FSI	Fluid-Structure Interaction
GBD	Ground Based Demonstrator
GFEM	Generalized FEM
IB	Immersed Boundary
IDDES	Improved DDES
LBM	Lattice Boltzmann Method
LES	Large Eddy Simulation
LLE	Laminar Leading Edge
LLF	Large Low-speed Facility
LS	Large and Swept
LST	Low Speed Wind Tunnel
MEMS	Micro-Electonical Mechanical Systems
MPI	Message Passing Interface

NWB	Niedergeschwindigkeits-Windkanal Braunschweig
M##	Project Month no. ##
PDR	Preliminary Design Review
PIV	Particle Image Velocimetry
PPM	Project Progress Meeting
PRM	Project Review Meeting
RANS	Reynolds-averaged Navier-Stokes
RBF	Radial Basis Function
RBM	Rigid Body Motion
RF	Reserve Factor
SA	Spalart-Allmaras turbulence model
SPIV	Stereo-PIV
SPR	Stereo Pattern Recognition
STS	Special Technology Session
TR-PIV	Time-Resolved PIV
URANS	Unsteady Reynolds-averaged Navier-Stokes
VLES	Very Large Eddy Simulation
WEB	internet
WMLES	Wall Modelled LES
WP	Work Package
WT	Wind Tunnel
ZDES	Zonal Detached Eddy Simulation

1 Executive summary

This is the Midterm Assessment Report of UHURA covering the progress within the first reporting period from 1 September 2018 to 29 February 2020.

The first reporting period has seen a smooth ramp-up of activity nearly as planned. The early distribution of background information allowed all partners to start their scheduled activities in time. The major design tasks in WP1 are finished, only the task on kinematics design is extended to include the outcome of verified wind tunnel loads into the assessment of kinematics weight on aircraft level at the end of the project. In WP2 the work on unsteady numerical simulation techniques is largely progressed, although not completely finalized. In WP3 the design of model modifications of the DLR-F15 model are completed, the corresponding parts are in manufacturing. Although no major activity has been planned for WP4, the initiation ran smoothly and the work package is ready to start. In WP5 the project management is running smoothly and first dissemination activities are on the horizon.

1.1 Project objectives

The major objectives for the first reporting period M1-M18 of UHURA are listed below:

WP1 design a deployable Krueger leading edge device, based on laminar leading edge shape for the DLR-F15 wind tunnel model.

WP2 adaptations of numerical tools assessments / improvements on both, grid strategy and unsteady simulation.

WP3 design and manufacturing of the modifications for the DLR-F15 wind tunnel mode

WP4 document on expectations on wind tunnel data to be used for comparison with numerical data

WP5 installation of database for communication and data exchange; continuous management and progress monitoring of the project including preparations of major meetings

1.2 Project achievements at a glance

A Krueger flap and corresponding kinematics has been designed for the DLR-F15-LLE airfoil. To achieve a realistic design, requirements from aircraft level have been specified and taken into account. The designs of the aerodynamic shape and the kinematics have been performed in a loop where side constraints on kinematics feasibility have been developed and included in the aerodynamic design iteration. The geometry of the Krueger flap configuration and the kinematics has been provided to wind tunnel model design. The designed Krueger flap configuration has been analyzed and loads for sizing model components have been provided. Further on, from an aircraft view recommendations for the speed of deployment and retraction of the Krueger device have been established. These numbers reflect the manufacturer knowledge on handling quality and certification criteria for Krueger devices.

Using initial design iterations, the simulation methods have been setup and sharpened for designated simulation type. On grid generation side, a robust implementation of local reconnection algorithm for unstructured meshes was obtained. Further, a demonstration of local-grid refinement in conjunction with Chimera capability on structured meshes has been established. Beside this, Immersed Boundary Methods and full re-meshing has been successfully applied. With regard to flow solver technologies, most of the partners have demonstrated their capabilities of simulating the deployment of the Krueger device. Methods in use range from URANS methods via different turbulence-resolving methods at the length and time scales of relevance up to particle based Lattice Boltzmann Methods (LBM). The methods are therefore ready to be used to simulate the experimental setup.

The modifications for the first of the two wind tunnel model have fully been designed and manufacturing is far progressed. Finite Element Analysis is completed and a corresponding stress report is just at finalization justifying the model to be entered into the first wind tunnel test. The model will be equipped with a significant number of MEMS unsteady pressure sensors. The needed circuit boards are designed and the manufacturing is closely finalised. In parallel, tests on using conventional pressure transducer for dynamic measurements in the envisaged frequency range have been performed and a corresponding setup is derived. The PIV methodology to be used to monitor the dynamic flow field has been selected and the implementation in terms of measurement window as well as hardware setup in the tunnel has been achieved. As there are a number of different measurement systems, a synchronisation approach has been determined and progress is made on the measurement protocol, including trigger, automation and communication approaches.

In order to prepare the comparison of numerical and experimental data, guidelines for validation have been compiled. By specifying common formats and templates and by collecting the expected list of measured values, a common ground for comparison is established.

On management side, a timely conduction of Kick-Off Meeting, 1st & 2nd Progress Project Meetings as well as the in time compilation of Quarterly Status Reports & Project Progress Reports serve a smooth progressing of the project. In total, 12 deliverables have been submitted in the reporting period. First contributions to scientific conferences have been made. A public WEB-site address has been reserved. For the data exchange between partners the UHURA databank is in service. Technical support is constantly provided.

2 Work progress and achievements

2.1 WP 1: Aero Design and Definition

Lead: AID

Progress achieved/results within reporting period (M1-M18)

The objective of WP1 until M18 was to design a deployable Krueger leading edge device, based on laminar leading edge shape for the DLR-F15 wind tunnel model.

The shape of the Krueger device (device length, nose shape) as well as the deployed position in front of the wing were optimised to achieve an aerodynamic lift optimum. At the same time constraints & requirements from aircraft level had to be respected (e.g. insect shielding requirement), as well as for kinematic design and sizing.

In Task 1.1, CIRA and DLR established a parametric description of the Krueger shape, incorporating requirements and constraints from kinematic design (Task 1.2) and overall aircraft level (Task 1.3). Embedded in a seamless end to end CFD process, numerical optimisation was applied to define the Krueger shape and its deployed position, maximising a lift objective. As two complete different methods were applied by CIRA and DLR, the achieved optimum can be judged as robust. A cross comparison of the partners final results was performed by DLR and CIRA.

Aerodynamic component loads were derived from the CFD calculations and from semi empirical approaches for the Krueger flap in intermediate and fully deployed positions. These loads were fed to Task 1.2 to size the kinematic and structure components.

ASCO designed and sized a realistic kinematic mechanism within Task 1.2 to deploy the Krueger flap from its retracted position on the wing lower side into deployed in front of the wing. Several iterations were performed with Task 1.1 to achieve a feasible and aerodynamically well performing integrated solution.

Task 1.3 provided constraints and requirements from aircraft level into the design process of Task 1.1 and Task 1.2 to ensure a realistic and relevant configuration.

WP1 is nearly completed. Deliverables regarding the designed shape (D11-1), the kinematics design (D12-1) and the aircraft related requirements (D13-1, D13-2) have been completed and submitted. Only D12-2 will be delivered in M30 instead M5 according to the agreed shift, but all data needed for further progressing by WP3 and WP4 has been made available by a Coordination Memorandum. The activities linked to D12-2 will be initiated in M28 after the wind tunnel tests in WP3 are complete.

2.1.1 Task 1.1 – Shape

Lead: DLR

Task 1.1 objectives for the reporting period (M1-M18) of UHURA

- performing the aerodynamic design of the Krueger flap, providing the final shape for WP3 and WP4

Progress achieved/results within the reporting period (M1-M18)

Within the first reporting period of the project, the design of a Krueger device suitable for the targets of the project has been finalized. Baseline geometries from former studies have been collected and provided to partners in Task 1.1 and covering an initial Krueger device and a classical three-element airfoil for WP2. Two concurrent design optimizations have been performed by the partners in Task 1.1. From these results after a cross-check of the shapes, a synthesis of the design has been achieved by combining favourable aspects of both designs. In a last step, requirements from the kinematics design have been incorporated (Figure 1). This last design has been evaluated also regarding loads, which have been provided to Task 1.2 for a final sizing loop of the kinematics.

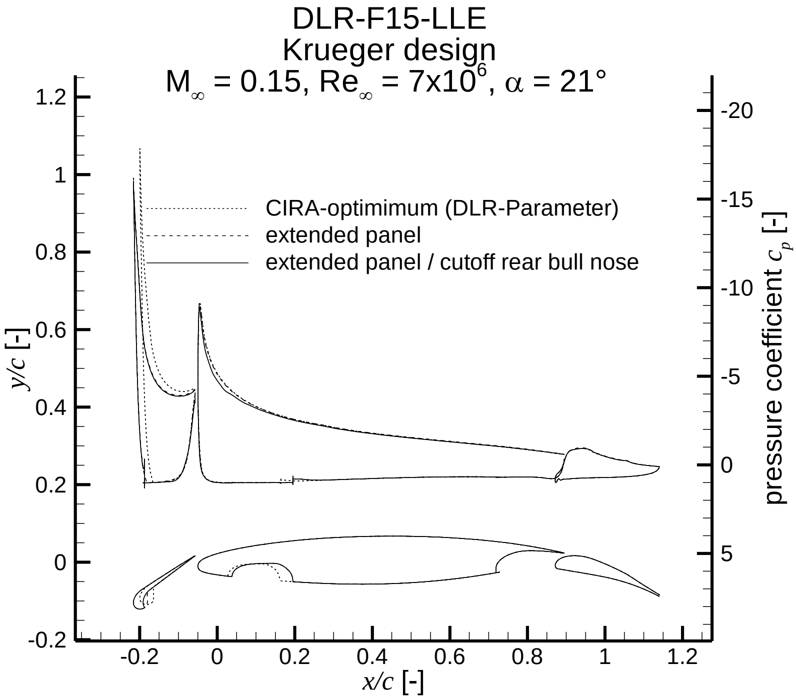


Figure 1: pressure distributions of the finally refined Krueger device with respect to kinematics requirements

Contribution of Partner 1 – DLR

Background information on airfoil geometry has been collected and provided for the targeted DLR-F15-LLE airfoil and a reference baseline DLR-F15 3-element airfoil.

To provide initial datasets for Task 1.2 and WP2, an initial Krueger device has been implemented based on results of the DeSiReH project. As an alternative, a movement law for the 3-element airfoil has been provided based on former studies. An initial set of loads data has been provided for Task 1.2 to start an initial sizing loop for the kinematics.

A numerical optimization loop has been performed to propose a meaningful Krueger device for the DLR-F15-LLE airfoil as the initial Krueger device shows premature separation. After comparison with data obtained by the partner CIRA and taking into account preliminary design constraints from the kinematics (Task 1.2), a synthesis of DLR and CIRA designs has been performed leading to a suitable final shape of the Krueger device.

The design synthesis has been completed for the folding bull-nose Krueger device. The geometry has been provided to the partners of WP2, WP3, and WP4. The corresponding deliverable D11-1 has been provided and submitted.

Contribution of Partner 3 – CIRA

CIRA set up an optimization procedure to perform the geometry design of the Krueger element. A specific, kinematic constraints-driven parameterization has been conceived to generate feasible shapes. An improved Krueger shape has been obtained as a result of a series of CFD-based optimizations aimed at increasing the maximum lift performance. The design has been cross-checked and validated by DLR.

A series of iterative refinements have been performed side by side with DLR for aerodynamic shape design. Cross-check analysis with DLR mesh and flow solver have been carried out together with turbulence model sensitivity analysis. Finally, CIRA contributed to detail the whole aerodynamic design process in the deliverable D11-1.

Work planned for the next reporting period

The task is completed.

2.1.2 Task 1.2 – Kinematics

Lead: ASCO

Task 1.2 objectives for the reporting period (M1-M18) of UHURA

- Define kinematics constraints linked to Krueger panel, actuation and deployment mechanisms for Task 1.1 and determine corresponding structural weights
- Define a Krueger kinematics design to be used as baseline for the DLR-F15 and DLR-F15*LS* model modification in WP3.

Progress achieved/results within the reporting period (M1-M18)

The initial Krueger shape from Task 1.1 was analysed regarding space allocation constraints.

D12-1 ('Kinematic constraints linked to Krueger panel, actuation and deployment mechanisms') was compiled and delivered according to planning in M3.

A preliminary kinematics design (and preliminary sizing) was completed for the initial Krueger shape. This preliminary sizing was required to perform the space allocation and kinematics integration analysis that delivered the integration constraints captured in D12-1 (Figure 2).

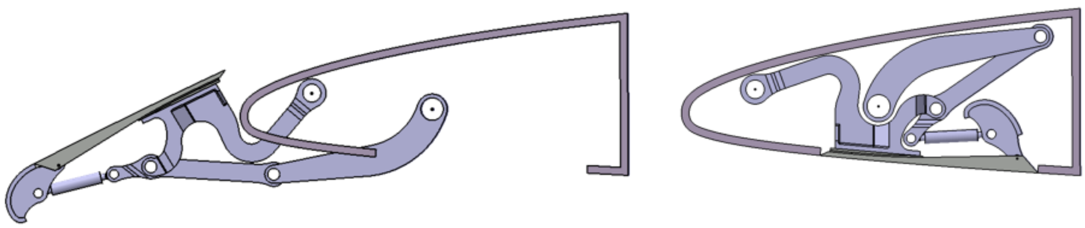


Figure 2: preliminary kinematics design A01 as provided in M3 together with D12-1

All the activities related to deliverable D12-1 and required to provide the necessary inputs for Task 3.1 should have been completed by M5. D12-1 was provided in time and a first design was delivered by M5. The remainder of this task (D12-2) has been shifted until completion of the wind tunnel campaigns in WP4 (M30).

The activities within Task 3.1 (which ASCO is supporting as well) identified some space allocation issues in the kinematical design provided in D12-1. Therefore, the kinematics design activity in Task 1.2 has been reopened in the reporting period and the design was updated in order to solve the integration issues (such as finding a good position to accommodate the drive shaft) identified during the DLR-F15 model modification activities (Figure 3).

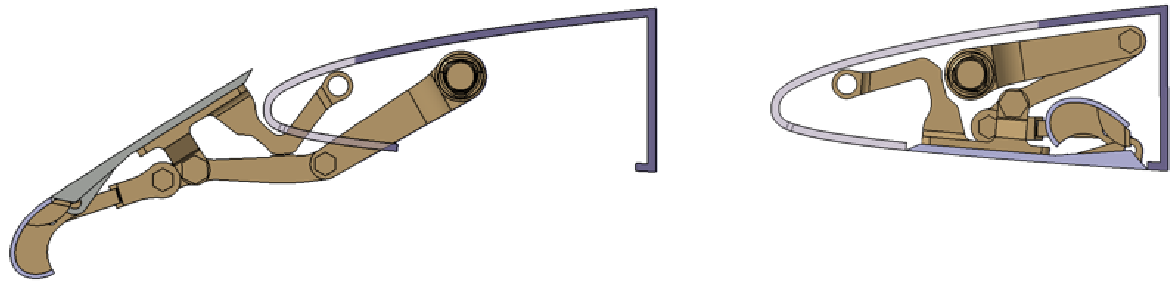


Figure 3: final designed Krueger kinematics H01 in (left) deflected and (right) retracted position

This design was fully sized within Task 3.1. Moreover, specific features where included in the kinematics design to alleviate the very large torques on the drive shaft that would appear during the static Krueger-extended AoA-sweeps during wind tunnel testing (refer to Task 3.1 section). This updated kinematical geometry was fully accepted during the CDR of the DLR-F15 model modification within Task 3.1 in M16.

A secondary (not-formal) deliverable of this Task was the relationship between the 3 different deployment angles (Krueger extension angle around its rotation point, drive lever rotation angle around the drive shaft & bull nose rotation angle around its rotation point on the upper Krueger panel). These relations are directly resulting from the geometrical configuration of the kinematical system. They serve, for example, also as an input in WP4 for the CFD computations of the dynamic flow conditions around the deploying Krueger flap.

Contribution of Partner 7 – ASCO

ASCO is the only partner in Task 1.2 and the above activity has been solely contributed by ASCO

Work planned for the next reporting period (M19-M36)

A simple up-scaled version of the kinematics design provided for the DLR-F15 model will be used for the DLR-F15*LS*. Nevertheless, a minor risk remains that the design is not compatible in terms of spatial integration or from stress point-of-view. In that case, the Task1.2 will be reopened again and an additional design for DLR-F15*LS* will be made meeting all extra constraints identified in Task 3.1.

After wind tunnel tests in WP3, the activities related to deliverable D12-2 will be initiated in order to include the measured loads into the weight estimation assessment on aircraft scale.

2.1.3 Task 1.3 – Definition of deployment cases

Lead: AID

Task 1.3 objectives for the reporting period (M1-M18) of UHURA

- Specification of A/C related requirements for the design of Krueger flap devices
- Specification of the selected cases to represent most aerodynamic-critical intermediate Krueger positions during deployment phase

Progress achieved/results within the reporting period (M1-M18)

The goal of WP1 was to design a Krueger system in a limited amount of time, which is fit for UHURA purpose and well represents a potential aircraft solution. Based on A/C manufacturers design experience, aircraft-level Krueger design requirements & constraints were introduced into the Krueger design process (Figure 4). During regular WP1 phone calls, requirements like relaxed shielding criteria, range of target deployment angle and aircraft based clearances have been discussed and applied to the aerodynamic shape and kinematic design process in Task 1.1 and Task 1.2. The applied recommendations have finally been summarized in D13-1. Finally Task 1.1 & Task 1.2 have achieved an integrated Krueger design, which is well balanced between shape and kinematic design space. It perfectly fits the need of UHURA's wind tunnel models and numerical objectives.

Task 1.3 also provided recommendations for the speed of deployment and retraction of the Krueger device. These numbers reflect the manufacturer knowledge on handling quality and certification criteria for Krueger devices, which finally allows the UHURA project to deal in a realistic and challenging scenario of deployment and retraction sequence. Performance critical deployment angles have been provided in order to allow for critical failure case analysis. The recommendations on deployment speed and critical deployment angle have been summarized in D13-2.

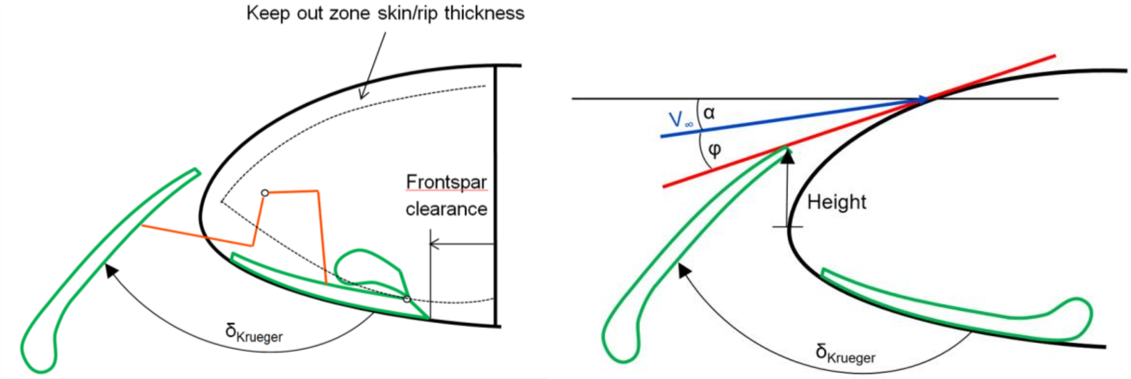


Figure 4: Illustration of design requirements provided within D13.1

Contribution of Partner 10 – AID

AID is the only partner in Task 1.3 and the above activity has been solely contributed by AID

Work planned for the reporting period (M19-M36)

The task is completed.

2.2 *WP 2: Numerical Simulation*

Lead: ONERA

WP2 Objectives for M1-M18 of UHURA

- Explore feasibility and potential of mesh quality improvements by local refinement and local reconnection during mesh deformation of unstructured meshes.
- Improve existing CFD tools and to assess best practices for the simulation of movable high-lift devices concerning: 1. flow modelling and solution methodologies, 2. fluid-structure interaction, and 3. flap movements.

Progress achieved/results within the first reporting period of UHURA

The objectives of WP 2 for the first 6 months of UHURA are to start to work on numerical tools assessments / improvements on both, grid strategy and unsteady simulation. The baseline configuration to be considered is the background information provided from WP 1, but partners can work on academic cases, too.

For Task 2.1, works on grid adaptation tools has started, for block structured grids (NLR) on single airfoil examples. It combines grid deformation, sliding grid, re-gridding and local grid refinements on blocks.

For Task 2.2, most of the partners have initial steady RANS simulations on preliminary Krueger shape. For some results (DLR, VZLU or KTH), a critical situation is observed when the Krueger is deployed perpendicular to the incident flow. A large separated flow is observed on the lower surface and a transient separation appears at main wing leading-edge that leads to a significant loss in performance (to be verified with unsteady simulations). Some works start on Krueger deployment simulations using chimera technique, mesh deformation, Immersed Boundary Methods. Preliminary results obtained using LBM methods have been presented by INTA. Concerning the acceleration of unsteady methods, NLR presented some results for a line-implicit scheme for both steady RANS and URANS (oscillating plate). Finally, IBK (in cooperation with CIRA) have developed an interface tool for fluid-structure interaction.

For the second reporting period (M6 to M12), all the partners were active, and some results have been presented, mainly for Task 2.2. A lot of work considers the use of chimera grids to manage the Krueger movement (DLR, ONERA, VZLU, NLR) with some differences linked to the solver used. Some partners consider a mix between grid generation using scripts for discrete Krueger position, and mesh deformation method for intermediate settings (VZLU, KTH). Works on the acceleration of URANS methods have been presented, as well as the progress of CFD/CSM interface tool for FSI simulations.

Note that DLR has presented a parametric study of the rotation speed for the complete cycle deployment/retraction on a preliminary Krueger shape.

For the last reporting period (M12 to 18) the finalisation of the different tools to be used for UHURA purpose (i.e. two parts of a (possible) deformable Krueger flap deployed with independent kinematics under unsteady flow conditions) has been completed

2.2.1 Task 2.1 – Improvement of meshing

Lead: NLR

Task 2.1 objectives for the reporting period (M1-M18) of UHURA

- Explore feasibility and potential of mesh quality improvements by local reconnection during mesh deformation of unstructured meshes.

- Development of a block-structured local grid refinement method and combination with the Chimera approach.

Progress achieved/results within reporting period (M1-M18)

Contribution of Partner 1 - DLR

Local reconnection offers a suitable way to implement a re-meshing strategy based on the Chimera approach that eliminates the need for non-conservative interpolation. The strategy is based by replacing overlapping mesh regions by a conformal triangulation. An initial multi-block structured grid and a Chimera grid are used for the development and assessment of the local reconnection approach. The full sequence of a Krueger flap deflection has been obtained on meshes that differ significantly in mesh resolution (1:4). Figure 5 (left) shows the reconnected mesh region around the Krueger panel on the fine grid level. The mesh quality of the interfacing meshes has been assessed based on established mesh quality criterions. It shows that the local reconnection retains the anisotropy of the baseline mesh over the full deflection range of the UHURA Krueger flap. Due to the triangulation, a slightly higher size variation is observed than in the baseline mesh. The method has been shown to be robustly implemented.

Contribution of Partner 6 - NLR

A baseline algorithm for block-structured local grid refinement has been revisited in view of high-lift applications including rigid body movements. The algorithm aims for a uniform mesh width by first refining the block topology and subsequently refining the grid per block. The local grid refinement capability will be combined with the Chimera approach to perform unsteady simulations of Krueger device deployment. The Chimera approach will facilitate the motion of the Krueger device, while local grid refinement will be used to inject grid points efficiently where needed for accuracy.

The local grid refinement algorithm has been improved on two accounts: First, when a block is locally refined, the smoothness of the grid is maintained by an appropriate smooth interpolation of the original grid-point distribution. Second, if a block is refined that is attached to a solid surface, the refined grid is mapped onto the original geometry definition in order to preserve the correct aerodynamic shape.

The validity of the method is demonstrated by a refined Chimera grid which has been generated around the DLR-F15 with a Krueger device consisting of two separate elements (bull nose and base, Figure 5 right). The grid around the main wing has been locally refined in order to accurately capture the flow characteristics of the separated flow region introduced by the moving Krueger device.

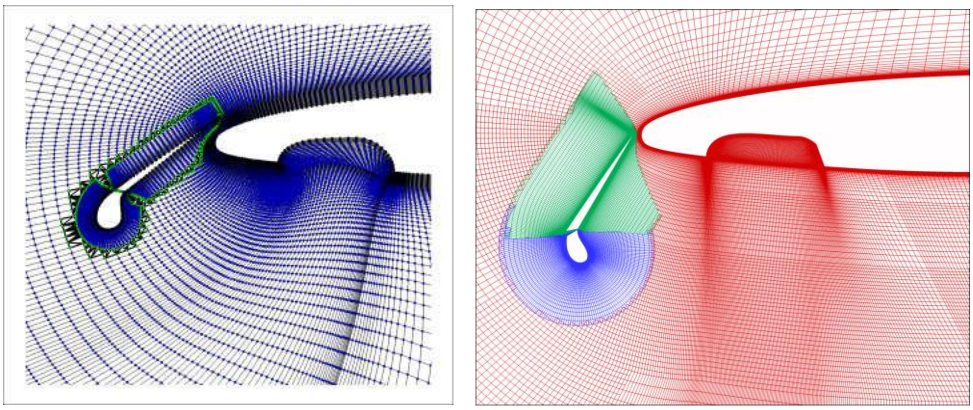


Figure 5: Improvement of meshing strategies for large deflections: (left) local mesh reconnection done by DLR; (right) local mesh refinement done by NLR

Work planned for the reporting period (M19-M36)

The activities on local grid refinement and local grid point reconnection have now been finalised.

2.2.2 Task 2.2 – Improvement of CFD solution methods

Lead: KTH

Task 2.2 objectives for the reporting period (M1-M18) of UHURA

The objective with Task 2.2 is different improvement of CFD solution methods for deployment and retraction of a Krueger device. In specific:

- to assess the capabilities in simulating moving frames in the present computational frameworks,
- to develop and implement selected improvements for accelerating of unsteady CFD,
- to improve on flap movement algorithms, and
- to study alternative methods for capturing unsteady CFD with mowing Krueger flap.

Progress achieved/results within the reporting period (M1-M18)

The work is divided into three subtasks with the following progress achieved:

(1) Acceleration of unsteady CFD. Numerical algorithms (NLR, KTH), quasi-steady approach (KTH) and efficient hybrid RANS/LES (KTH).
(2) Improvements of flap movement algorithms. Chimera (DLR, VZLU, ONERA, NLR) and Immersed boundary (CIRA).
(3) Alternative methods. Lattice-Boltzmann method (INTA) and advanced RANS for hybrid methods (Dassault).

Moreover, most of the partners have demonstrated their capabilities of simulating the deployment of the Krueger device.

<u>*Contribution of Partner 1-DLR*</u>

To model the deployment and retraction phase of a Krueger device the chimera technique with automatic hole-cutting has been selected. An unstructured 3 block 2D mesh has been created with the Centaur mesh generating system.

Successful steady simulation without deployment has been performed. The results look reasonable. The convergence was sufficient (more than 6 orders of magnitude in terms of the density residual).

Unsteady (URANS) simulations of the complete deployment and retraction phase of the Krueger device have been made and the influence of different deflection speeds have been investigated (Figure 6). It was found that the drop in lift coefficient for the critical position can be much reduced by a more rapid deployment. To model the deployment and retraction phase of a Krueger device the chimera technique with automatic hole-cutting has been selected.

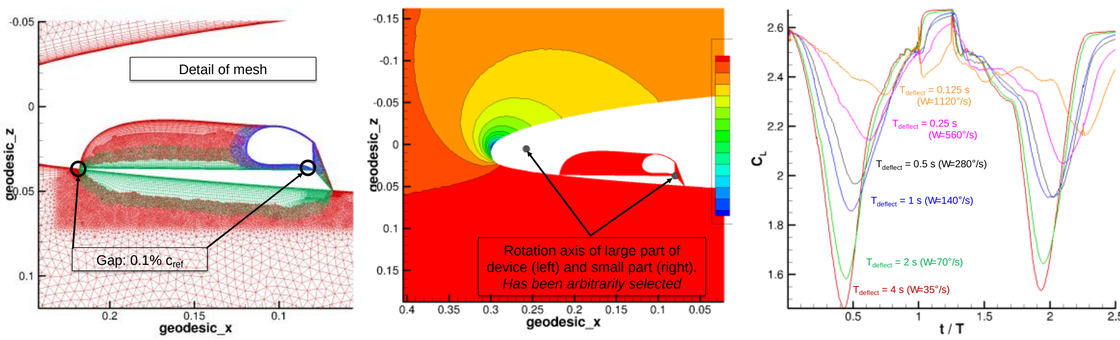


Figure 6: Chimera mesh and solution; lift coefficient during a complete cycle for different angular velocities, DLR TAU simulations.

Based on the 2D mesh a 3D mesh has been created (staggering of 2D meshes). So far, no 3D simulations have been performed.

A first 2D block-structured mesh for the wing with the Krueger device has been generated to save number of mesh nodes by using the DLR tool MEGACADS for mesh generation. This is due to the fact, that very high numbers of nodes are required by using CENTAUR. 1st unsteady simulations for the deflection and retraction of the device are promising.

A concept is evolved to couple an alternative approach for the meshing of the movement of the Krueger device to the solver of the DLR TAU code. The alternative approach is using the local reconnection approach done in Task 2.1. Within the remaining activity of Task 2.2 the handling of changing grids in solution process will be implemented on solver side.

Contribution of Partner 2-CIRA

SIMBA method: the main activities planned for months M1-M18 are devoted to developing and validating a dynamic immersed boundary (IB) method for simulating compressible and viscous flows around moving/deforming objects. Besides, part of the developments deals with a CIRA-IBK interface for coupling the in-house SIMBA code with a structural solver in the framework of a CFD/CSM partitioned approach. A brief summary is listed below.

1. The CIRA Cartesian method has a new data management that allows automatic mesh adaptation during time-accurate computations. A proper Lagrangian-Eulerian model takes into account the effects of rigid movements and structural deformations in the surrounding flow field.
2. The SIMBA validation campaign covers some test-cases from the literature dealing with imposed rigid body motions (RBM). The dynamic IB-method is used to compute the transient turbulent flow around the "DLR-F15-3eRef" slat-main-flap and "DLR-F15-LLE+Krueger" Krueger-main-flap airfoils during their rigid deployment laws (Figure 7).
3. CIRA and IBK have developed an FSI interface to allow the loads' mapping and communications between CFD and CSM meshes. The research effort aims at exploring different coupling strategies.
4. A "Static two-way FSI-coupling" allows a loose interaction between CFD and CSM. Time-accurate aerodynamic loads are used to compute structural deformations at each time-step or every N time-steps. The structural solver applies linear and static assumption and delivers the modified shapes to CFD. An implicit loop drives the codes to loads-convergence. The deformation velocities are not accounted for. This FSI strategy has been applied to compute the 2D aeroelastic loads during the "DLR-F15-3eRef" deployment (Figure 7 left).
5. The development of a "Dynamic two-way FSI-coupling" is ongoing. This allows a tight interaction between CFD and CSM. The instantaneous CFD loads are feed into the CSM non-linear solver, which gives back the deformation and its velocities in a seamless way. An implicit loop drives the codes to loads-convergence. If successful, the dynamic coupling will be used to compute the 2D aeroelastic loads during the "DLR-F15-LLE+Krueger" deployment (Figure 7 right).

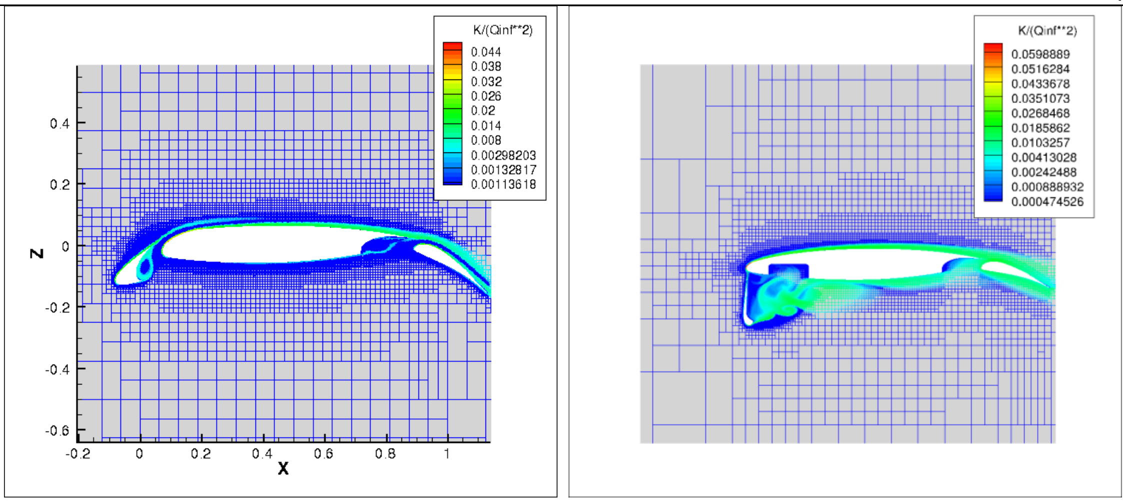


Figure 7: Snapshots of transient DLR-F15 slat and DLR-F15-LLE Krueger deployments, SIMBA solutions

UZEN method: a procedure for parametric re-meshing has been developed, in order to update the multi-block mesh during the Krueger motion at every time step, following the assigned trajectory. In principle the procedure should handle a new Krueger shape and motion with minor development effort. The procedure is going to be tested for the DLR-F15-LLE test case delivered by DLR at the beginning of the project.

Contribution of Partner 3-VZLU

Work has been started by sorting incoming geometries, grid generation of test geometries. The limits of the available mesh deformation strategy for CFD simulation have been tested. The sequence of grids was prepared by a script and grid deformation with solution remapping was used, which serves as a reference case. For further use and higher flexibility also the interface boundary conditions between independent regions were tested and improved.

The Chimera technique has been implemented in sequential steps in order to evaluate the possibilities and compatibility with the CFD solver. In the first step the implementation was done to test the interface data management inside the solver, so test case grids were prepared and tested on 2D and 3D in 1CPU as well as with parallelization via MPI library. The solver relies on grids prepared with overlap by ad hoc tools. In the second stage the grid hole cutting algorithm with adjustable overlap has been implemented outside of the solver. Special care has been taken to maintain functionality of the solver acceleration techniques, like multigrid, and also of the functionalities as aero-elasticity.

In the third stage the chimera technique was implemented with the possibility to deactivate parts of the domain directly inside the solver (Figure 8), which brings the possibility of the Krueger device movement while lowering the pre-processing demands.

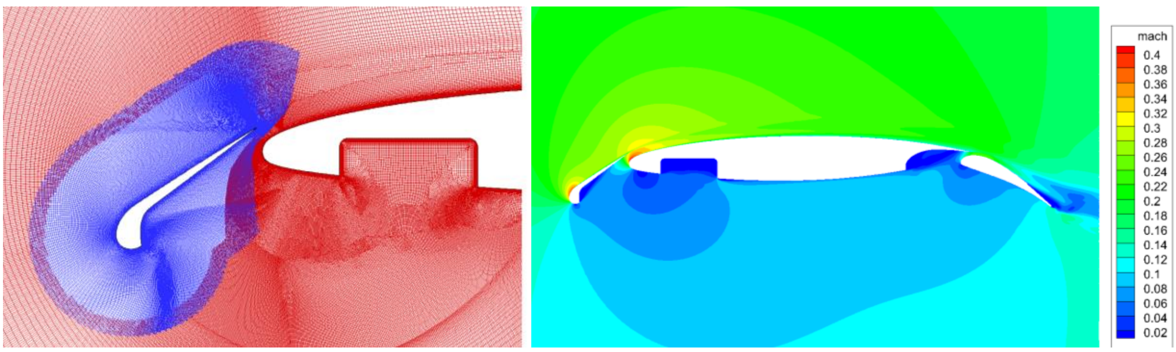


Figure 8: Chimera grid illustration, VZLU implementation

Contribution of Partner 4-ONERA

Preliminary automatic pre-processing procedure with Cassiopee tools of chimera grids around the different elements at two fixed positions has been implemented in the elsA environment. The two different positions considered are fully deployed and partially deployed (~90°, Figure 9).

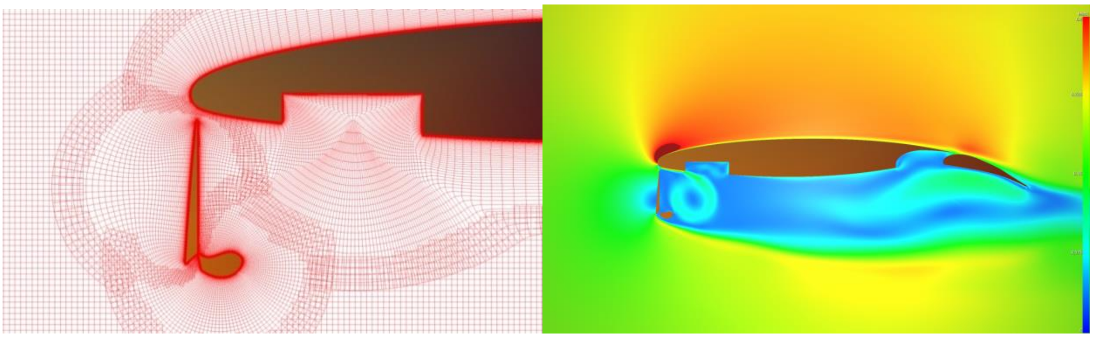


Figure 9: Chimera grid and solution – ONERA implementation

Then, kinematics of the Krueger elements (main part and bull nose) are controlled independently and first URANS computations of a complete cycle of deployment / retraction has been done.

This first methodology is ready for use for UHURA test cases to be investigated. A second methodology for the blanked cells management is under evaluation in term of computational efficiency.

Contribution of Partner 5-INTA

An assessment of a Lattice Boltzmann Method (LBM) based on a stress wall-modeled LES (WMLES) has been carried out. Studies regarding grid resolution and numerical settings for LBM WMLES have been performed with the aim of establishing best-practices guidelines for the validation phase to be carried out in WP4. First, a set of 3D (2.5D) static simulations (with fixed geometry position) have been conducted on the DLR-F15-LLE initial design at four selected representative positions of the Krueger device deployment/retraction: retracted, ~90°, leading-edge passage and fully deployed (Figure 10). Results have been compared with reference 2D RANS calculations for two configurations (retracted and deployed). Preliminary results showed that tripping turbulence was necessary to obtain resolved turbulence in the boundary layer of the upper surface. Hence, the strategy of turbulence tripping by means of roughness elements has been examined in the context of WMLES. A parametric study of the size and geometrical distribution of the roughness elements has been conducted for the retracted Krueger device position. The results show an improvement in the simulation in comparison with reference RANS solution even though the flow is inevitably perturbed.

Finally, a set of dynamic computations have been carried out using the numerical settings obtained from the analysis of the static cases. Complete 3D deployment and retraction simulations of the Krueger device have been performed using an immersed boundary method to deal with moving geometries (Figure 10). The results look reasonable overall in spite of the aforementioned difficulties related to turbulence generation. The necessary computational resources in terms of CPU-hours have been assessed, showing the potential of this alternative method to tackle scale-resolving simulations for complete Krueger device retraction/deployment phases. The experience gained in the assessment study will be used in the validation stage within WP4.

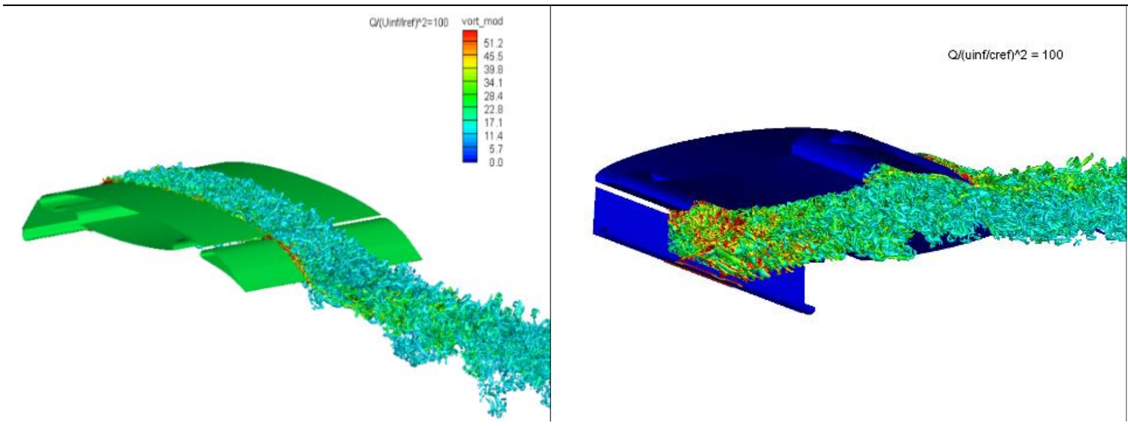


Figure 10: Iso-surface of dimensionless Q criterion for two positions of the Krueger device, LBM simulations by INTA.

<u>Contribution of Partner 6-NLR</u>

The flow solver development activities concern:

- Development of a line-implicit time integration approach for high-lift applications.
- Improvement of the interpolation process for large disparities in cell size in the interface region of discontinuous grids.

A line-implicit scheme has been implemented that accelerates the convergence per time step for the dual time-stepping approach. Its efficiency has been verified for building block applications that represent steady and unsteady flow cases such as an oscillating boundary layer. Test computations using this scheme are performed on the Chimera grid for the moving Krueger device generated in Task 2.1 to compute the time-dependent flow.

In order to improve the treatment of discontinuous interfaces, the in-house developed flow solver has been generalized to the full Chimera approach. Thus, full 3D interpolation is used instead of 2D interpolation along discontinuous interfaces, so that any disparity in cell size is automatically taken into account. The Chimera approach has been tested for the simulation of the unsteady flow field around a deploying Krueger device, consisting of a double-hinge motion for the bull-nose and base elements (Figure 11). Verification of the time-dependent flow solutions shows that the developed flow modelling capability is ready to be employed within UHURA.

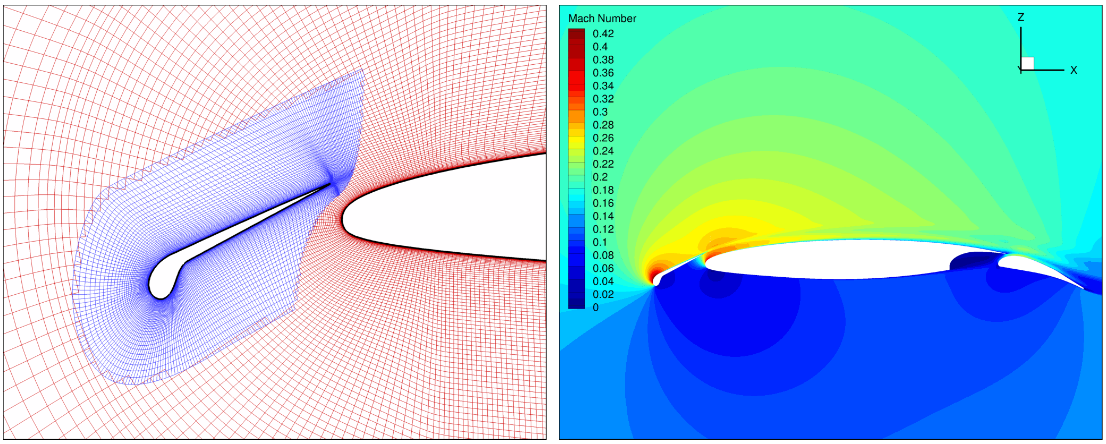


Figure 11: Chimera grid and solution for fully deployed Krueger flap, NLR implementation

<u>Contribution of Partner 8-KTH</u>

Automatic parametric meshing using Pointwise for different flap setting has been made (subcontracted as planned) for the initial and final test geometries containing a structured block in the wake region behind the Krueger flap suitable for LES resolution.

U-RANS of the moving two-hinged Krueger flap have been made by use of mesh deformation and remeshing using the automatic meshing tool for a full deployment and retraction cycle with different deployment velocities.

Refinements of numerical schemes for accurate and efficient hybrid RANS-LES computations have been made. Numerous hybrid RANS-LES studies of a fixed position around 90 deg are done for studying the effects of mesh refinement, time step and numerical schemes for best accuracy and efficiency. Different hybrid RANS-LES methods are tested and analysed concerning resolution and spectral content. The conclusion is that simulations of the full cycle will be affordable for the experimental setup, and that the Spalart-Allmaras DDES (SA-DDES) gives the most accurate and reliable results.

The quasi-steady approach has been implemented and tested for a pitching airfoil. The unsteady computation at a specific time can be well reproduced by a steady-state computation with forcing computed based on the unsteady RANS.

Hybrid RANS-LES (SA-DDES) computations of a full deployment cycle of 1.2s has been made for the two-hinged flap (Figure 12).

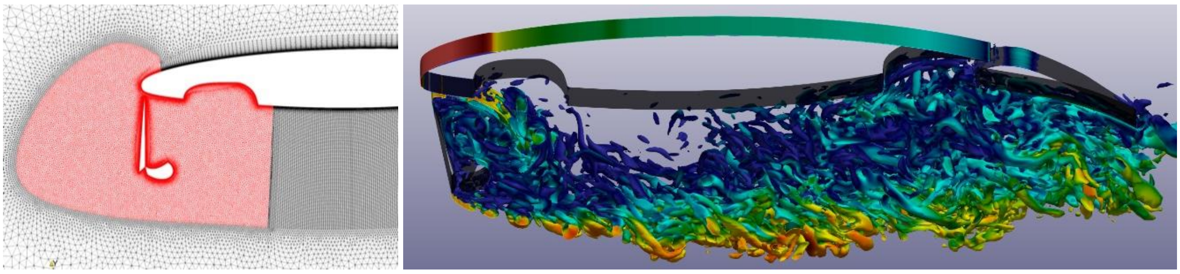


Figure 12: Mesh and snapshots of Q criterion at T = 0.5 s (71.5°) during the deployment, DDES simulations by KTH.

Contribution of Partner 9-IBK

IBK is developing an FSI-Interface tool in cooperation with CIRA. This tool should enable FSI-simulations employing existing CFD and CSM tools. The UZEN/SIMBA of CIRA and NASTRAN are used as CFD and CSM tools, respectively. The data exchange format will be adaptable to the used tools. In the current work, the CFD data exchange format is TECPLOT-format while the CSM uses the NASTRAN bdf-format. The main task of the FSI-interface tool is to provide a means of transferring aerodynamic loads from CFD to CSM and transferring mesh deformations and deformation velocities from CSM to CFD. With a proper tool chain, FSI-simulations involving CFD-tool, FSI-interface and CSM-tool should be realized. Therefore, the method development concerns primarily with the interpolation procedure, data processing and process control. The interpolation procedure is based on the radial basis function (RBF). The method enables accurate aerodynamic load data transfer from CFD-mesh to CSM-mesh and then to transfer the deformation data from CSM-mesh back to CFD-mesh. Prior to the application of the FSI-interface tool, CFD and CSM models have to be prepared and they should be compatible each other. IBK is responsible for preparing the CSM model.

The initial version of the FSI interface tool concerns a “static two-way coupling” in the way that the CSM applies the linear static solver. It allows a loose interaction between CFD and CSM where deformation velocities are not taken into account. This FSI-method has been successfully tested on the conventional 3 element airfoil (DLR-F15-3eRef) where slat and flap are simultaneously deployed.

The FSI interface tool is then further developed to deal also with a “dynamic two-way coupling”, where the dynamic behavior of the structure is accounted for. Both structural deformations and deformation velocities will be then exchanged between CFD and CSM. The method is now exercised on the DLR-F15-LLE Krueger configuration (Figure 13). Due to current aerodynamic limitations the Krueger panel and Bullnose are merged into a single Krueger element. The Krueger kinematics is accordingly adapted. Setups and computations are on-going. Small delay in delivering the results and deliverables is expected.

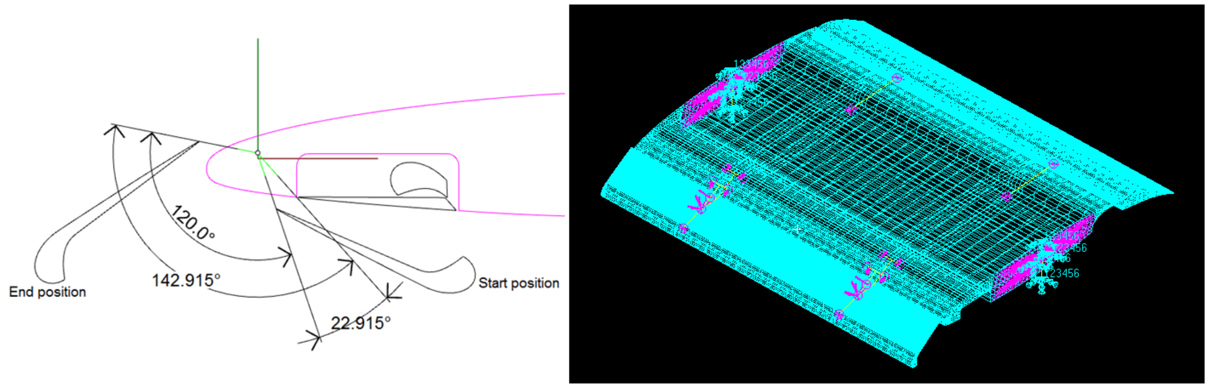


Figure 13: The FSI interface tool applied on the DLR-F15 LLR Krueger configuration

Contribution of Partner 11-Dassault

Different hybrid RANS-LES methods (VLES, IDDES and ZDES) as well as different subgrid length scale models have been implemented and tested. In particular advanced RANS models are considered. Implementation and validation is still ongoing.

DES computations have been performed on the fully extended Krueger slat configuration.

Work planned for the next reporting period (M19-M36)

The objective with Task 2.1 during months 18-21 is basically to finish the development works to be ready for the next phase of the project when the development work will be utilised for the wind tunnel setup in WP4. The deliverables in Task 2.2 will be completed. In specific

- to assess the capabilities in simulating moving frames in the present computational frameworks.
- to assess the selected improvements for accelerating of unsteady CFD
- to finish the improvements on flap movement algorithms, and
- to complete the study of alternative methods for capturing unsteady CFD with mowing Krueger flap.

2.3 *WP 3: Validation Experiments*

Lead: DNW

WP3 Objectives for M1-M18 of UHURA

- Design of the modifications of the wind tunnel model DLR-F15 and DLR-F15*LS*
- Definition of the measurement system setup.
- Experimental evaluation of the unsteady capability of standard pressure measurement equipment

Progress achieved/results within reporting period (M1-M18)

The design of the wind tunnel model modifications for the DLR-F15 model has been finalised (CDR at M16). The model stress analysis has been finalised and reporting is scheduled to be delivered within this reporting period. Model manufacture is scheduled to be finished before end of M19. Design modifications of the DLR-F15*LS* model have started.

The setup of measurement techniques has progressed. The evaluation of the unsteady capability of standard pressure measurement equipment has been completed and reported. The definition of the test setup and measurement approach has started.

2.3.1 3.1 – Model modification

Lead: DLR

Task 3.1 objectives for the reporting period (M1-M18) of UHURA

- design model modifications for DLR-F15 model to incorporate the Krueger device and leading edge designed in WP1
- perform FEM analysis for stress report on wind tunnel model
- manufacture and assemble DLR-F15 model modifications and instrumentation

Progress achieved/results within the reporting period (M1-M18)

Contribution of Partner 1 - DLR

After receipt of the wing geometry and the designed Krueger device from WP1, model design has been performed for the modification of the DLR-F15 wind tunnel model. The CAD data has been verified and the Krueger device has been implemented (Figure 14). The design comprises a full-span and a part-span version of the Krueger flap (Figure 15). First load assessments in wind tunnel conditions showed a high overload for the Krueger drive shaft. Load mitigations have resulted in a reduction of the angle of attack for the dynamic movement. This reduced angle of attack is in line with flight conditions for the operating Krueger device. The detailed design phase was initiated by issuing a design check list, which has been discussed and consolidated by a Preliminary Design Review (PDR) in conjunction with the 2nd Progress Meeting (PPM2). The design of the model has been finalized by a CDR held in M16. A corresponding design report (D31-1) has been provided. Manufacturing has been started right after and the process is in good progress. First parts – mainly parts of the kinematics – are ready and available (Figure 16). The remaining parts are expected for early M19 (March 2020) for final assembly. The shipping of the model to ONERA L1 wind tunnel is expected for late M19.

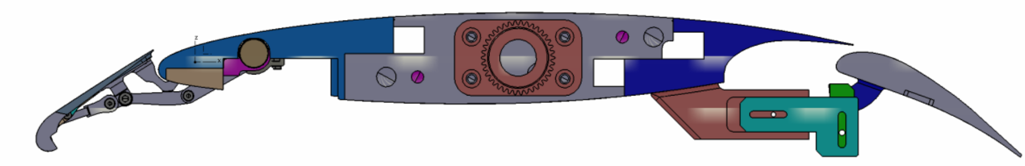


Figure 14: DLR-F15-LLE wind tunnel model with Krueger flap

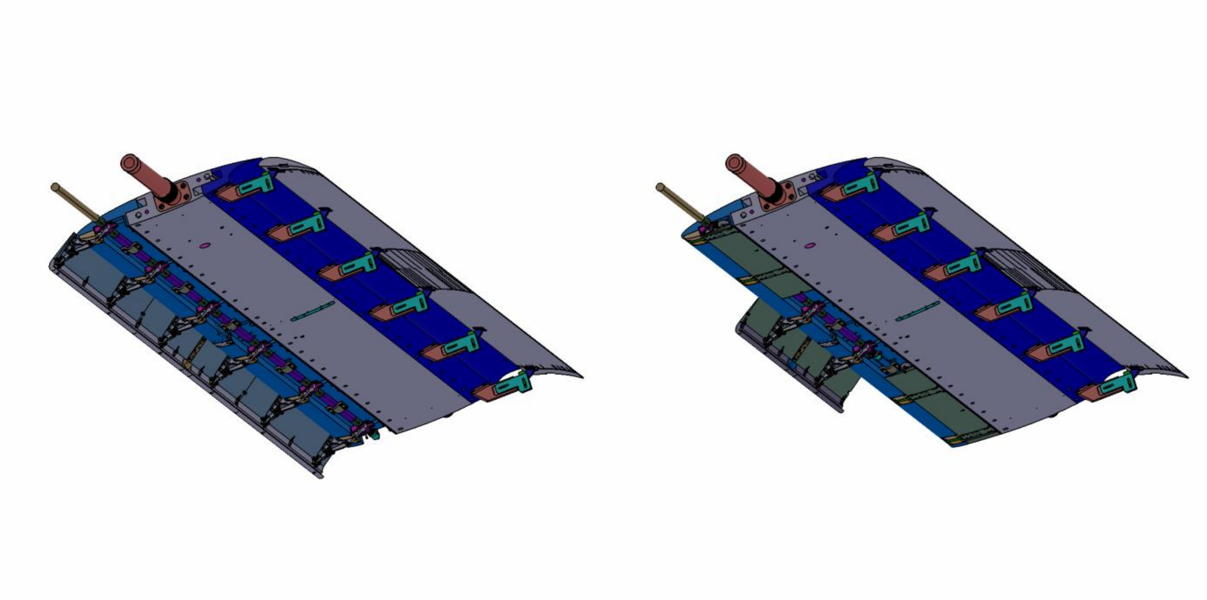


Figure 15: setup of wind tunnel model with (left) full span and (right) part span Krueger flap

Figure 16: manufactured Krueger kinematics for the DLR-F15 model

Contribution of Partner 7 - ASCO

After participating to the Task 3.1 Kick-Off Meeting in M9, ASCO assisted in the definition of the design/sizing ownership split of the model. ASCO was identified as responsible for the final sizing of the kinematical (moving) components, excluding the Krueger panel and bull nose.

Based on the aerodynamic loads obtained from DLR in WP1, ASCO set up a full-span GFEM to compute all interface loads appearing within the kinematical system (Figure 17). A selection of the critical load cases for component sizing was made. Three loading conditions were considered: static fully extended Krueger, dynamic (operating) Krueger & Krueger in 'barn-door' position (90° to flow field). Following interface loads and moments were computed for the 3 loading condition for all AoA:

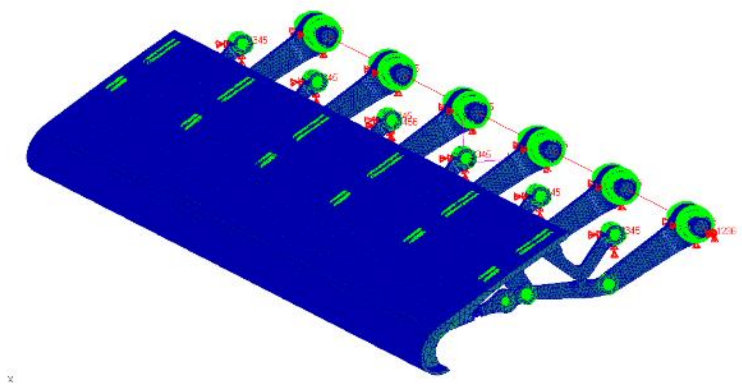


Figure 17: Illustration of the full-scale GFEM to compute all interface loads and moments

Following the results of the drive lever reaction torque computations, an issue was identified: the accumulated torque along the different support stations would require a drive shaft diameter that could not be integrated into the confined wing leading edge opening; moreover, the induced angular deformation of the drive shaft would be excessive. Hence, Task 1.2 (kinematics design) was reopened to investigate design changes that could solve this issue.

In order to reduce the reaction torque on the drive shaft in the most critical condition (i.e. statically fully extended Krueger at AoA = 21°) a contact feature between the Gooseneck and Drive Link components was introduced (Figure 18). Through this contact, reaction load is diverted to another load path and the drive shaft torque is drastically reduced. This leads to a drive shaft diameter that could be integrated into the wind tunnel model.

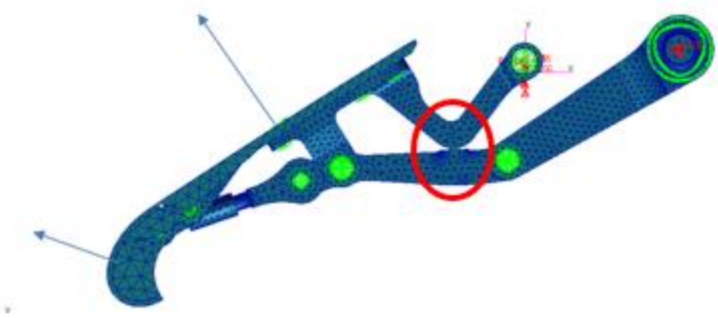


Figure 18: contact feature between Gooseneck and Drive Link to alleviate drive shaft reaction torques

All kinematical components in the ASCO-scope were sized to avoid failure of a kinematical component and protect the wind tunnel. Sizing was done by means of hand-calculation methods, DFEM or GFEM. For all parts a reserve factor > 1 proves sufficient strength. These values include the Safety Factors required by the wind tunnel institutions.

The final kinematics design and sizing was presented and accepted by the WP3 partners during PDR in M13 and CDR in M16. ASCO compiled a summary Stress Report of the sizing activities on the DLR-F15 model kinematics as Part 2 of the IBK deliverable D31-3.

Contribution of Partner 9 - IBK

IBK is mainly responsible for Bullnose and Krueger panel structural design and their interface to the kinematics. Common criteria regarding max. combined stress, shear stress and max. dynamic loads have been derived for both wind tunnel entities ONERA and DNW. The distributed Krueger loads on the Bullnose and Krueger panel for the critical case have been mapped to the FE model. The FE-analyses for the Krueger configuration of the DLR-F15 model has been carried out. IBK and ASCO shared the work in the way that ASCO does the design and FE-analyses for the kinematics and IBK does the FE-analysis for the whole model. The stress report for the model is in progress.

The definition of a concept for strain-gauge measurement as a provision for Krueger-force measurement has been started. An FE-analysis to determine the proper location of strain gauges for load monitoring is ongoing.

Work planned for the next reporting period (19-M36)

Complete model design and manufacture model modifications for the DLR-F15 model. Transfer modifications to large DLR-F15*LS* model. Manufacture modifications on large model.

2.3.2 Task 3.2 – Adaptation of measurements.

Lead: DLR

Task 3.2 objectives for the reporting period (M1-M18) of UHURA

In this task unsteady optical flow field measurement techniques and their synchronized interplay during the Krueger device deployment and retraction phases will be adapted to the DLR-F15 and DLR-F15*LS* models in order to characterize the flow in a plane (or a thin volume) around the moving wing parts. The related WT campaigns in L1, DNW-LLF and DNW-NWB are planned in strong collaboration with DNW and ONERA coordinated by DLR. 2D TR-PIV, phase locked dual Stereo PIV and SPR measurement methods have been assessed according to the defined requirements (desired measurement volume and spatial resolution) and experiences from previous campaigns. Synchronization strategies of these optical measurement techniques with many phase locked positions of the Krueger device motion and with unsteady pressure probes in the model have been discussed and defined for implementation at the respective wind tunnel campaigns. This combined and synchronized application of techniques will allow for a detailed characterization of the unsteady and transient flow field dynamics (shear layer and slat cove vortices), respective turbulence statistics and the dynamic model deformations according to the resulting Collar triangle of forces.

Progress achieved/results within the reporting period (M1-M18)

For the subtask 3.2.1 (DNW) (Unsteady pressure measurements / time resolved static pressure measurements) the aim is to establish if the standard pressure measurement system can be used for time resolved static pressure measurements. Within this reporting period, the effect of tube length has been assessed with a theoretical model. The results of the theoretical model were verified with a wind tunnel experiment in the DNW Low Speed Wind Tunnel (LST). The results include a definition of maximum tubing length and a data acquisition approach to synchronise the reading from conventional electronic scanning pressure modules with other measurement systems.

For Task 3.2 common progress of all involved partners (DLR, DNW and ONERA) has been made regarding discussion and definition of synchronization techniques and interchange of protocols between wind tunnel and measurement system units. The wind tunnel tests at ONERA L1, DNW-NWB and DNW-LLF will include a large variety of measurement systems and instrumentation. For a meaningful validation of unsteady CFD synchronicity between the sub-systems of different partners will is of high importance. The list below highlights the complexity of the wind tunnel experiment. The different sub systems have a multitude ofampling frequencies and data protocols:

List Data Acquisition Systems: (provider, description, WT test)

1. ONERA /DNW, Wind tunnel Flow Reference system (L1, NWB, LLF)
2. ONERA /DNW, Pressure modules (L1, NWB, LLF)
3. DLR, MEMS Unsteady pressure sensors (L1, NWB, LLF)
4. DLR, Angular Encoder of Krueger Shaft (L1, NWB, LLF)

5. DLR, Krueger Drive system, (L1, NWB, LLF)
6. DNW,SPR position Measurement system (LLF, possibly NWB)
7. DLR, Strain Gauges ion kinematic (L1,NWB, LLF)
8. DLR/ ONERA,PIV (L1, LLF)

The consortium is converging on a measurement approach to fulfil the requirement of synchronicity and to handle acquisition of all sub systems in an efficient manner. This approach will rely on:

- Hardware TTL level triggering to synchronise all sub-systems
- A Handshaking protocol to handle acquisition efficiently and to guarantee sound wind tunnel bookkeeping of data.

Contribution of Partner 1 – DLR

The available PIV related measurement methodologies have been assessed by all involved groups depending on the optical access and different sizes of the PIV field-of-view for the flow around the Krueger equipped F15 model at ONERA L1 and the respective larger F15LS model at DNW-LLF. Decisions regarding the particle image acquisition strategy and synchronization with SPR and dynamic pressure transducer probes have been made accordingly. For both wind tunnel tests phase-locked Stereo 3C2D- and 2C2D-PIV measurement techniques are foreseen allowing for unsteady phase resolved flow field measurements and mean and Reynolds stress statistics at many stages of the deployment and retraction phases of the Krueger device. Additionally, at ONERA L1 a time-resolved PIV system will complement the overall measuring systems allowing for a transient flow field characterization in a sub-volume downstream of the moving Krueger device. In DNW-LLF a synchronized SPR system will be applied in order to receive the exact Krueger device shapes and deformations during the individual deployment processes and phase positions of the SPIV measurements. Furthermore, both models will be equipped with many dynamic (MEMS at ~150 Hz, few Kulites ~kHz) and static pressure transducers (see Task 3.1), which will acquire data in synchronization with the PIV and SPR techniques.

A second activity of DLR is concerned with the setup of dynamic MEMS pressure sensors for unsteady measurements of local pressures. For the DLR-F15 model the design of the circuit board for mounting the Bosch BMP388 sensors has been completed. The first circuit boards for the Krueger bull nose have been equipped (Figure 19) and are currently tested and calibrated. The programming for data acquisition is in progress.

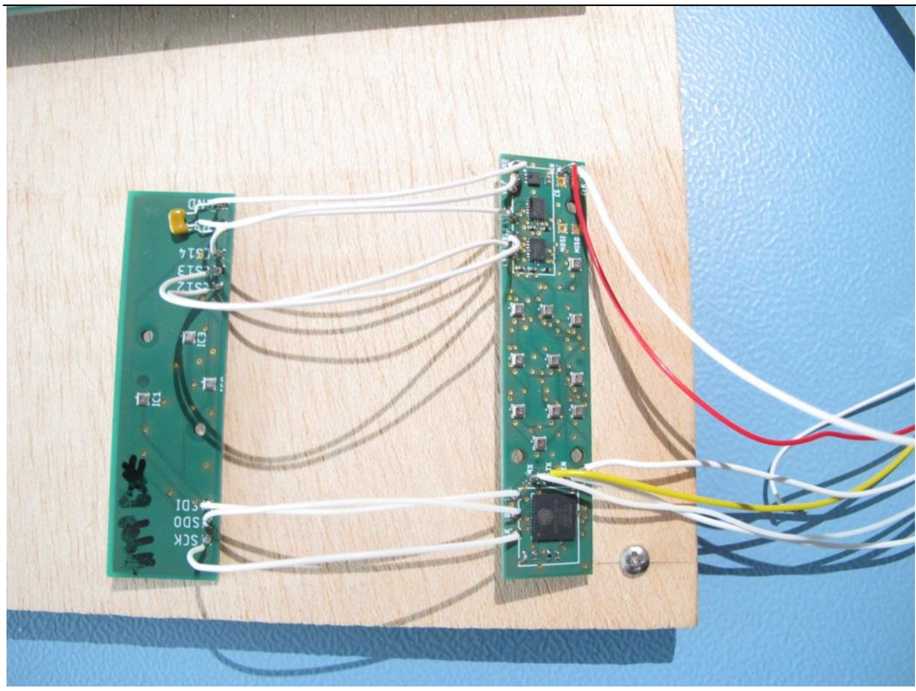


Figure 19: circuit boards with a total of 14 Bosch BMP388 MEMS pressure sensors for the Krueger bull nose of the DLR-F15 model

Contribution of Partner 12 – DNW

The experiments to verify the measurements of unsteady pressures using conventional pressure modules have been performed in the DNW-LST. A moving wind tunnel model was manufactured consisting of a rotating cylinder (Figure 20). Model actuation rate was similar and above to the UHURA requirements (up to 180⁰/s was achieved). The pressure signal from conventional pressure tap-tubing -module configuration were compared to surface mount device (Kulite) results

Analysis of the results has been finalised and reporting was performed in order to complete deliverable D32-1. The results have shown that unsteady pressures at the acquisition frequencies required by UHURA can be measured using conventional pressure modules, provided that the tubing length is shorter than 0.7 m. Furthermore, DNW has developed a programmable sequencer and acquisition software modules within the wind tunnel data acquisition system to allow for synchronous time resolved measurement of both pressure signals and other measurement techniques. These experiences are a vital preparation for the final wind tunnel experiments in the DNW-LLF.

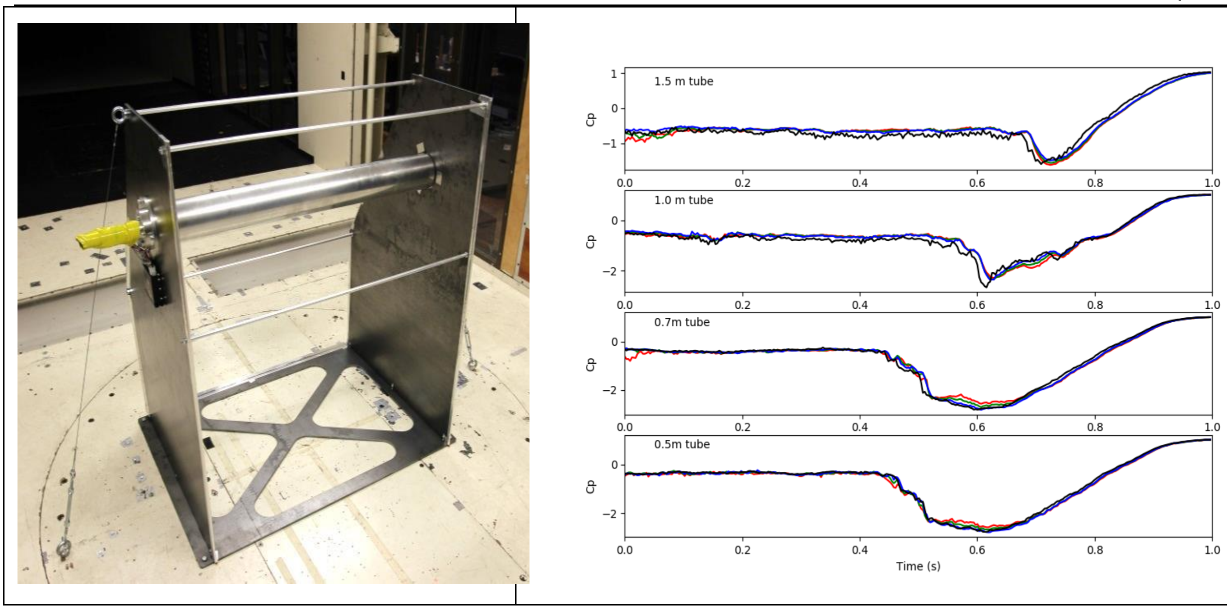


Figure 20: (left) Rotating wind tunnel model in the DNW-LST. (right) Pressure signal from a high bandwidth Kulite (black line) compared to a pressure tap-tube-transducer system (colored lines) for different tube lengths.

Work planned for the next reporting period (M19-M36)

Within the next 6 month experimental campaign at ONERA L1 WT will be performed and first preliminary evaluations of SPIV and TR-PIV measurements will be provided. A strategy for a phase locked synchronization of many sub-systems will be elaborated in practice and experiences gained from the found criticalities and solutions can be transferred for the two other planned wind tunnel tests in DNW-LLF and DNW-NWB. This will additionally ensure a proper acquisition and synchronization of all involved moving model parts, the wind tunnel main parameter settings and the individual optical and probe measurement techniques. Furthermore, final decision will be made regarding the data format of all results achieved by the various data acquisition and measurement systems as input for further post-processing steps and comparisons with the numerical simulations.

Additionally the configuration of the SPR setup will be explored. To capture the full 180 degree rotation a 4 camera SPR system will be designed. Additionally an appropriate marker placement and post-processing strategy will need to be explored.

2.3.3 Task 3.3 – Experiments

Lead: DNW

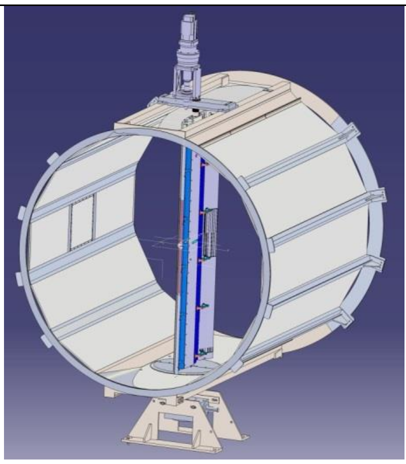
Task 3.3 objectives for the reporting period (M1-M18) of UHURA

- Design and preparation of the wind tunnel experiments.
- Ensure experimental design compatibility with model design and validation activities

Progress achieved/results within the reporting period (M1-M18)

Discussions on the design of the wind tunnel experiments have been progressed. This includes discussions on synchronisation of different measurement sub-systems and the measurement sequence and automation.

The test setup of the wind tunnel tests in ONERA L1 and DNW-NWB have been designed (Figure 21). This included design of the PIV setup and mounting of the Krueger device drive system.



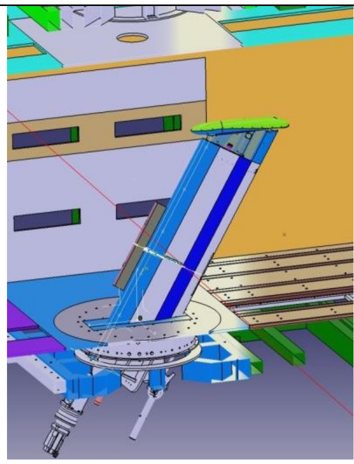


Figure 21: installation of DLR-F15 wind tunnel model in (left) ONERA L1 and (right) DNW-NWB wind tunnels

Work planned for the next reporting period (M19-M36)

Finalise design of the measurement approach including aspects on synchronisation and integration/automation before the ONERA L1 wind tunnel test

Perform wind tunnel testing with DLR-F15 model in ONERA L1 and DNW-NWB wind tunnels, and with DLR-F15*LS* model in DNW-LLF wind tunnel

2.4 *WP 4: Validation & Assessment*

Lead: NLR

WP4 Objectives for M1-M18 of UHURA

- development of a roadmap for the comparison of data generated by wind tunnel experiments and CFD simulation activities;
- start the preparatory modelling activities related to the simulation of Krueger device deployment on the modified DLR-F15-LLE model, prior to the campaign in the ONERA L1 wind tunnel.

Progress achieved/results within reporting period (M1-M18)

Task 4.2 features an early start to facilitate a harmonisation activity on experimental and numerical data for validation purposes. Future comparisons are described in deliverable D42-1. Task 4.1 was planned to start in M14. However, several partners are in the finalisation of their CFD tool developments (Task 2.2) and the final geometry definition for the wind tunnel model was delivered late (M17). As a consequence, the activities for Task4.1 have been delayed. This might not necessarily affect the target date of most of the Task 4.1 deliverables since partners are well prepared for Krueger deployment simulations due to signification commonalities with the applications adopted in Task 2.2.

2.4.1 Task 4.1 – Assessment of simulation methodologies

Lead: CIRA

Task 4.1 objectives for the reporting period (M1-M18) of UHURA

- start preparatory activities (mainly CAD/CSM preparation and meshing) for the subsequent computation of the modified DLR-F15 model to be tested at ONERA-L1 WT at M18.

Progress achieved/results in the reporting period (M1-M18)

The final CAD of the DLR_F15-LLE model with Krueger (ONERA-L1 geometry) was delivered end of M17 from Task 3.1, while several partners are in the finalization of their CFD tools upgrading in Task 2.2. Accordingly, little activities were carried out in Task 4.1 so far. This is not seen as critical, as Task 4.1 activities are embedded between (and linked to) Task 2.2 and Task 3.1, and logically follow the timeline of such tasks.

Work planned for the next reporting period (M19-M36)

At M19 a telecon will be organized by CIRA, in order to review both individual objectives and working plan with the involved partners in Task 4.1, as well as a recap/harmonization of the test matrix distribution. It is expected that in M19-M20 all partners involved will start preparatory activities for the ONERA-L1 test case, to be finalized with CFD results between M26-M28. Subsequent activities will consider a similar CFD codes assessment working plan for the next two WT campaigns planned, i.e. DNW-NWB (M22) and DNW-LLF (M26).

2.4.2 Task 4.2 – Validation and assessment – data comparison of numerics and experiment

Lead: VZLU

Task 4.2 objectives for the reporting period (M1-M18) of UHURA

- establish a roadmap for the comparison of wind tunnel test data and numerical results of simulations

Progress achieved/results within the reporting period (M1-M18)

The data gathered during coordination meetings, available documentation and other discussions regarding mainly the experimental campaigns was summed, put into the context of CFD work. Information on future wind tunnel data has been gathered from coordination meetings in WP3 regarding the experimental campaigns and test article instrumentation in available design reports. Future comparison of surface pressures, flow field data (PIV) and loads data are described in deliverable D42-1 "Roadmap for the comparison of wind tunnel test data and numerical results". The document has been reviewed and submitted.

Work planned for the next reporting period (M19-M36)

After the definition of comparison data was done in the Deliverable 42-1, there will be a pause in the activities of this task until M28, when the main part of the comparison starts with gathering partners' data. The measurement data of the wind tunnel tests of Task 3.3 will be analysed i and will prepared for comparison with CFD results obtained in Task 4.1 for validation purposes.

2.4.3 Task 4.3 – Assessment and exploitation

Lead: AID

Task 4.3 objectives for the reporting period (M1-M18) of UHURA

No objectives in reporting period

Progress achieved/results in reporting period (M1-M6)

Task 4.3 is not yet active and is scheduled to start in M31

Work planned for the next reporting period (M19-M36)

The coming work is concerned with the exploitation of transient aerodynamic data to assess the impact of Krueger motion on complete aircraft level and to analyse span-wise deployment concepts for a Krueger implementation. The measured/computed unsteady loads on the Krueger device are utilised to perform weight estimations for a Krueger structural concept. The collected information aims to provide guidelines and best practices for design approaches for novel Krueger devices on future aircraft.

2.5 WP 5: Management & Dissemination

Lead: DLR

Progress achieved/results before reporting period (M1-M8)

The objective of this work package is the continuous management and progress monitoring of the project including preparations of major meetings. Especially in the ramp up of the project the installation of database for communication and data exchange was a major aim.

The project was started on time and a kick-off meeting was held in October 2018 where already first steps were reported, mainly on the provision of background information and the setup of the database. The database server has been installed and access information has been provided to all partners. The 1st Progress Meeting was held in April 2019 at KTH, Stockholm, Sweden. The 2nd Progress Meeting was held in September 2019 at INTA, Madrid, Spain.

WP5 Objectives for M1-M18 of UHURA

- Monitor project status
- Perform periodic reporting
- Provide data exchange capabilites

Progress achieved/results within reporting period (M7-M12)

The project is running smoothly. Minor delays are encountered in few work packages. Status of issues is closely tracked to minimize the impact on the overall project. Database is up and working for data exchange.

2.5.1 Task 5.1 – Management

Lead: DLR

Task 5.1 objectives for the reporting period (M1-M18) of UHURA

- Preparation, calling and chairing of Kick-Off meeting
- Perform Quarterly Status Reportings
- Conduct 1st and 2nd Progress Meeting (PPM1/PPM2)
- Issue of 1st and 2nd Progress Report
- Update of UHURA Handbook
- Submission of Deliverables
- Preparation of Midterm Review Meeting

Progress achieved/results before reporting period (M1-M18)

The management of the UHURA project has run smoothly during the first reporting period of the project. No cost or serious time problems have been reported.

The Kick-off meeting took place on October-16th/17th, 2018 at ASCO, Zaventem, Belgium. The first Progress Meeting (PPM1) and General Assembly has been held on April 4th/5$^{th.}$, 2019 at KTH, Stockholm, Sweden, the second Progress Meeting (PPM2) and General Assembly on Sept 18th/19th, 2019 at INTA, Madrid, Spain. For all meetings it is intended to always combine General Assembly and Progress Meetings in order to bring all partners together for a technical review and discussion.

Table 1 shows the planned and scheduled project meetings up to now. Table 2 lists additional meetings of dedicated Tasks and Work packages to more closely establish the cooperation.

Table 1: List of project meetings, dates and venues;

Month of UHURA	Progress Meetings; General Assembly	Progress Reporting
M1 **Kick-off**	Oct 16th/17th 2018 – ASCO (Zaventem)	-
M6	PPM1 Apr 4th/5th 2019; KTH (Stockholm)	Interim Report 1 (IR1) Apr-2019
M12	PPM2 Sep 18th/19th 2019, INTA (Madrid)	Interim Report 2 (IR2) Aug-2019
M18	PPM3 / PRM1 Apr 2nd 2020, ONERA (Lille)	Progress Report 1 (PR1) Mar-2020
M24	PPM4 Sep 2020, DNW (Marknese)	Interim Report 3 (IR3) Aug-2020
M30	PMP5 Mar 2021, CIRA (Capua)	Interim Report 3 (IR3) Mar-2021
M36	PPM6 / PRM2 Aug 2021, AID (Bremen)	Progress Report (PR2) Aug-2021

Participation in "General Assembly" meetings is mandatory for all partners.

Table 2: additional WP/task technical meetings schedule

WP	Topic of Meeting	Lead	Date	Host / Location
1	WP 1 progress	AID	18/01/2019	Telecon
1	WP 1 progress	AID	21/02/2019	Telecon
1	WP 1 progress	AID	08/03/2019	Telecon
3.3	Task 3.3 Kick Off meeting	ONERA	28/01/2019	ONERA (Lille)
3.3	Task 3.3 – Progress (Model/Equipment etc ..)	ONERA	21/03/2019	Telecon
3.1	Task 3.1 Kick-Off meeting	DLR	07/05/2019	NLR (Amsterdam)
3.1	Task 3.1 progress	DLR	as of 22/05/2019	regularly bi-weekly
3.1	PDR of the DLR-F15 model	DLR	17/09/2019	INTA (Madrid)
2.2	Task 2.2 meeting	KTH	18/09/2019	INTA (Madrid)
3.1	CDR of the DLR-F15 model	DLR	04/12/2019	NLR (Amsterdam)

WP	Topic of Meeting	Lead	Date	Host / Location
3.2	Task 3.2 measurement synchronisation	DNW	21/02/2020	Telecon
2.2	Task 2.2 meeting	KTH	01/04/2020	Telecon

Contribution of Partner 1 – DLR

The Kick-Off meeting was prepared and held on October 16th/17th at ASCO premises.

Quarterly Status Reporting was initiated and collected every three months.

Updates of the UHURA handbook have been issued including the status reports obtained by Quarterly Status Reporting.

The 1st Progress Meeting (PPM1) has been held on April 4th/5th at KTH, Stockholm.

The 1st Progress Report (D51-1) has been completed and submitted.

The 2nd Progress Meeting (PPM2) is has been held on Sep 18th/19th at INTA, Madrid.

The 2nd Progress Report (D51-2) has been completed and submitted.

12 deliverables have been submitted in the meantime to the SyGma site.

Work planned for the next reporting period (M19-M36)

Closely monitor project progress.

Conduct 2nd Midterm Review Meeting, scheduled for April 2nd at ONERA, Lille.

Continue Quarterly Status Reporting and updates of Handbook.

Prepare the Progress Meetings and Progress Reports.

2.5.2 Task 5.2 – Dissemination

Lead: DLR

Task 5.2 objectives for the reporting period (M1-M18) of UHURA

Monitor dissemination activities of the project.

Progress achieved/results before reporting period (M1-M18)

Contribution of Partner 1 – DLR

The exhibition of UHURA together with the AFLoNext Ground Based Demonstrator has been proposed to the organizing committee of the AeroDays 2019 conference. Unfortunately due to complexity of the setup it was only able to show the demonstrator during specific visits to INCAS where the GBD is stored.

In the frame of the ECCOMAS 2020 conference, a Special Technology Session (STS 07) has been setup, which contains some scientific overview presentation on UHURA achievements.

Contribution of Partner 7 – ASCO

ASCO performs internal dissemination to early implement the project's content into its business strategy.

Work planned for the next reporting period (M19-M36)

The dissemination of the project will be monitored. Specific scientific contributions by partners to conferences are expected. The setup of a project web site is targeted to be completed in the coming period.

Table 3: List of documents and papers published

No.	Author(s)	Title	Where/when published
1	Wallin S, Hanifi A, Bagheri F	Meshing and CFD strategies for large scale turboprop WT model integrating morphing high-lift devices"	10th Aerospace Technology Congress, October 8-9, 2019, Stockholm, Sweden
2	Ponsin J	Experiences of using LBM Xflow in the EU H2020 Project UHURA	3DExperience Conference Design, Modeling & Simulation, March 11-12, 2020, Barcelona, Spain

2.5.3 Task 5.3 – Database

Lead: IBK

Task 5.3 objectives for the reporting period (M1-M18) of UHURA

- Provision of the UHURA database server on which all technical input data, reports, deliverables, minutes of technical and management meetings, technical results and publications are stored and exchanged between partners. Access to the server are granted and restricted only to the UHURA participants only.
- Maintenance of the database server
- Providing technical support for the database

Progress achieved/results before reporting period (M1-M6)

The database server had been established and already in service. It provides a common platform for data exchange between all UHURA-partners. Guidelines for accessing the server has been issued and all partners can now access the server. Two deliverables had been issued, namely:

- D53-1 Database server with online access capabilities
- D53-2 Guideline for the access, security and data transfer for the UHURA database server.

Database server is maintained online around the clock, enabling partners to access the server for data uploading and downloading. Technical support is provided to place the data on the right place and also to help partners in accessing data.

Contribution of Partner 9 – IBK

IBK is the only participant within the Task 5.3. All the task objectives mentioned above are performed by IBK

Work planned for the next reporting period (M19-M36)

Continuing maintenance of database server and technical support

3 Impact

The UHURA project addresses the mode specific challenges in the area of „Aviation”. UHURA as a Research and Innovation Action (RIA) concentrates on focused research on advanced high-lift aerodynamics targeting two broad lines of activities that is specified by the Horizon 2020 Programme

- Resource efficient transport that respects the environment and
- Global leadership for the European transport industry

governed by the Transport Challenge "Smart, green and integrated transport".

3.1 *Impact on society by addressing environmental footprint of aviation*

UHURA aims to qualify the Krueger flap device as the leading edge high-lift system enabling laminar wing technology which, contributes to a reduction of aircraft drag of approximately 10% and consequently a reduction of fuel consumption and emissions.

Within the first reporting period the project activities prepared the basis to realize this impact. A Krueger flap has been designed for the DLR-F15-LLE airfoil. The requirements of aircraft industry have thoroughly been taken into account. By this, the current design and related experiences closely match the needs of industry and reflect the current expectations on potential improvements. Finally, the detailed information expected to be obtained from the coming wind tunnel test will provide further insight on the impact of integrating the high-lift design into the laminar wing. Thus, the project will at the end provide answers to important questions of integrating laminar wing technology into future aircraft designs. Due to the improved simulation capabilities introduced in the frame of UHURA, a simplification of the high-lift system is envisaged that significantly contributes to increased system reliability and safety, reduced Recurring Costs (RC) in production and assembly as well as COC benefits through reduced maintenance efforts, overhaul and repair.

3.2 *Impact on society by strengthening European aviation industry as key employer*

UHURA will contribute towards maintaining the leadership of the European aeronautics industry. UHURA will develop computing solutions for key industrial problems to facilitate the introduction of innovative products and services. In order to validate numerical simulation approaches, two existing wind tunnel models are currently modified. Numerical simulation methods have been adopted to be able to simulate the unsteady aerodynamics of high-lift devices and the experimental setup for performing dedicated experiments to create validation data has been designed and mostly manufactured. By this, the tools for a full validation and quantification of the unknown unsteady aerodynamics are available for the second phase of the project. The experimental data base that will be created during the UHURA project is expected to serve as a broad validation data base for the future.

The exploitation of unsteady high-lift aerodynamic modelling including CFD-CSM coupling and its validation thanks to enhanced wind tunnel testing techniques addressed by the UHURA project aims

- to eliminate the uncertainty imposed by the impact of unsteady flow during deflection/retraction within the high-lift design with consequences on aircraft loads and therefore structural weight;
- to provide validated numerical flow analysis and CFD-CSM coupled simulation enabling taking into account critical load cases during deflection/retraction of the high-lift system at high accuracy;
- to transfer the knowledge and capabilities gained in this project to other types of moving surfaces at an aircraft, e.g. control surfaces, spoilers, speed brakes, landing gear doors, or thrust reversal, to contribute to a reduction in weight and costs of those devices too, due to

a more prediction of unsteady loads and corresponding improved sizing of such components;
- by this to contribute to a significant reduction in the design cycle time due to more accurate and more early specific design even for non-primary flight conditions.

The close integration of major European aircraft manufacturers into the project guarantees the future application of the experience gained in the project within the design procedures. By rolling out simulation capabilities refined and validated in the project enables those to fully exploit the gained experience into the processes needed to implement Krueger devices on new aircraft types.

4 Update of the plan for exploitation and dissemination of result

The exhibition of UHURA together with the AFLoNext Ground Based Demonstrator has been proposed to the organizing committee of the AeroDays 2019 conference. Unfortunately due to complexity of the setup it was only able to show the demonstrator during specific visits to INCAS, where the GBD is stored.

In Table 4 the currently planned events of project dissemination are listed. In the scope of the International Aeronautics Exhibition ILA '20 it is planned to provide a slide show to be shown at the INEA exhibition.

A major part of dissemination of the UHURA project is the deployment of the scientific results to the community, majorly by contributions to scientific conferences and articles in peer reviewed journals. Table 4 lists the currently foreseen dissemination activities. One contribution to a conference has already been provided (see Task 5.2 description). Three further contributions are scheduled. For the ECCOMAS 2020 conference it is planned to give two talks on scientific achievement obtained in the UHURA project within a specifically organized Special Technology Session (STS).

For the second reporting period, a significant larger number of scientific publications is expected. At the end of the project it is planned to organize a project workshop showcasing the achievements of the project to a wider audience. It is currently foreseen to hold this workshop at the premises of Airbus in Bremen. This would allow especially a wider outreach towards industry and its representatives not directly involved in the project.

Table 4: expected major events to disseminate UHURA's results and achievements

Event	Type	Expected date	Audience	Aim
10th Aerospace Technology Congress	conference	October 2019	scientific	highlight UHURA meshing strategies
3DExperience Conference Design, Modeling & Simulation	conference	March 2020	scientific	preliminary assessment of LBM methods for the UHURA application
ILA 2020	aeronautics fair	May 2020	wider audience interested in aeronautics	showcase video on UHURA activities
ECCOMAS 2020	conference	July 2020	scientific	special technology session on high-lift aerodynamics simulations
UHURA Final Workshop	workshop conference	August 2021	representatives of stakeholders, industry and funding bodies	provide information on UHURA's achievements to an audience of prospected users, especially industrial entities not directly involved in the project.

5 Risk assessment and mitigation

Risk assessment and mitigation is supported by a quarterly report procedure. Tasks indicate arising issues in terms of budget, schedule or content and propose a measure to minimize the impact on the overall project. Table 5 provides an overview on the quarterly reporting done so far. Few minor time problems (yellow) are indicated.

Table 5: Quarterly status summary of UHURA tasks

		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
		M1-3	M4-6	M7-9	M10-12	M13-15	M16-18	M19-21	M22-24	M25-27	M28-30	M31-33	M34-36
Task	Leader	Sep-Nov '18	Dec'18-Feb'19	Mar-May'19	Jun-Aug'19	Sep-Nov'19	Dec'19-Feb'20	Mar-May'20	Jun-Aug'20	Sep-Nov'20	Dec'20-Feb'21	Mar-May'21	Jun-Aug'21
Task 1.1	Wild, J.		S	C									
Task 1.2	Vervliet, A.				T								
Task 1.3	Strüber, H.		T	SC									
Task 2.1	Maseland,H.		S	S	T	T	C						
Task 2.2	Wallin. S.				T	T	T						
Task 3.1	Wild, J.				T	T	T						
Task 3.2	Schröder, A.												
Task 3.3	Philipsen, I.												
Task 4.1	Iannelli, P												
Task 4.2	Prachar, A.			T	T	T							
Task 4.3	Strüber, H.												
Task 5.1	Wild, J.												
Task 5.2	Wild, J.												
Task 5.3	Graumann, G.												

color code:		
	not started	T - **Technical** Problem
	no problems	B - **Budget** problem
	minor problems	S - **Schedule** problem
	major problems	C - Task **completed**
	finalized	

6 Use of resources

Figure 22 shows the budget planned for the overall project in relation to the actual (estimated) costs of the project in M18. Actually about 27% of the budget has been spent. Due to the small delay in terms of model manufacturing and wind tunnel testing, the costs especially in the categories "Other Direct Costs " and "Subcontracting" are proportionally less used. This will change in the soon future as the first test is on the horizon and the test shall be completed until M27. For the "Personnel Costs" one third of the budget has been spent. This is a significant underspending, but can be explained in the following when looking at the contribution of personal effort to the different work packages.

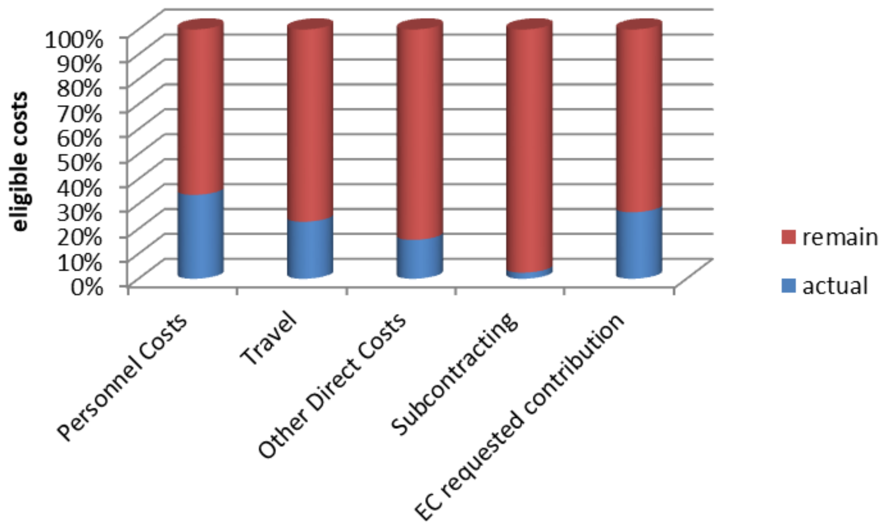


Figure 22: overview on spent budget divided into cost categories

Figure 23 lists the planned work effort for the full project runtime and used personal effort divided into the work packages. Figure 24 shows the relation for the reporting period only. It shows that 70% of the personal effort planned for the reporting period has been used.

The usage of resources is mainly concentrated on WP1 and WP2, which is according to the project planning. The underspending is according to the slight delays and re-planning in Task 1.2 and Task 2.2. Although in WP3 only a quarter of the personal effort is spent, this is in line with the planning as most of the wind tunnel work is to come in the next time. WP4 has not yet fully started and the spent resources are in line with the planned preparatory work. WP5 is in good shape showing a lean project management. Additionally, most personal resources will be spent in second reporting period due to the financial cost reporting and dissemination activities to come.

As a general conclusion, the project is in a good shape in terms of budget. Actual underspending is expected to be compensated in the second project phase. The use of resources and budget is in relation and no urgent need to account for changes in accounting methods is identified.

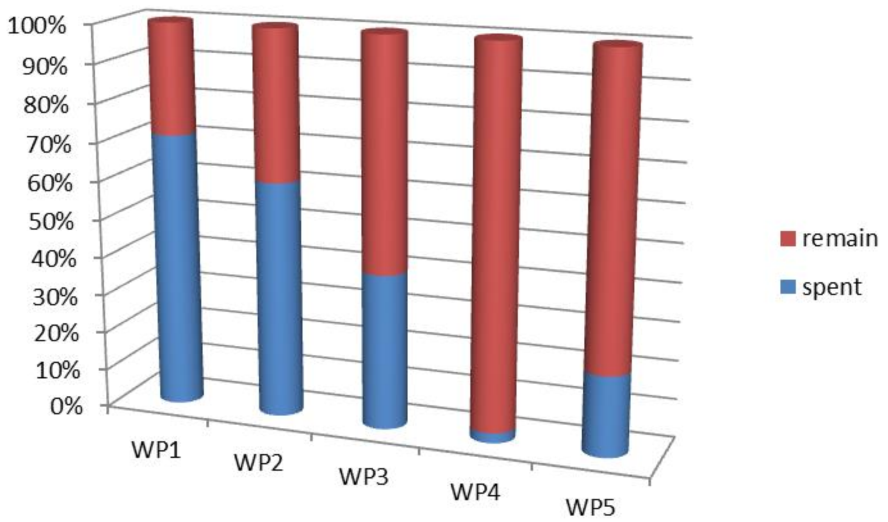


Figure 23: comparison of used personal effort resources and planned work for overall project runtime divided into work packages

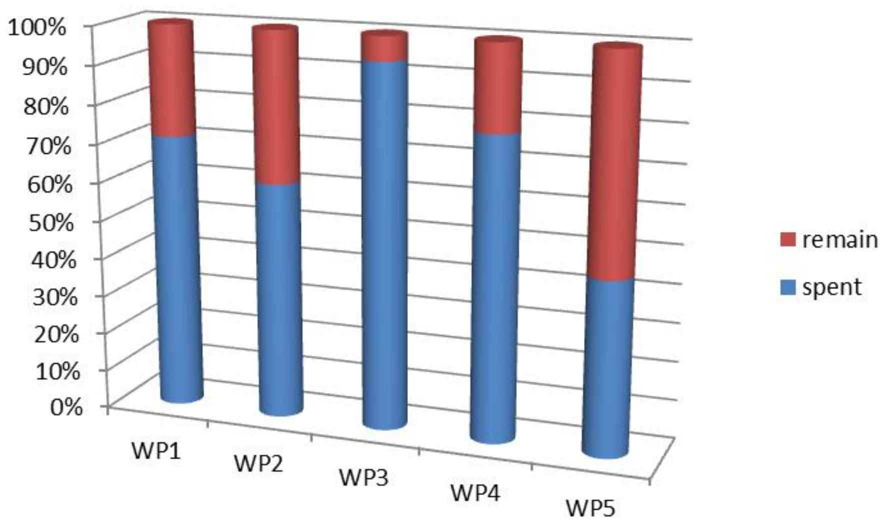


Figure 24: comparison of used personal effort resources and planned work for reporting period divided into work packages