Design, Simulation and Flight Reynolds Number Testing for Advanced High-Lift Solutions

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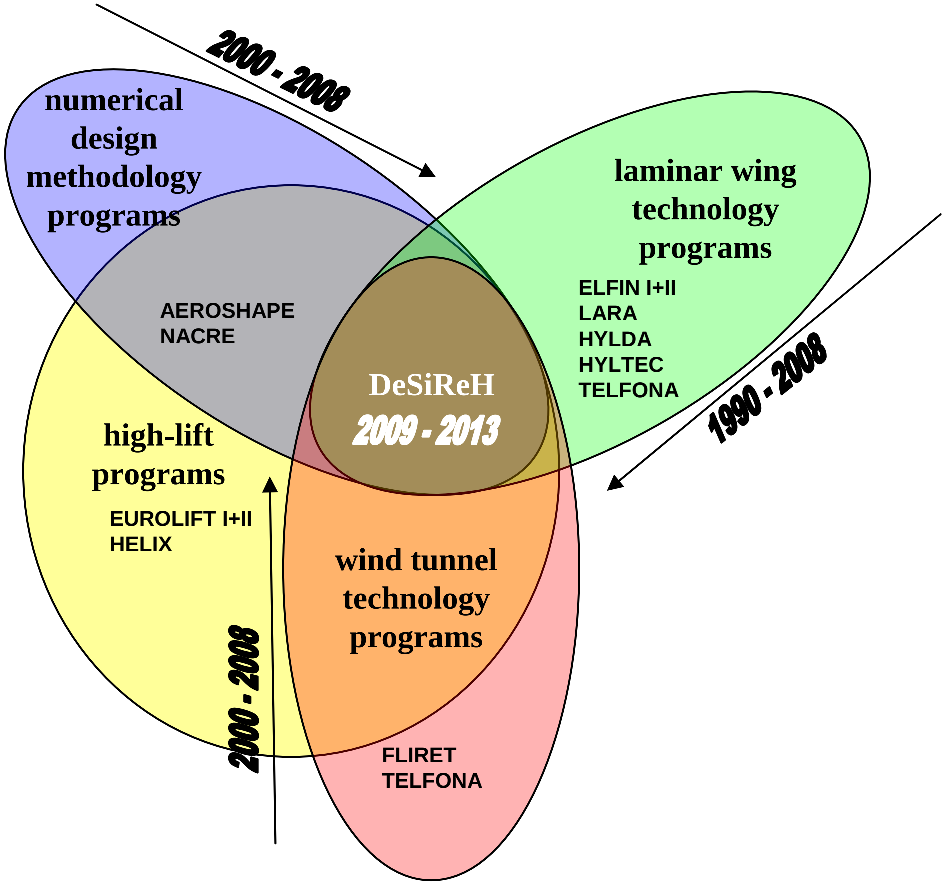
- Intention
- Goals
- Structure
- Results

DeSiReH's Target

- **Integrate research topics of previous EC projects in DESIREH in an attempt to foster high lift code application**



DeSiReH - Goals

Design chain based on high-fidelity methods

Embed and apply high-fidelity methods and advanced optimization approaches tailored for high-lift designs.

Reduce time to market

Improved capability to provide reliable predictions at flight conditions without the need of existing experience as benchmark through industrial embedded high-fidelity methods based optimization chain.

Reduction of environmental impact

Make a significant step beyond conventional high lift systems by designing and testing high lift for future high-lift concepts (low complexity, especially focusing "enabling" solutions for laminar wings)

High-Lift Performance prediction for "sharp edge" optimized design

Provide more precise prediction of 3D complex high lift flows addressing advanced optimization approaches including fluid-structural coupling and improved physical modelling (DES, turbulence models).

DeSiReH – Quantification of key Objectives

- **Maximum lift improvement up to 5%**

  Advanced optimization approache in terms of multi-physics & multi-objectives suited to design advanced & more efficient 3D high-lift systems.

- **Cost reduction of up to 5%**

  Provide **best practice approach** for reliable high-lift flow simulation for complex industrial high-lift configurations for a faster aircraft design

- **Reduction of environmental impact**

  Step beyond conventional high-lift systems by **designing and build a high-lift system for laminar wings** without degradation in high-lift performance

- **Drag reduction by 15%**

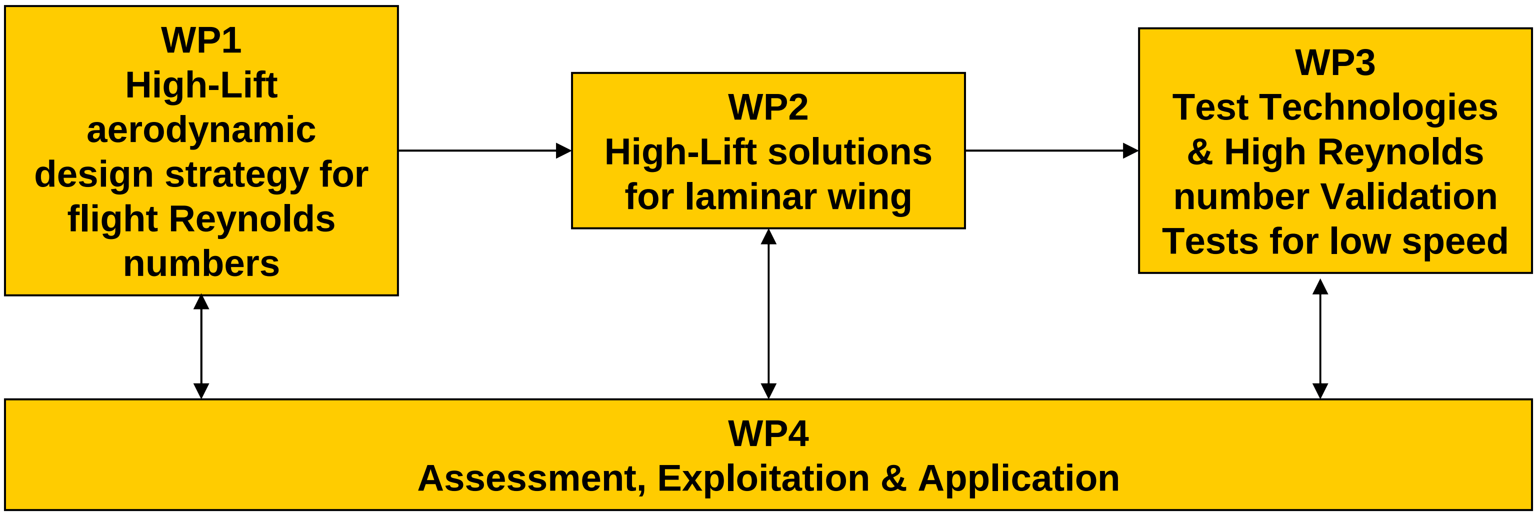
  Support a 15% drag reduction through laminar wing technology with installed high-lift system

DESIREH - Consortium

- Industry:
- SMEs:
- Non-profit public bodies:
- Universities:

- Effort: 356 PM (20 PM Management)
- Volume: 7.1 M€ – EC-funding: 5.0 M€

DeSiReH – Description



WP1: Embedding enhanced numerical optimization-environment based on high-fidelity methods in the design chain for High-Lift solutions.

WP2: Adaptation of the design chain to novel high-lift solution considering requirements of the laminar wing technology.

WP3: Flight Reynolds number testing and design verification

WP4: Design recommendation, Assessment of solutions versus V2020 targets

DESIREH – Time Line

2009	2010	2011	2012	2013

WP0: Management and Co-ordination

- T0.1 Project Management and Co-ordination / T0.2 Databank Maintenance

WP1: High-Lift aerodynamic design strategy for flight Reynolds numbers

- T2.1 Efficient formulation of optimization problem
- T2.2 Evaluation of different optimization strategies
- T2.3 Enhancement of prediction tools

WP2: High-Lift solutions for laminar wing technology

- T2.1 Design & optimization of compatible HL-system
- T2.2 High fidelity performance prediction
- T2.3 Design verification

WP3: Test Technologies & High Reynolds number Validation Tests for low speed

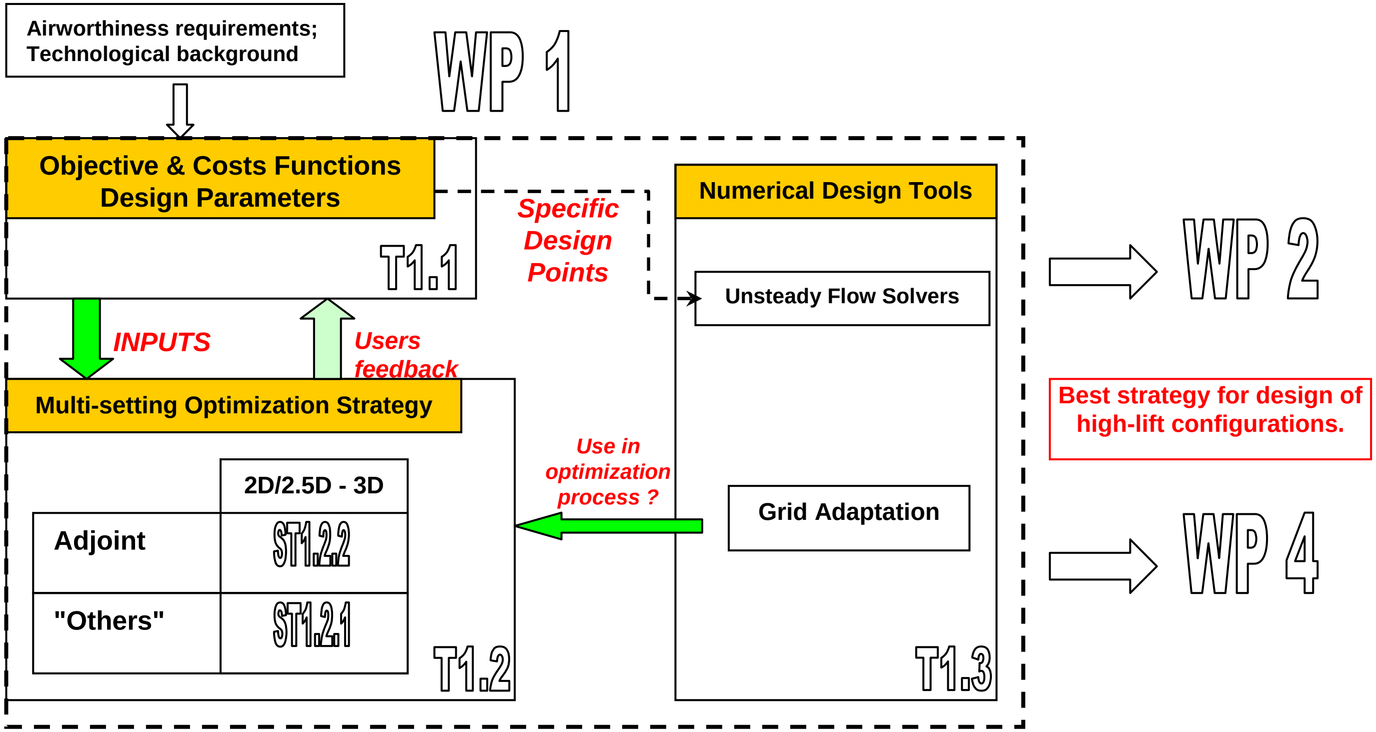
- T3.1 Advanced measurement techniques
- T3.2 Model manufacture
- T3.3 Flight Re number test

WP4: Assessment, Exploitation Application

- T4.1 Design recommen-dations
- T4.2 Strategy towards Vision 2020 targets

WP1 – High-Lift aerodynamic design strategy for flight Reynolds numbers

- specification of the design targets and parameters of high lift systems
- improvement of application of numerical design methods for an industrial application
- improvement of the efficiency of computational fluid dynamics (CFD)



WP1 – definition of design problem

performance indicators for high-lift for objective functions

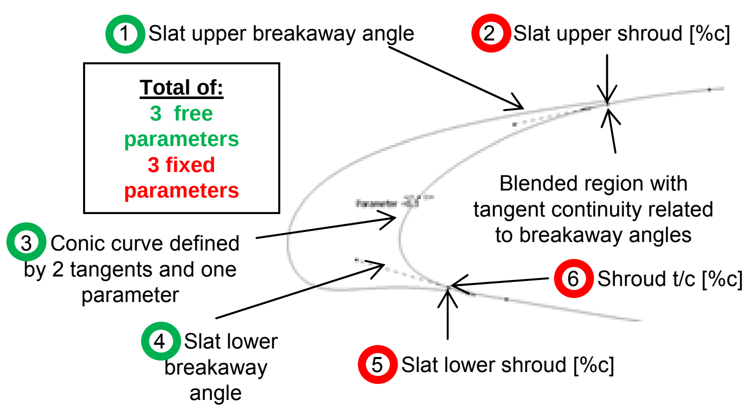
$$\underbrace{\max\left(0.03C_{L0} - C_{D,\alpha=0}\right)}_{\text{roll distance}} \qquad \underbrace{\min\left(V_{LOF}\right) \rightarrow \max\left(C_{L,\max}\right)}_{\text{roll distance, lift off speed}}$$

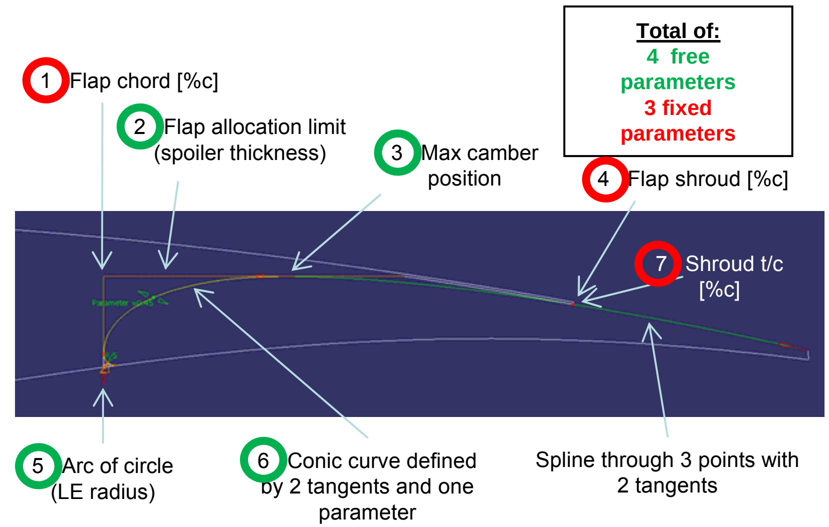
$$\underbrace{\max\left(0.274\frac{1}{\sqrt{C_{L,\max}}} - S_2^2\frac{CD}{C_{L,\max}^{3/2}}\right)}_{\text{second segment climb rate}} \qquad \underbrace{\max\left(0.257\frac{1}{\sqrt{C_L}} - \frac{C_D}{C_L^{3/2}}\right)}_{\text{third segment climb rate}}$$

$$\underbrace{\min\left(C_{D,V_{REF}}\right) \rightarrow \max\left[\left(\frac{C_L}{C_D}\right)_{\max}\right]}_{\text{fuel burn during approach}} \qquad \underbrace{\max\left(C_{L,\max}\right)}_{\substack{\text{approach speed}\\ \text{landing field length}}}$$

$$\underbrace{\frac{C_D}{C_L} < \frac{T}{G} - 3.2\%}_{\text{go-around climb angle (FAR25)}} \qquad \underbrace{\max\left(\frac{C_D^2}{C_L^3}\right)}_{\text{steep descent glide path angle}}$$

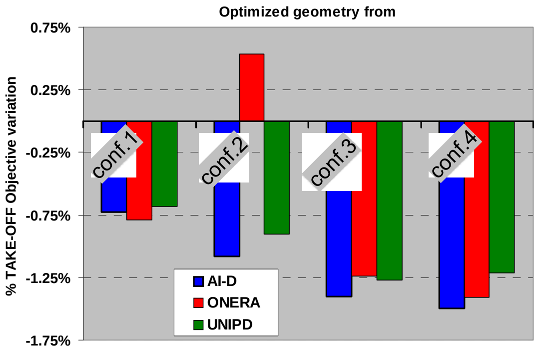
appropriate geometry definitions

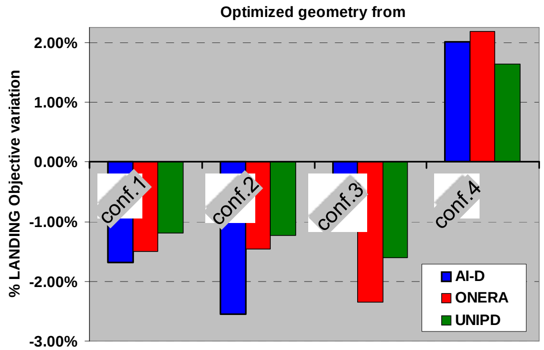




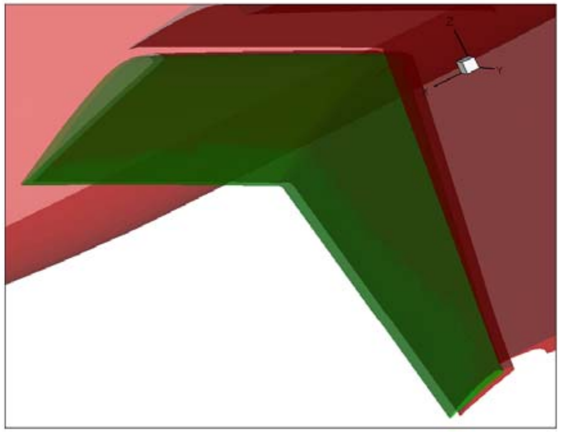
WP1 – optimization studies

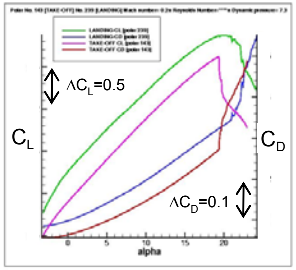
- simultaneous take-off/lanfing optimization
- 3D high-lift wing optimization

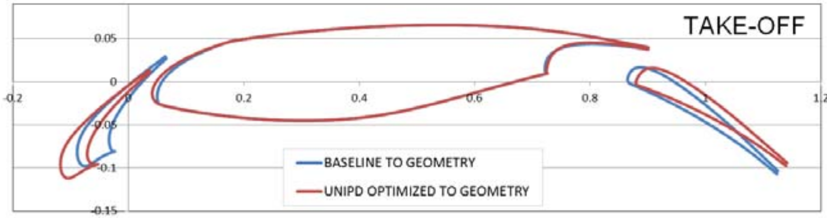


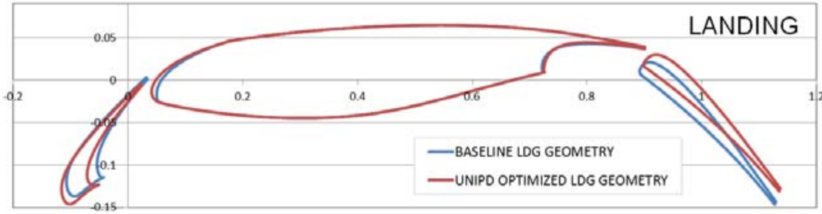


conf.1: sequential approach
conf.2+3: genetic multi-point optimizer
conf. 4: weighted one-point optimizer

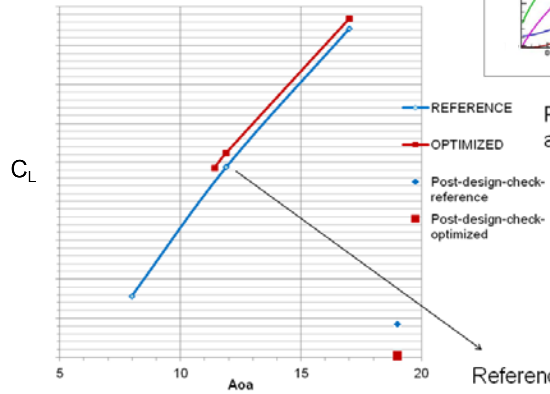








C_L- Aoa
3D TO configuration



Post design check at 19° within stall area, no constraint violation at 17°

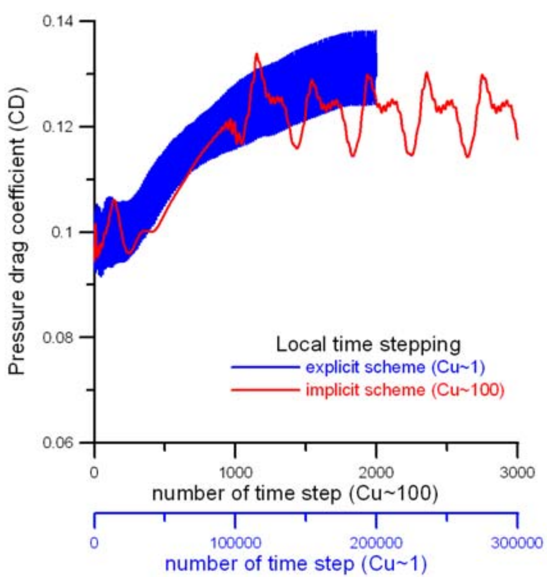
At $C_{L,initial}$ $\Delta(C_L/C_D)$ ~+2% for optimized configuration (37 drag counts)

Reference starting point @ TO-DP1

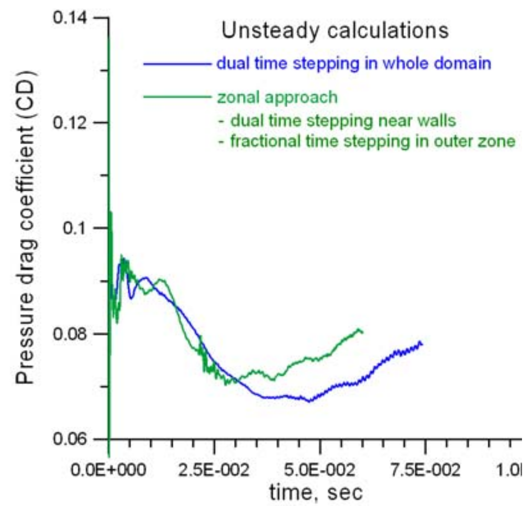
WP1 – improvement of CFD for high-lift flows

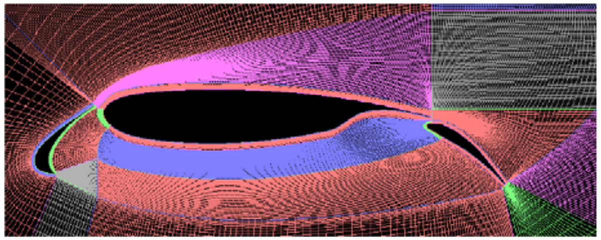
- acceleration of URANS CFD
  - evaluate emerging CFD techniques for application in high-lift conditions
  - unsteady flows due to local separations (e.g. flaps)

line implicit solvers on unstructured grids

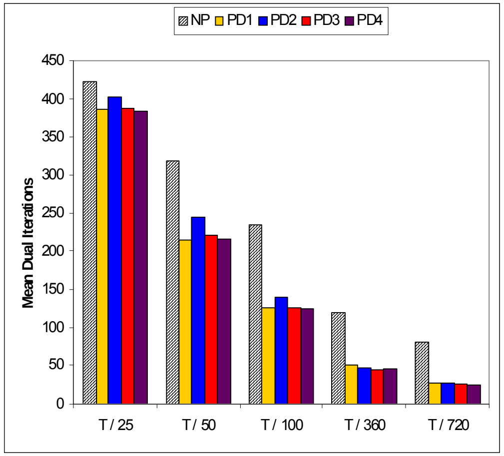


fractional time step approach





higher order time extrapolation

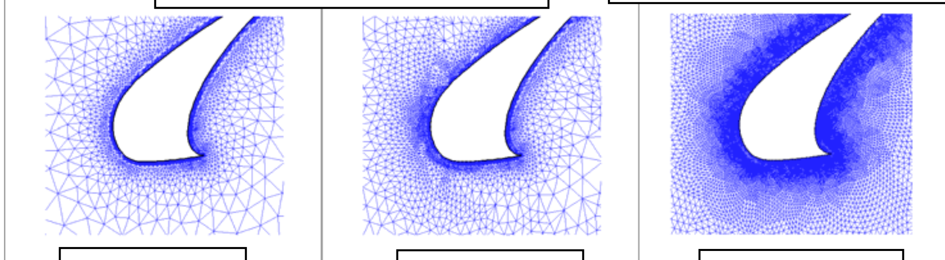


WP1 – improvement of CFD for high-lift flows

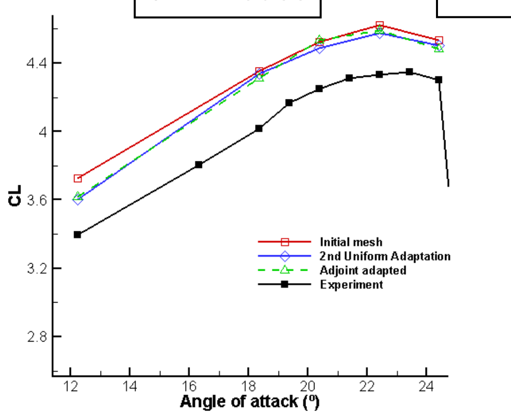
- improvement of mesh quality
  - grid adaptation sensors (flow feature, entropy, adjoint)
  - capturing of wake flows

adjoint based adaptation

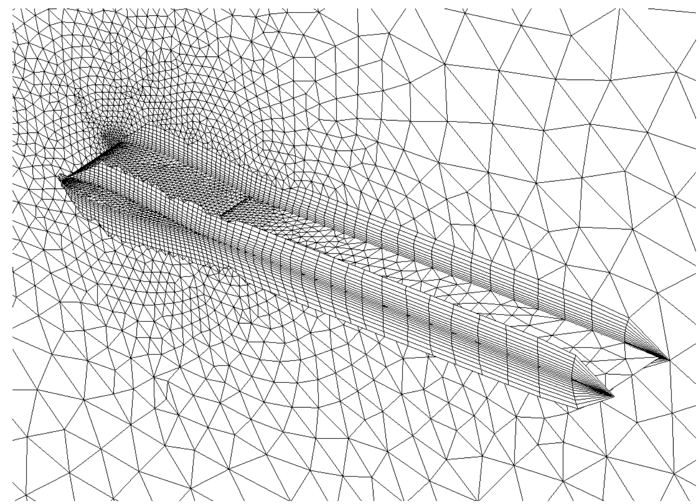
adjoint based refinement | vs. uniform refinement



55 K nodes | 84 K nodes | 460 K nodes

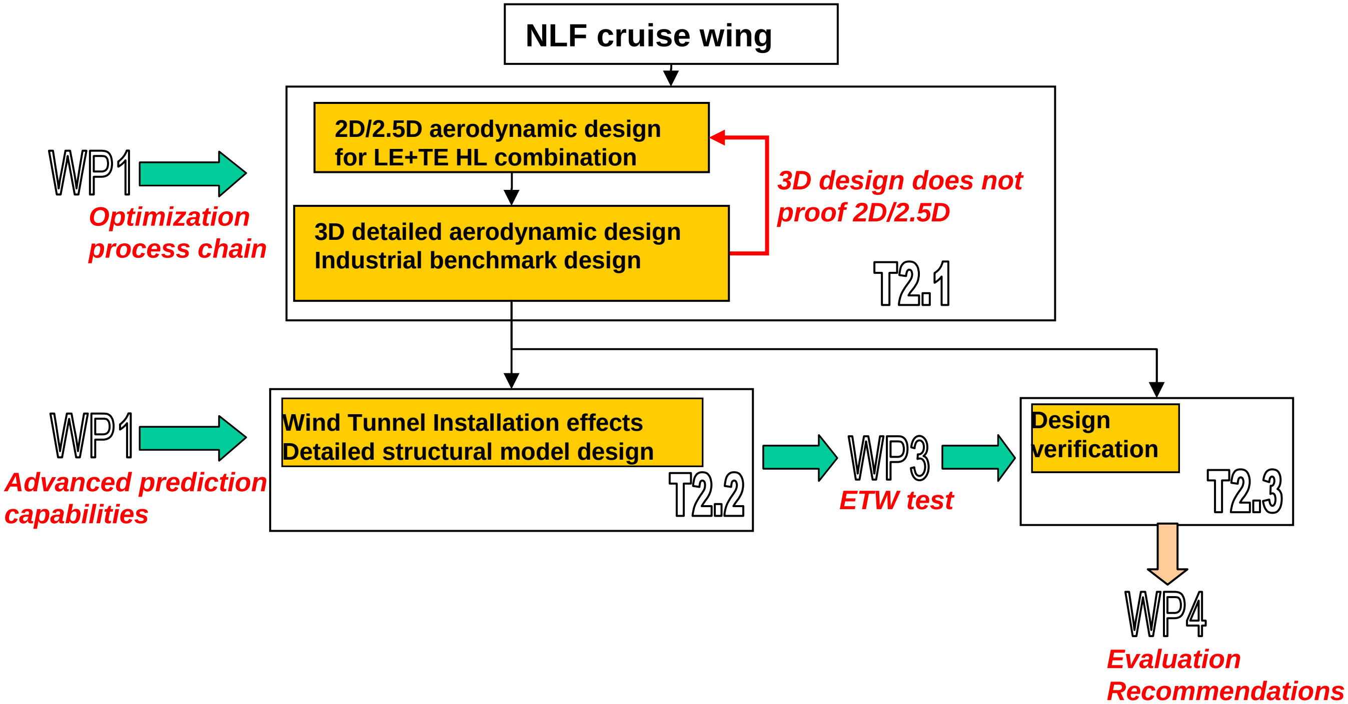


wake resolution



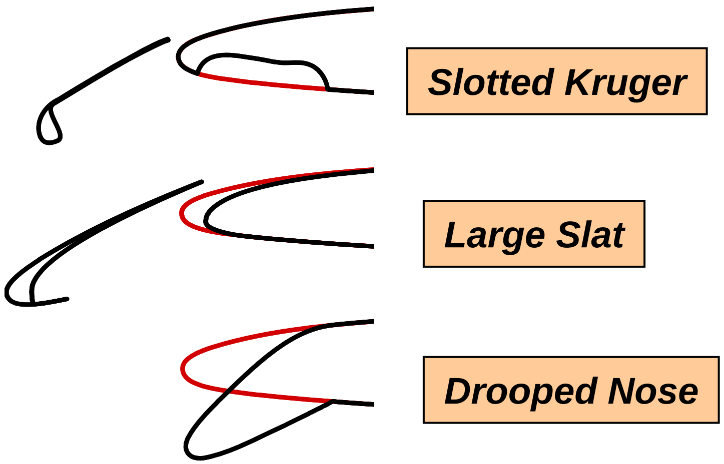
WP 2 - High-Lift solutions for laminar wing

- design a high-lift system for the TELFONA laminar wing
- evaluate the mechanical integration and possible infringements on laminar flow
- prepare detailed insight towards the expected uncertainties of wind-tunnel testing

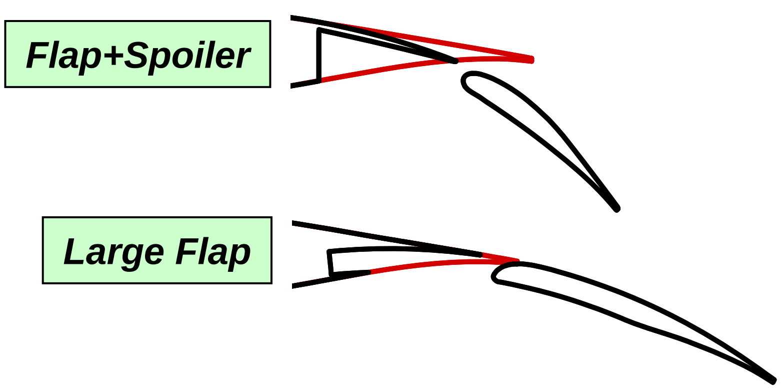


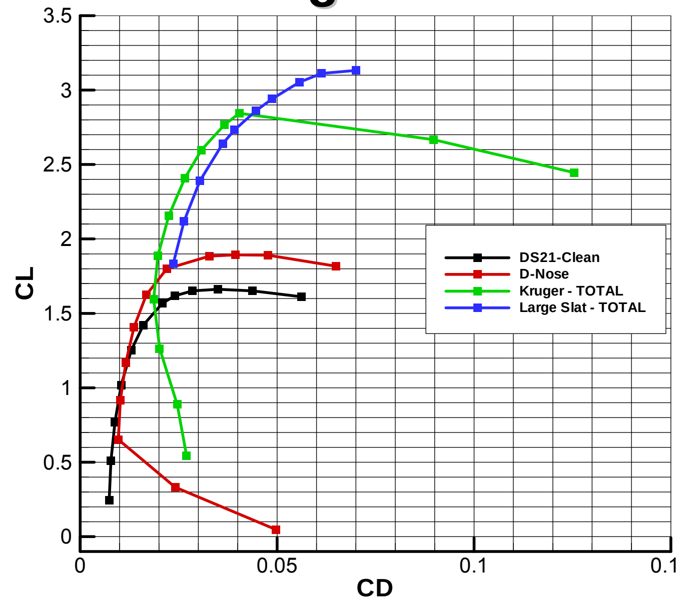
WP2 – high lift concepts for laminar wing

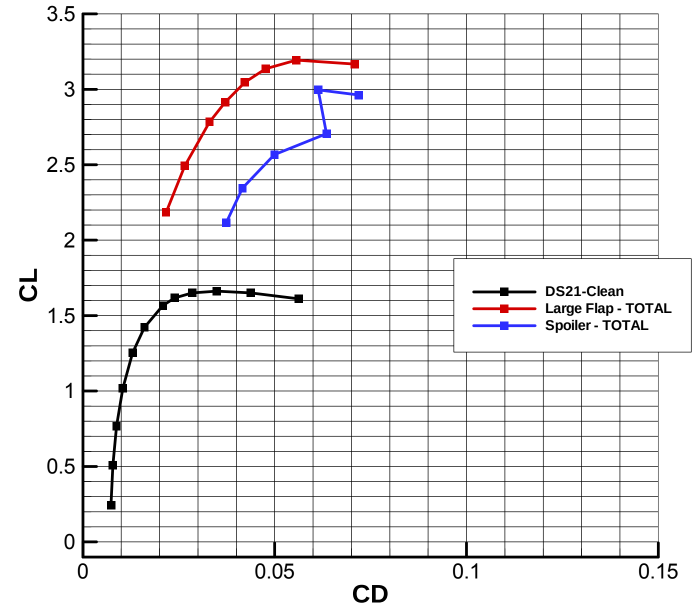
- leading edge



- trailing edge

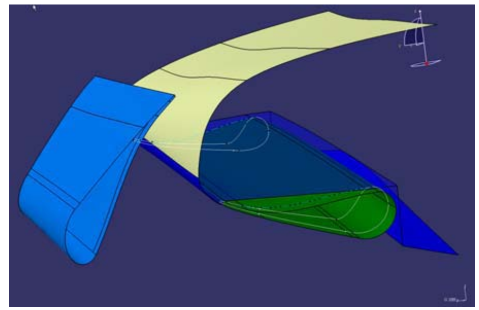


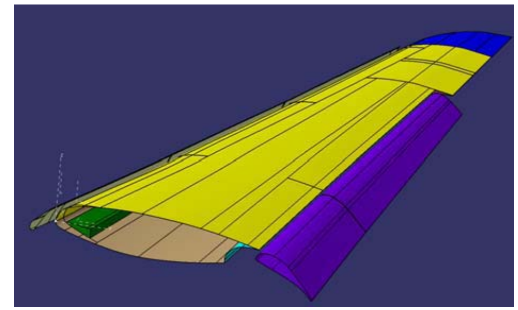




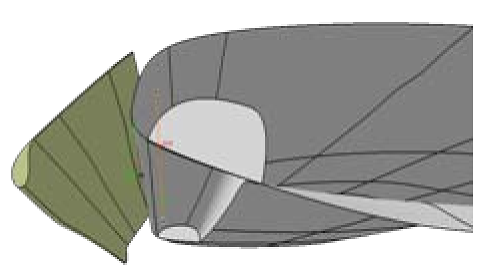
WP2 – high lift integration on TELFONA wing

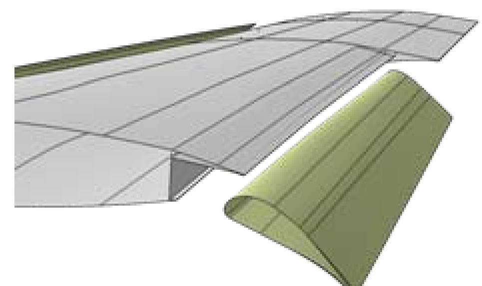
- reference design
  - ‘industrial standard’
  - 125° Krueger
  - standard flap



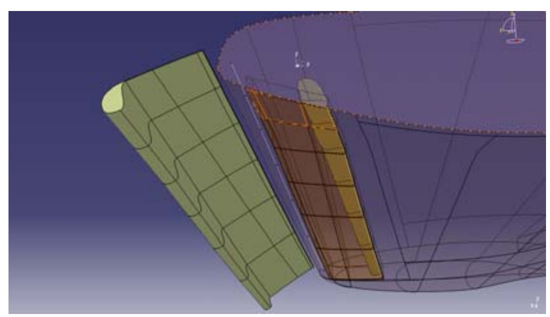


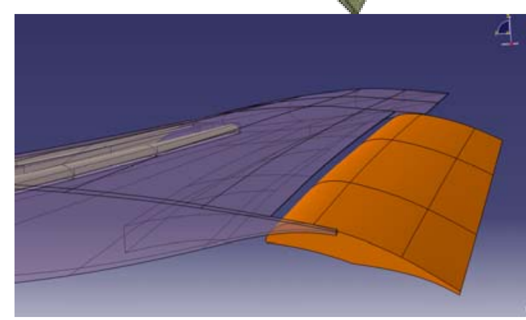
- alternative 1
  - folded Krueger
  - flap+spoiler droop





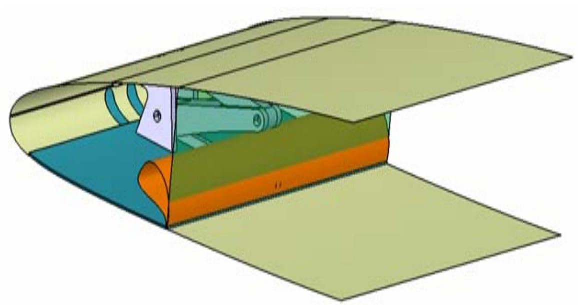
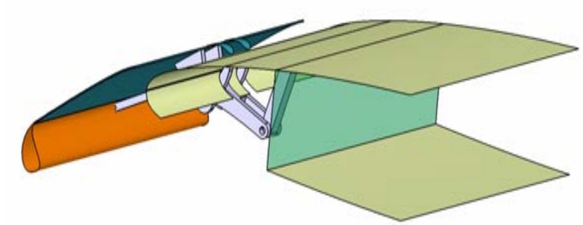
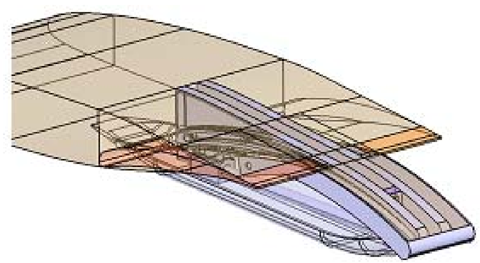
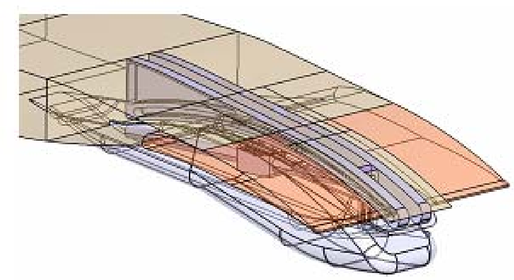
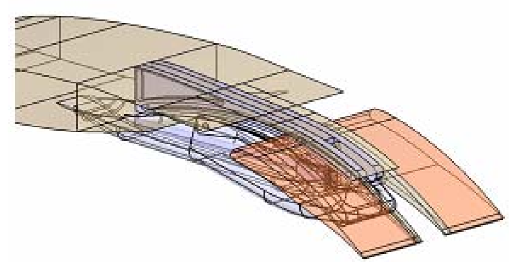
- alternative 2
  - 145° folded Krueger
  - large flap





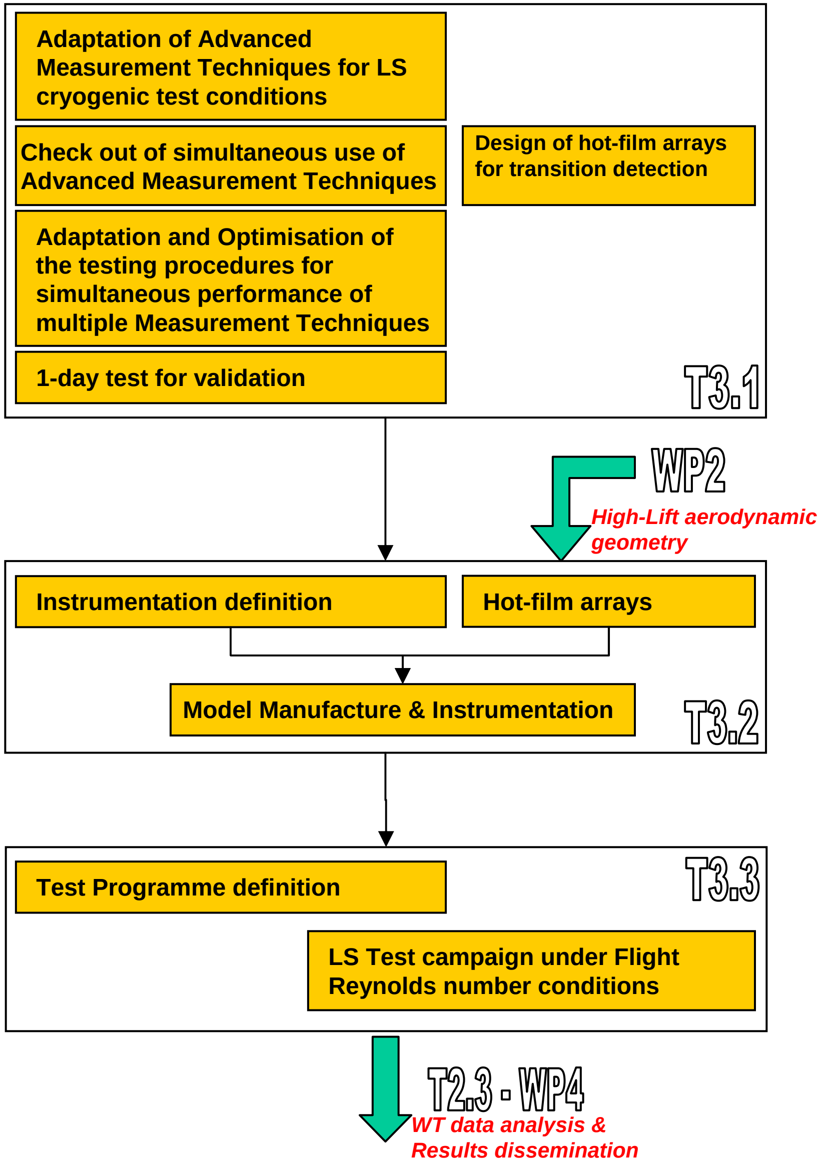
WP2 – high lift integration on TELFONA wing

- mechanical integration
  - check feasibility of high-lift concept with respect to mechanical integration
  - derive constraints for optimization

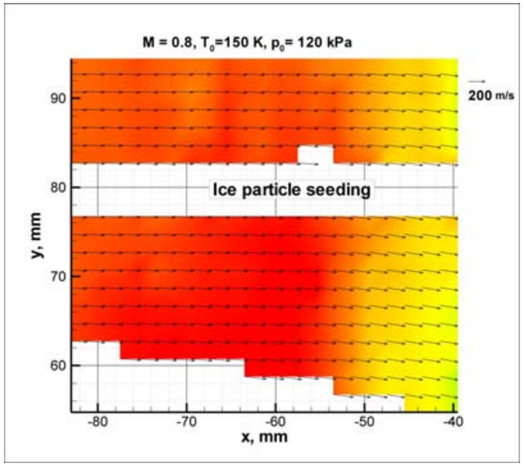
WP3 – Test Technologies & High Reynolds number Validation Tests for low speed

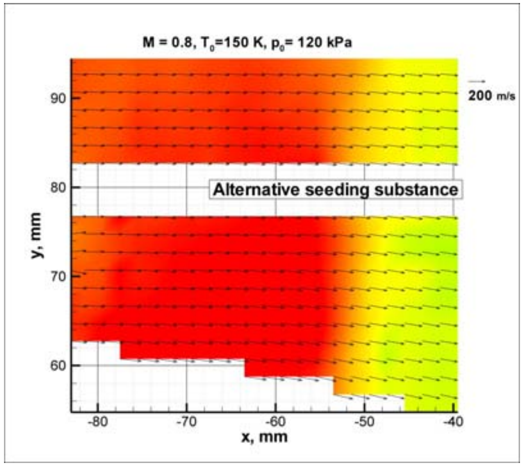
- Qualify advanced measurement techniques for simultaneous use within an industrial-like campaign in ETW
- Provide a wind-tunnel model for the assessment of the designed high-lift system
- Perform aerodynamic performance tests in ETW at Flight Reynolds number for the verification of the global objectives



WP3 – test techniques

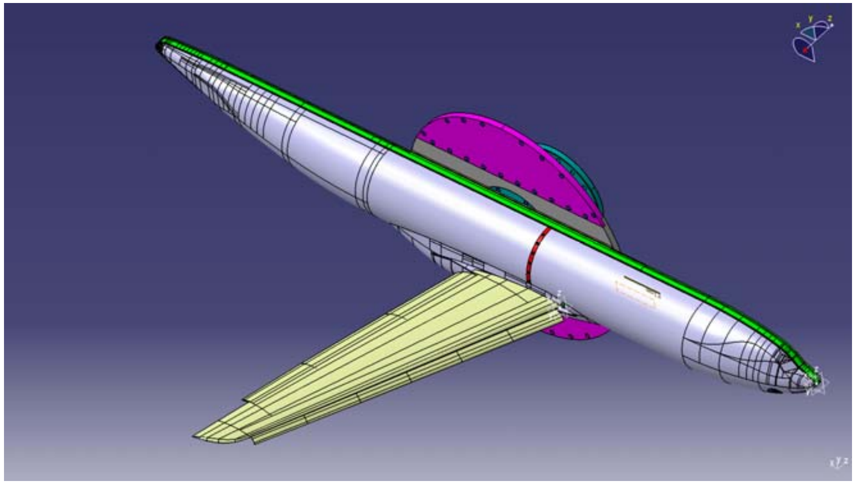
- goal: simultaneous application of all relevant test techniques without any need of model/instrumentation change in ETW
- targeted test techniques:
  - force balance
  - static pressure probes (200-300)
  - temperature sensitive paint (transition)
  - stereo pattern tracking (deformation)
  - cryo-PIV (flow field)
- major implications to consider:
  - smaller and more regular particles for PIV
  - PIV seeding particles to be non-destructive for TSP paint
  - thermal lense problem
  - complete remote control of all test techniques





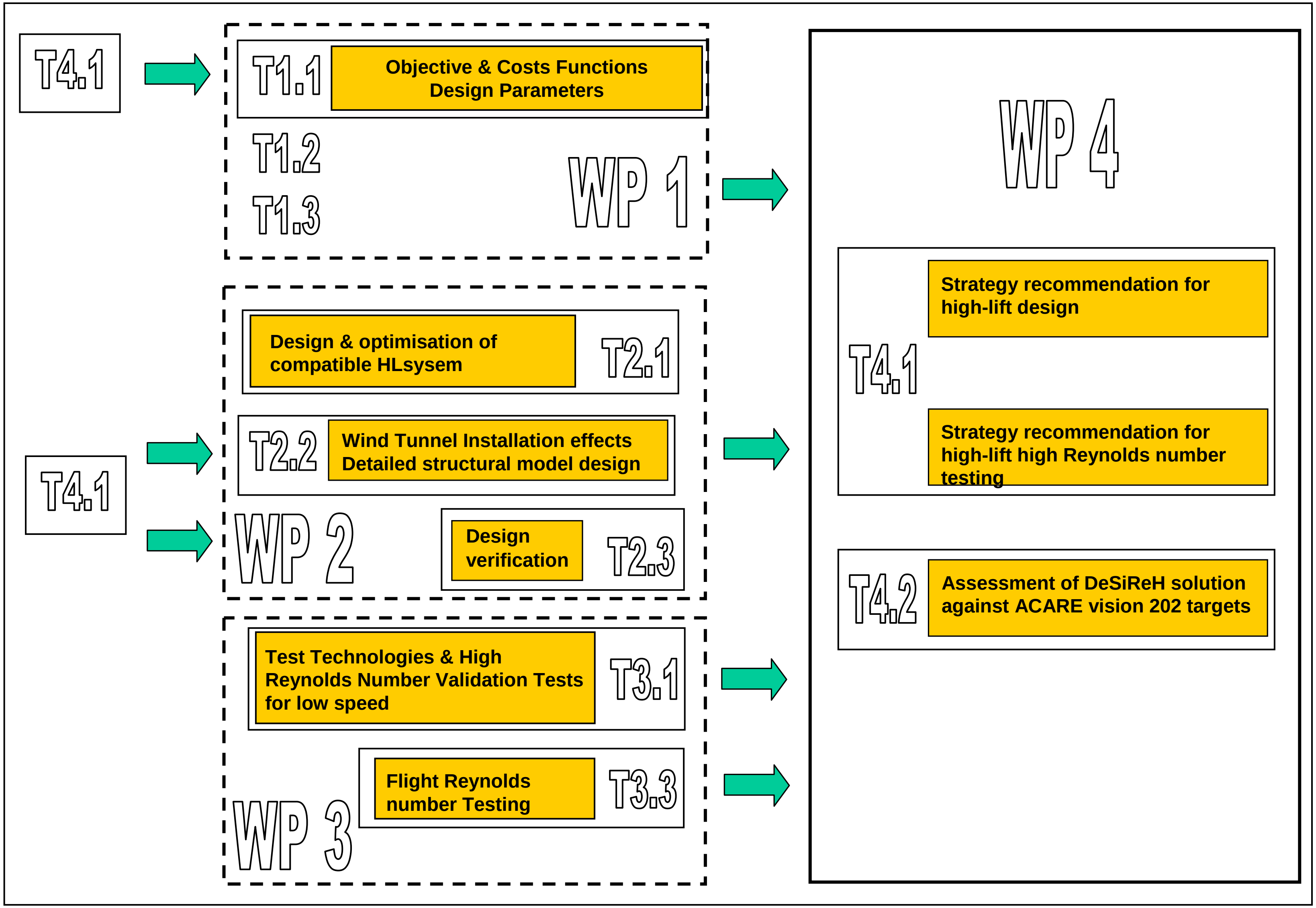
WP3 – model design and manufacturing

- TELFONA high-lift wing scaled 1:11.75
- attached to DLR-F11 model
  (used in EUROLIFT I+II projects)
- target Mach number: M=0.2
- target Re-number: Re=16.7x10^6
  - can be achieved at different pressure/temperature levels to study deformation influence



- wind tunnel test scheduled for spring 2012
  - 7 day entry in ETW

WP4 – Assessment, Exploitation & Application



Key Results of First Half of the Project

- industrial design recommendations have been formulated (WP4)
- design space (objectives/parameters) of high-lift design have been screened (WP1)
- evaluation of design strategies in progress (WP1)
- evaluation of enhanced CFD capabilities for high-lift flows (WP1)
- first high-lift concepts have been analyzed for suitability for laminar wing including integration aspects (WP2)
- requirements of measurement techniques for simultaneous application are analyzed, maturity of techniques evaluated (WP3)

next major steps

- selection of high-lift design for wind tunnel test (WP2)
- detailed CFD analysis of high-lift wing model including wind tunnel installation and deformation effects (WP2)
- model design, manufacturing and high Re-number test (WP3)
- assessment regarding Vision 2020 (WP4)