EWADE 2017

13th European Workshop on Aircraft Design Education

Innovative Tools for Aircraft Preliminary Design – Development, Applications and Education

F. Nicolosi

UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

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Design of Aircraft and Flight technologies
RESEARCH GROUP
www.daf.unina.it

AIRCRAFT DESIGN roots @ UNINA

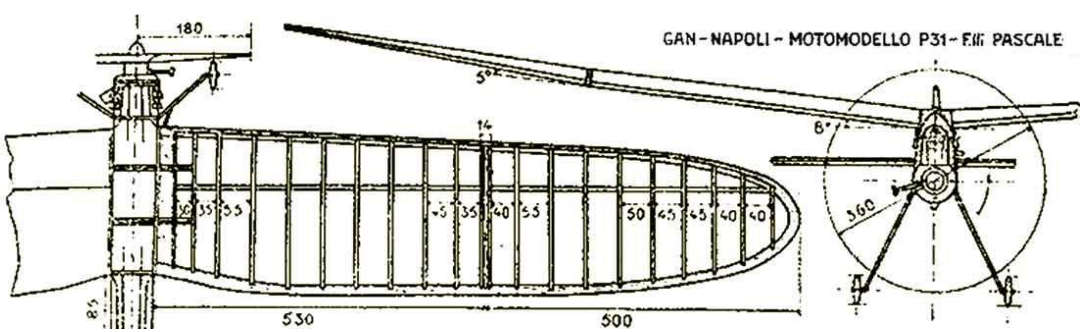
Prof. Luigi PASCALE (1923-2017)

- **Designer, Professor and Pilot**
- **Founder of Partenavia and Tecnam**

Università degli Studi di Napoli Federico II

Together with his brother Giovanni they started designing paper airplanes at the age of 7.

"We were two kids animated by a great passion for the flying machines: the paper planes were the first expression of interest that would inevitably bring us to model aircraft construction,"



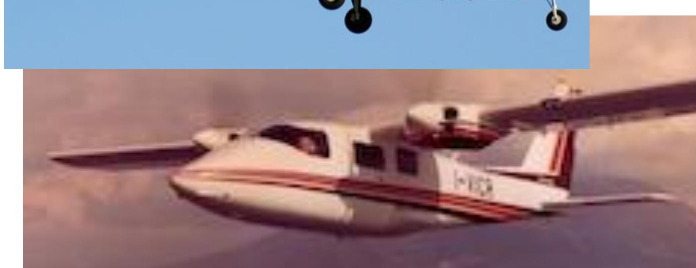
AIRCRAFT DESIGN roots @ UNINA

Prof. Luigi PASCALE (1923-2017)

- **P48 Astore**
- **P52 Tigrotto**
- **P55 Tornado**
- **P57 Fachiro**
- **P59 Jolly**
- **P64 Oscar**
- **P66 Charlie**
- **P68 Observer**
- **P68 Viator**
- **P70 Alpha**

=> Tecnam in 1986

PARTENAVIA Aircraft



P55 Tornado

AIRCRAFT DESIGN roots @ UNINA

Prof. Luigi PASCALE (1923-2017)

COSTRUZIONI AERONAUTICHE TECNAM

<ins>**TECNAM was founded in 1986**</ins>

- **P92 Echo**
- **P96**
- **P98**
- **P2000**
- **P2002**
- **P92-2000RG**
- **P92J**
- **P2006T**
- **P2008**
- **P2010**
- **P2012 Traveller**

AIRCRAFT DESIGN roots @ UNINA

Prof. Luigi PASCALE (1923-2017)

COSTRUZIONI AERONAUTICHE TECNAM

P2012 Traveller

11 seats

AIRCRAFT DESIGN Research Group @ UNINA

DAF (Design of Aircraft and Flight Technologies) research group

- Focused on Aircraft Design
- Applied aerodynamics and aerodynamic design of transport aircraft
- Wind-Tunnel tests
- Flight Mechanics
- Flight Dynamics, flight tests and flight simulation

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE
SEZIONE INGEGNERIA AEROSPAZIALE

Prof. F. Nicolosi

Prof. A. De Marco

Prof. P. Della Vecchia

Ing. S. Corcione (Post- Doc), Ing. D. Ciliberti (Post-Doc)

Ing. V. Cusati (PHD)

Ing. M. Ruocco (PHD)

Ing. V. Trifari (PHD)

Ing. L. Stingo (PHD)

Design of Aircraft and Flight technologies RESEARCH GROUP
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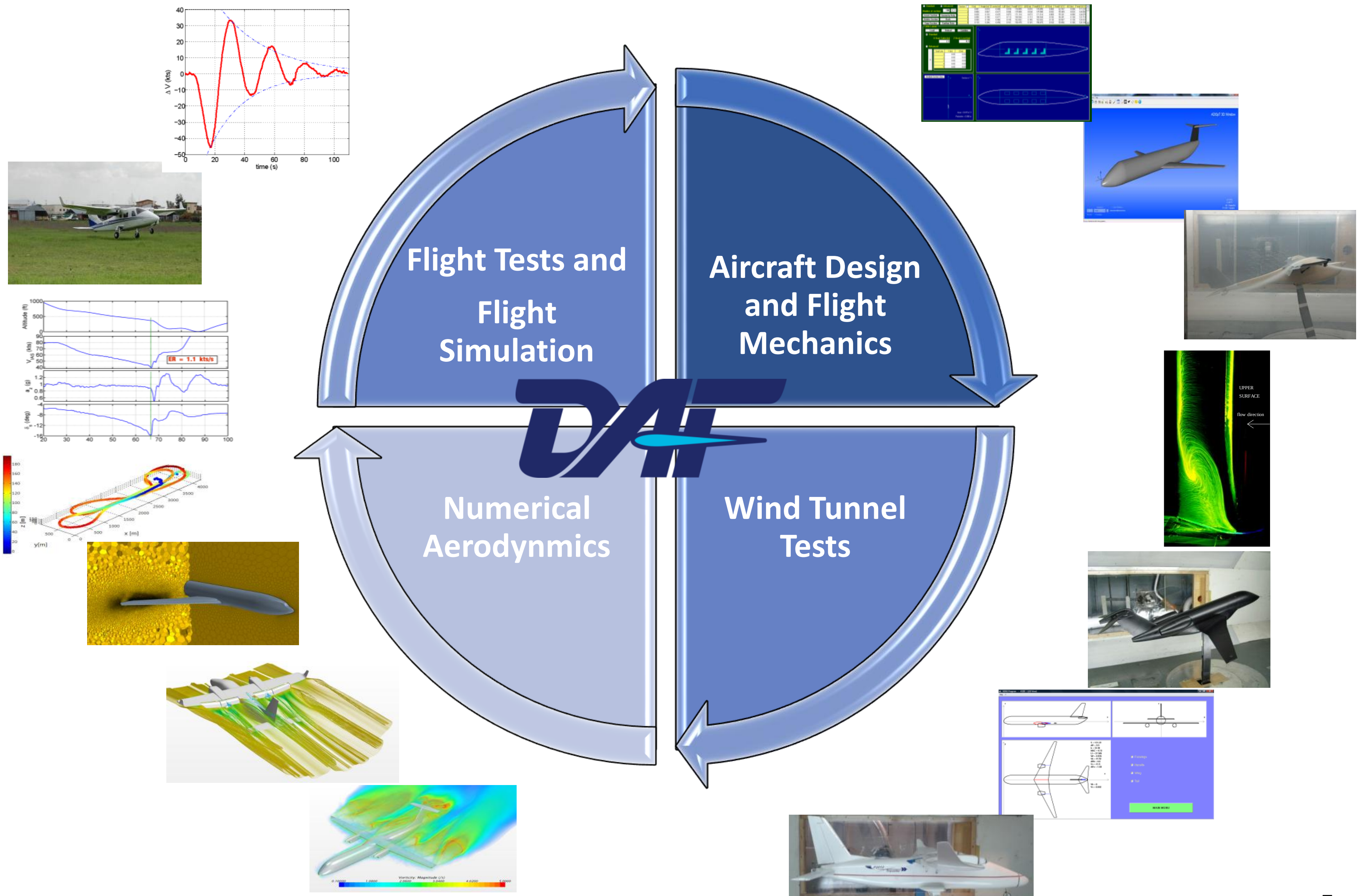
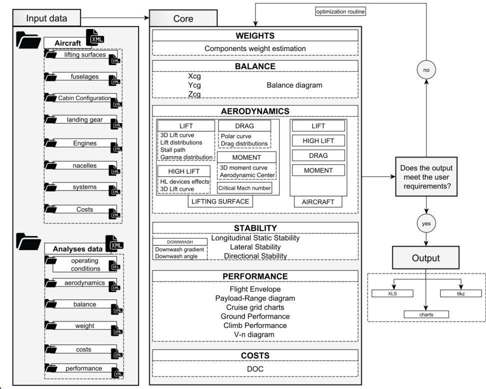
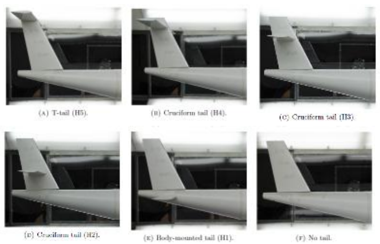

Flight Tests and
Flight
Simulation
Aircraft Design
and Flight
Mechanics
Numerical
Aerodynmics
Wind Tunnel
Tests
time (s)
ER = 1.1 kts/s
UPPER
SURFACE
flow direction

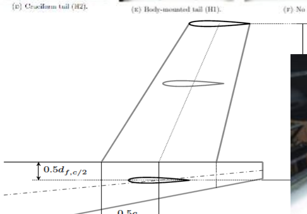
Our approach

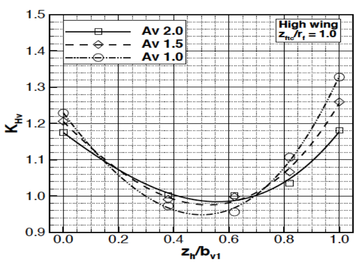
MDO Approach
Integration
Multi-fidelity analysis
Optimization algorithms
User interface
Software Engineering

AIRCRAFT DESIGN FRAMEWORK





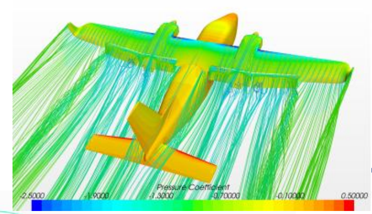




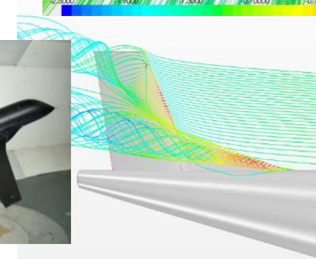
Hi-Fi methods in the loop
New Configurations
Get used with typ values
(design experience)

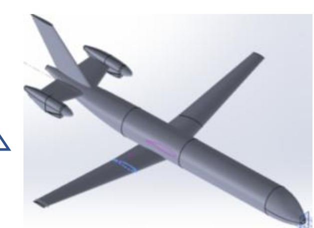
Industrial results
Applications can suggest dev of new surrogate models

Semi-emp. methods
Surrogate models
Compr. of physics involved
Development of L1 tools
Component and process model



ANALYSIS METHODS





DESIGN APPLICATIONS

INNOVATIVE TOOLS AND AIRCRAFT DESIGN FRAMEWORK

Fundamental steps and ingredients

(a) Derive new semi-empirical formulations (or surrogate models) especially for non-conventional configurations
(b) Integrate medium to high fidelity tools into the analyses
(c) Multidisciplinary approach (i.e. including systems and direct operating costs)
(d) Include innovative propulsive systems
(e) Deal with innovative configurations
(f) Include new and efficient optimization algorithms (i.e. Nash Game theory)
(g) Use advanced software engineering to enhance tool capabilities, speed and usability (for example user-friendly graphic interface or inter-operability with other software)

AIRCRAFT DESIGN COURSE in Naples (about 40-50 students per year)

- Second semester, 9CFU, about 80 h frontal lectures, in English
- 30% applications and exercises

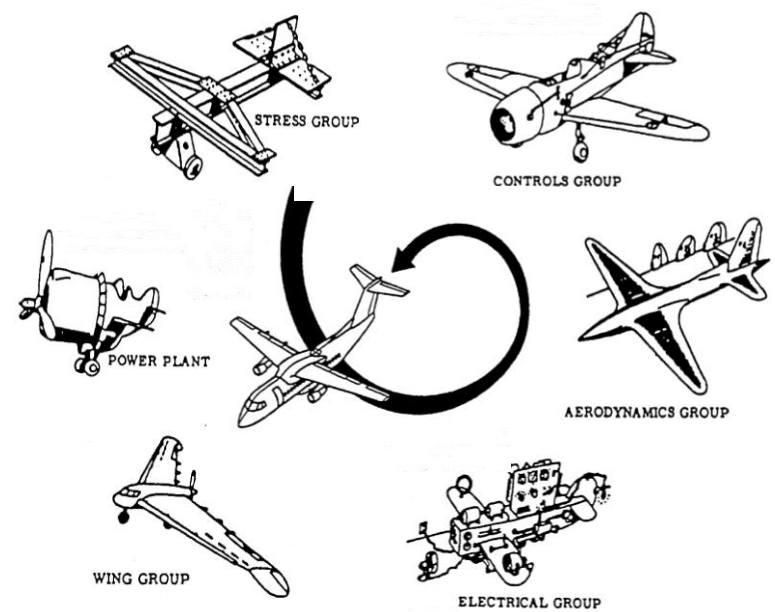
It is **mandatory** for students to develop in 3-5 months a design project in group of 3-4.

⇒ Rough Assignment (very few indications)

The groups of students will be tutored by my and other Researchers, Post-Doc and PHD in the group.

- Search, collect and graph data for similar aircraft (understanding differences)
- Building complete aircraft TLAR (Requirements and Spec.)
- Weight prediction, conceptual sizing
- Wing analysis (and maybe some CFD 2-D airfoil analysis)
- Fuselage arrangement, CAD (some develop some Catia drawings)
- Drag polar, flight performance, ground performance
- Stability and control, Weight & Balance (Class II)
- Costs

Aircraft Design course GOALS:



- **Learning how to Design an aircraft**

Getting familiar with the design process
Solve open-ended problems moving into *uncertainty*

=> Design looks difficult, but *it is fun*

- **Design means also Synthesis**

Integrate all the knowledge acquired in 5 years of Aerospace Enginnering studies Education to Multi-disciplinary approach and thinking

- **Aircraft Design Exercise**

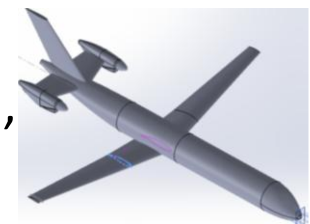
A Conceptual/Preliminary Design of an aircraft will be carried out in GROUPS
⇒ Enhance team-working capabilities and communications (soft skill)
⇒ Search, collect and select quality data and information from literature, web, etc.
(get familiar with typical engineering values and order of magnitude)
⇒ Create THEIR OWN design with their efforts and calculations
⇒ Reporting and presentation of results (in english)
⇒ Be in time w.r.t. their assignment (like in Industrial practice)

CURRENT MAIN RESEARCH PROJECTS IN AIRCRAFT DESIGN

CERVIA Project (Funded by MIUR, Italian Ministry for Research and Education) With Leonardo

Development of an efficient aircraft design platform in Java (JPAD)

AGILE Project (H2020)



DLR, ONERA, NLR, Airbus DS, Bombardier, Leonardo, Fokker, CIAM, POLITO, TU Delft

Innovative 3rd generation aircraft design framework with collaborative architecture

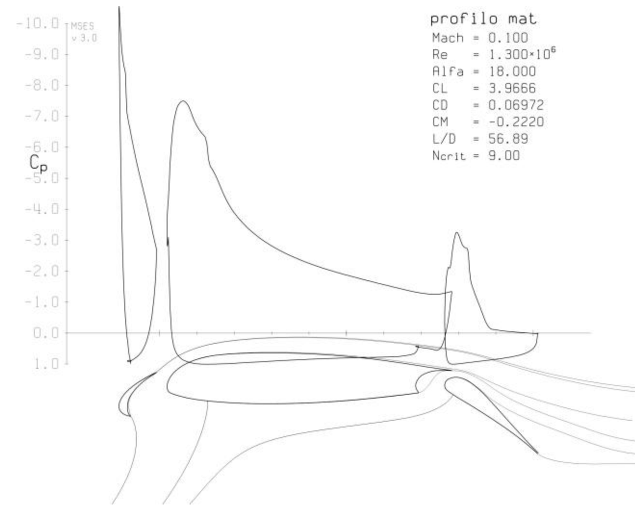
IRON Project (H2020, Clean Sky 2)

With Leonardo, CIRA, ONERA, TU Delft, Avio GE, Dowty propeller

Design of an Innovative 130 pax Regional Turboprop with rear engine installation

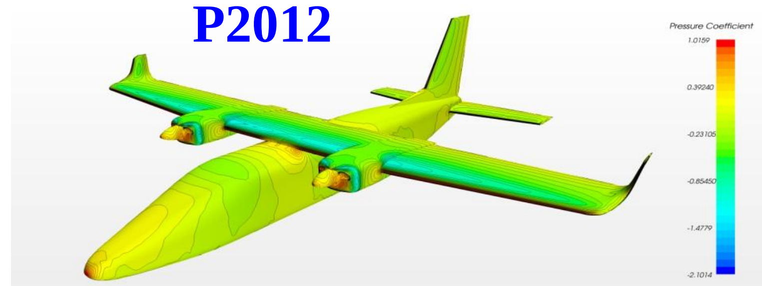
PAST PROJECTS

EASY-FLY



G97

P2012



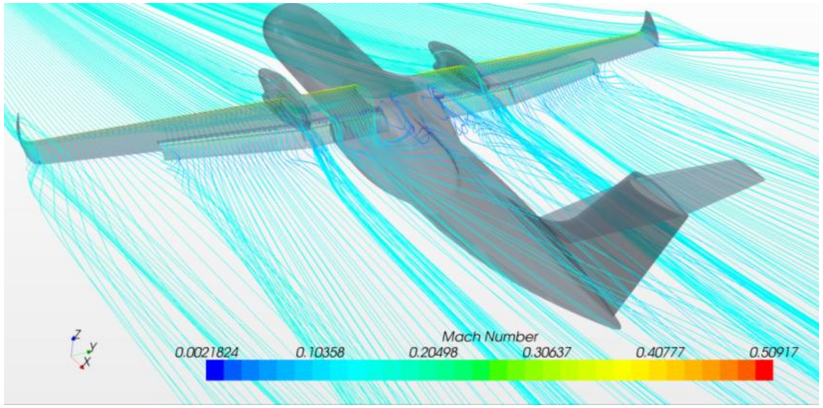
P2006

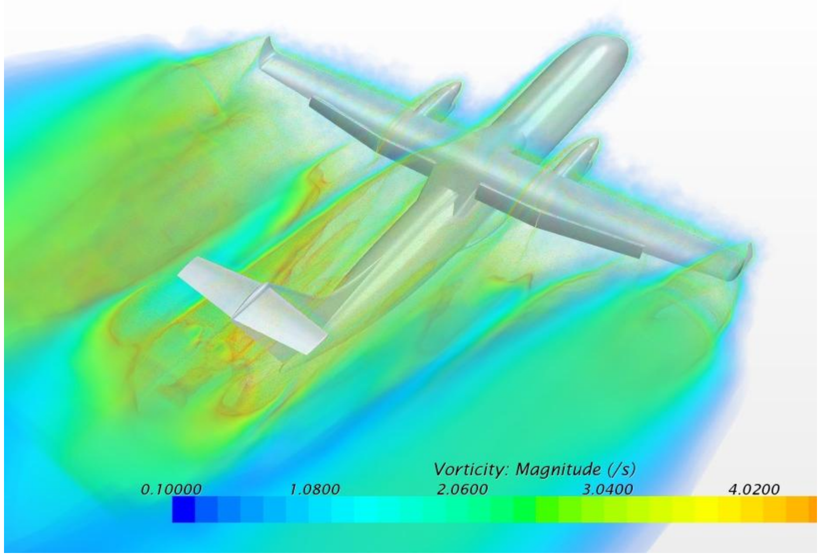
INDUSTRIAL APPLICATIONS

Several Collaborations and contracts with :

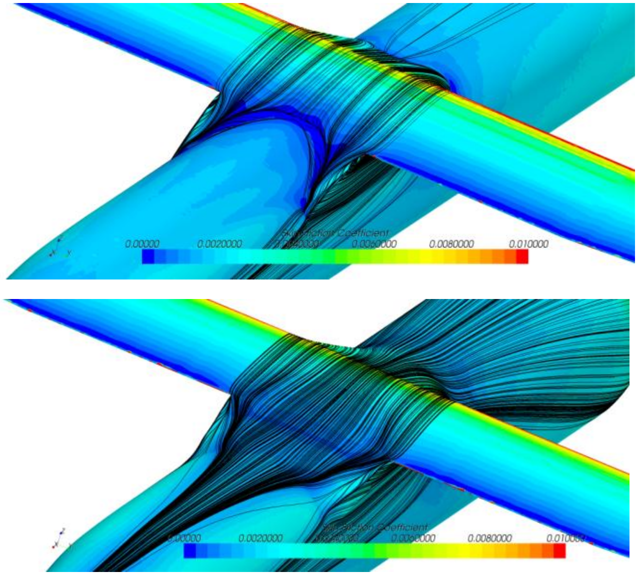
- Tecnam
- Other ULM companies
- Piaggio AERO
- ATR
- ALENIA (Now Leonardo) for NGTP aircraft

NGTP stall prediction



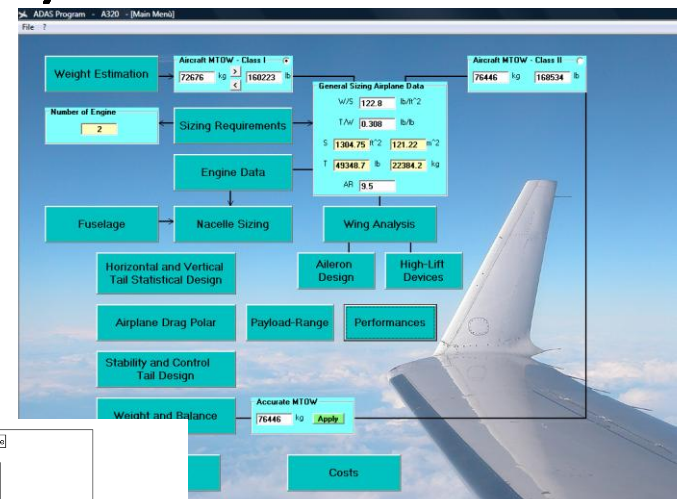


Karman Optimization (ATR)

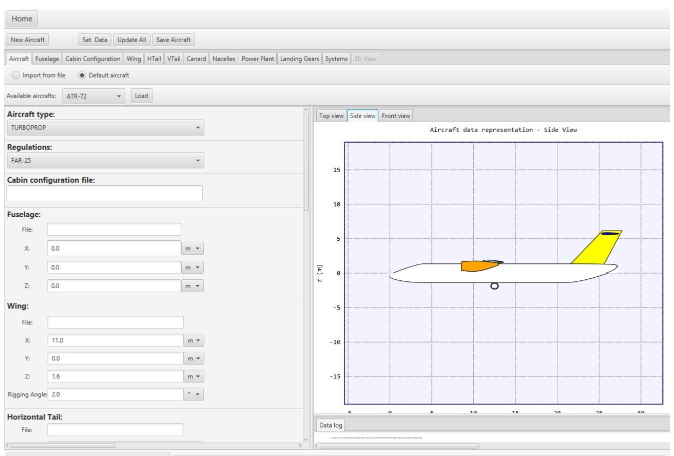


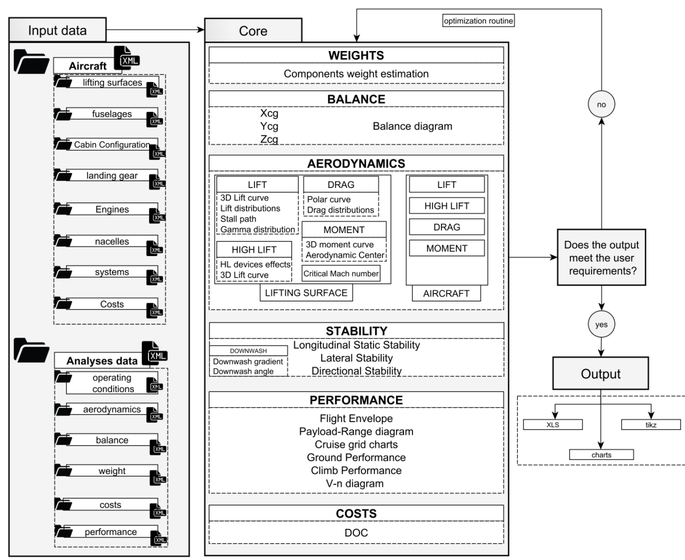
SOFTWARE and Framework for AIRCRAFT Preliminary Design

- **Several tools (in Fortran, Matlab) developed since 1993**
- **ADAS (Aircraft Design and Analysis Software)**
  2005-2015



- **JPAD (Java Program for Aircraft Design)**
  2013-2017 (still active)

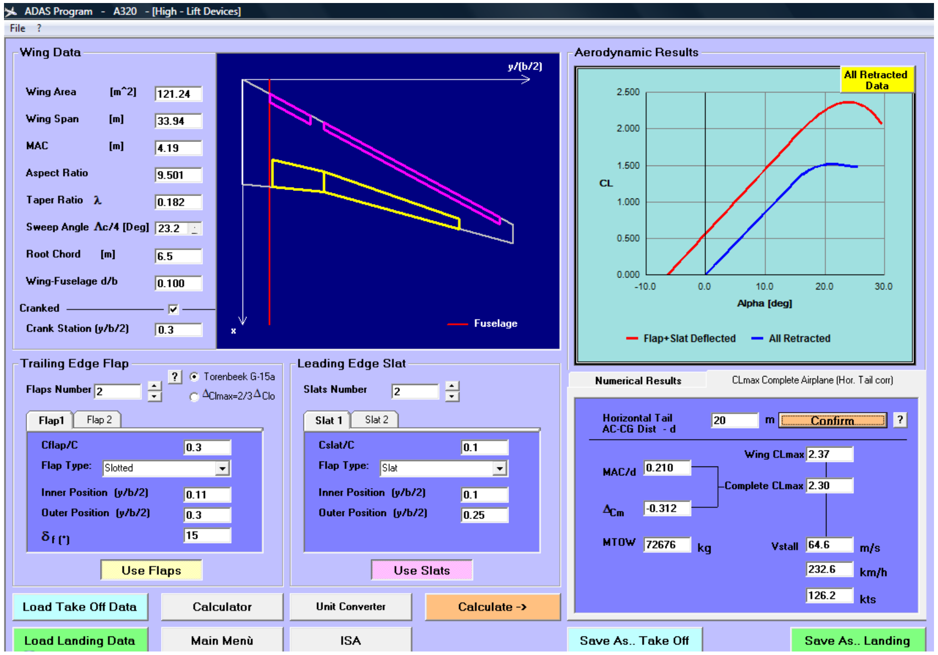


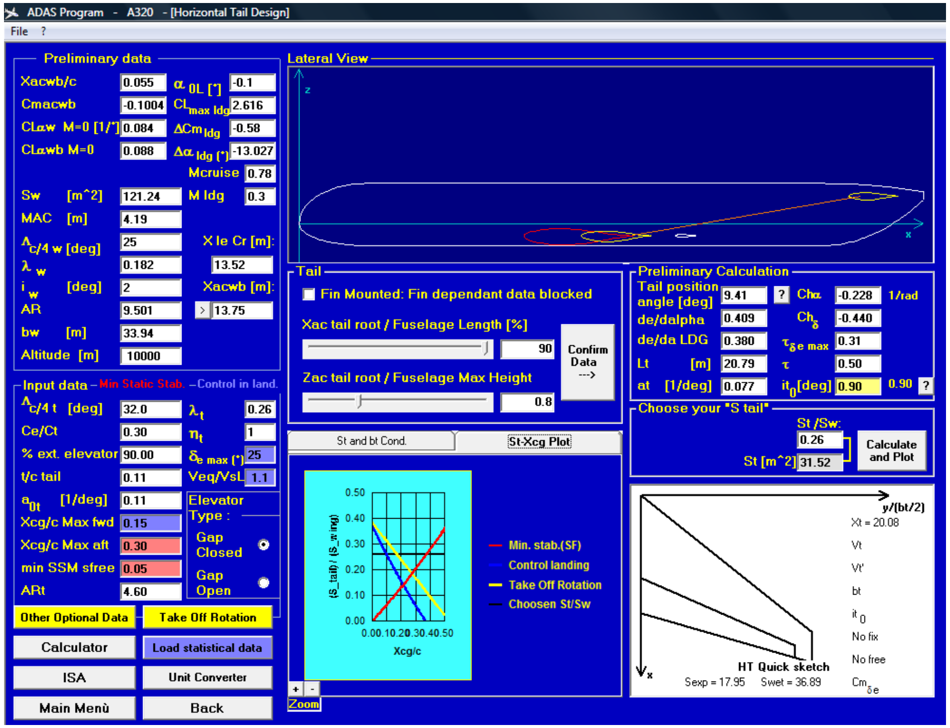


SOFTWARE for AIRCRAFT Preliminary Design

ADAS (Aircraft Design and Analysis Software) 2005-2015

- Written in *VISUAL BASIC (80 form x 1000 Average code lines)*
- *User Friendly GUI* and useble on any *Microsoft Windows Platform*
- Indipendent calculation modules including some non-linear effects
- Mainly developed for teaching (used in my Aircraft Design Course)
- Development started 2005





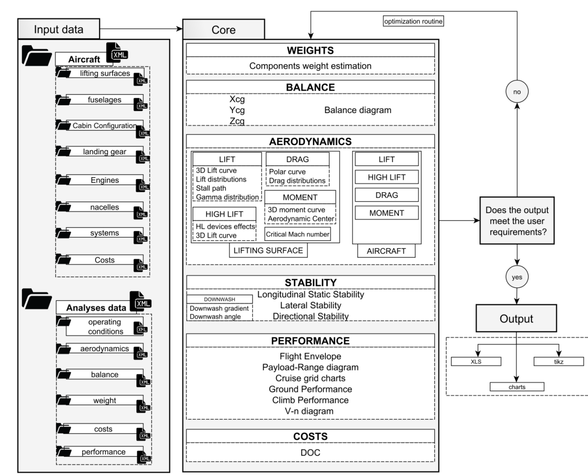
JPAD — Java Programs for Aircraft Design

- A fast and efficient tool useful as support in the preliminary design phases of an aircraft
- Lean software design to manage the great amount of data and calculations
- Support for simultaneous management/analysis of several aircraft and/or different configurations of same aircraft
- Includes some prediction methodologies developed by the DAF research group of the University of Naples (vertical tail design and fuselage aerodynamics analysis)
- Conceived for collaborative design activities
- Interoperability with other tools/disciplines (CAD/AVL/FEM analysis)

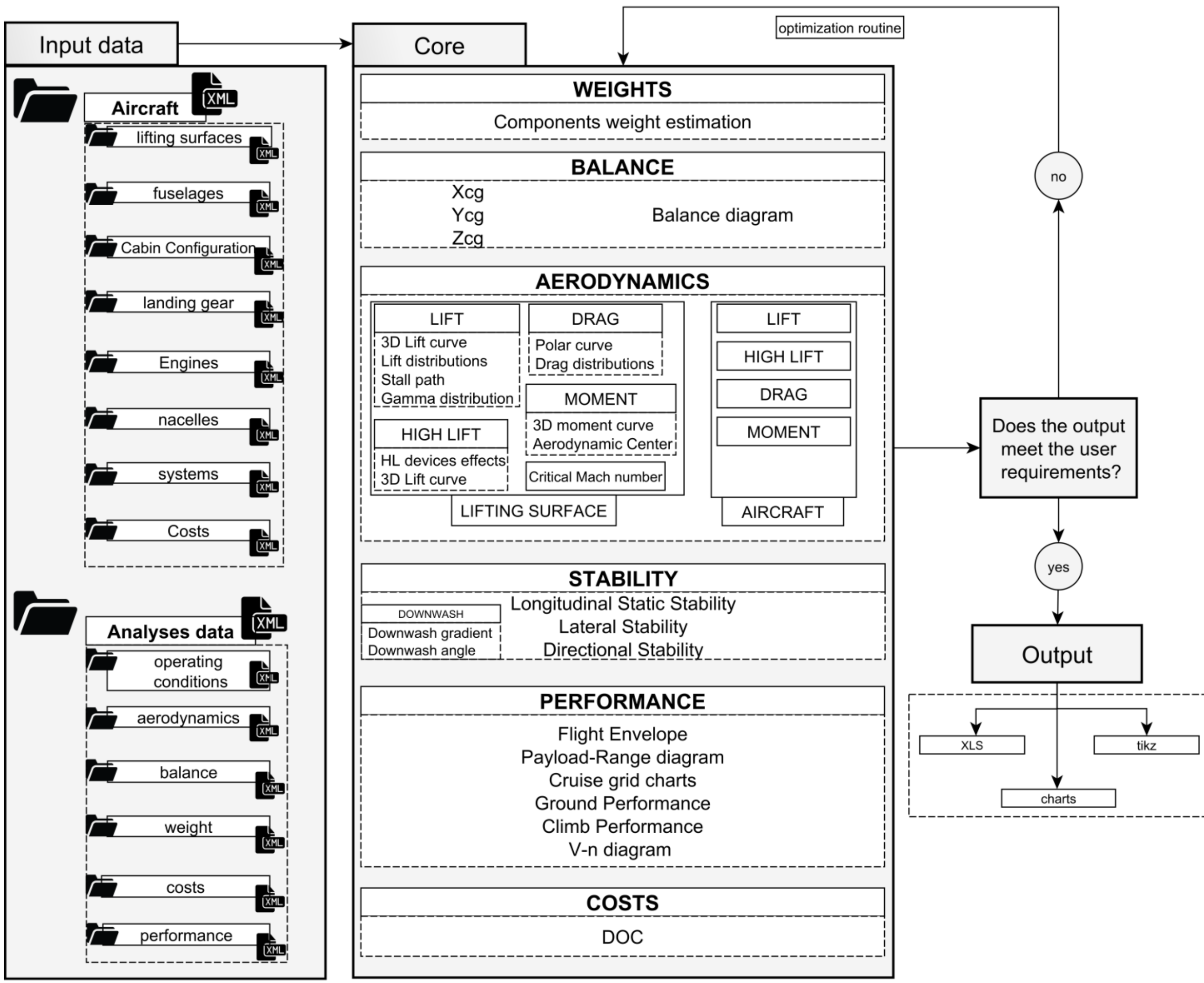
WHY JAVA ?

- Widely supported, continuously updated and improved
- Many open source libraries available
- Widely supported GUI framework and a GUI visual builder
- Object-Oriented paradigm (abstraction of Aircraft)
- Promote modularity:

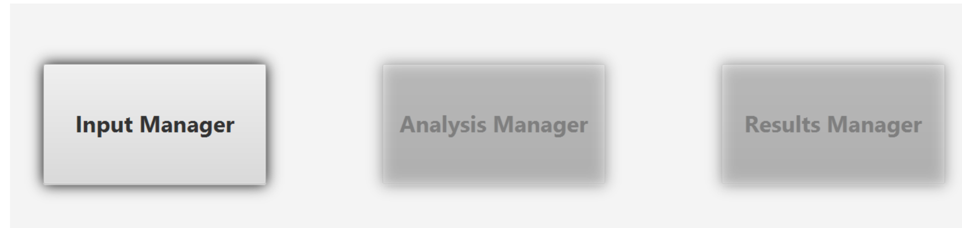
  easier to work with in an ever changing team

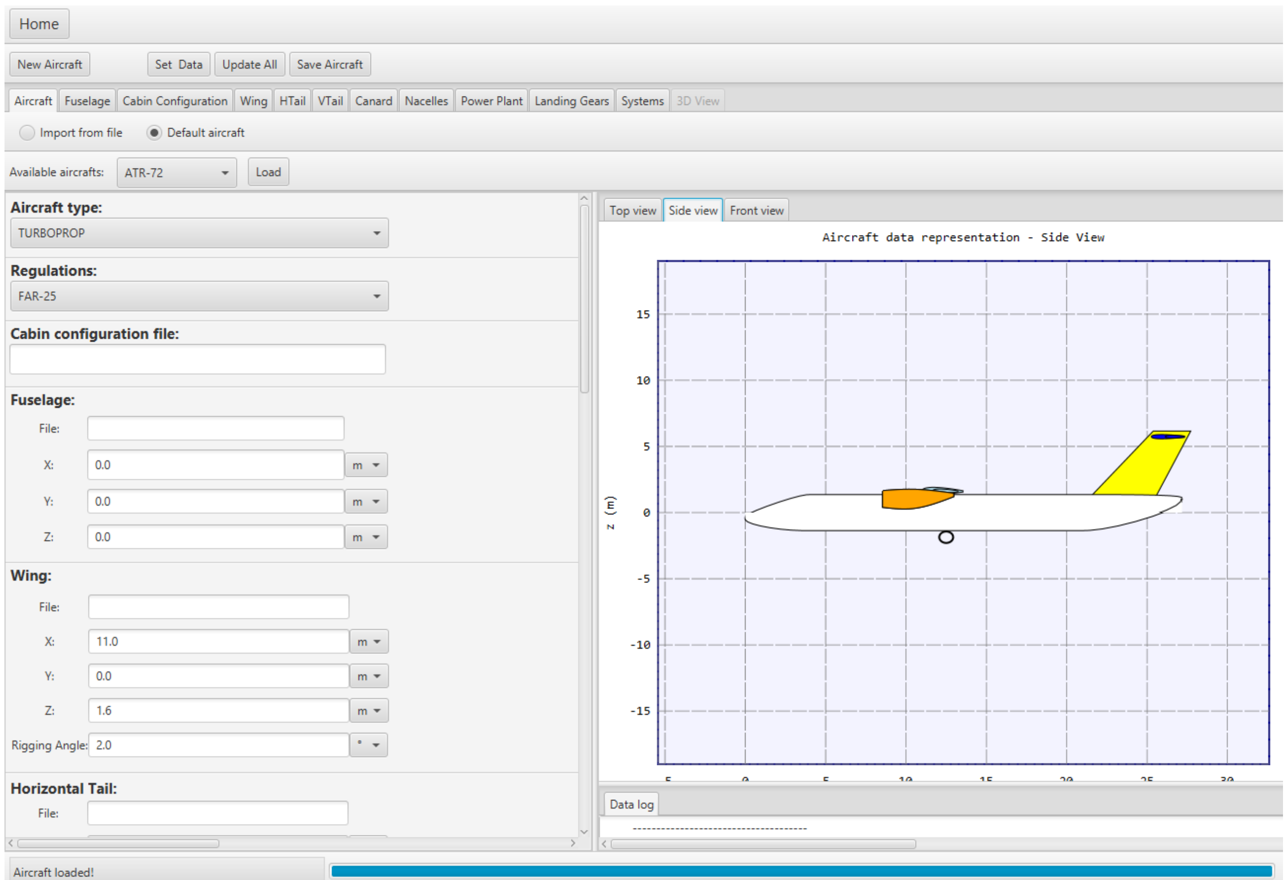


Software Structure

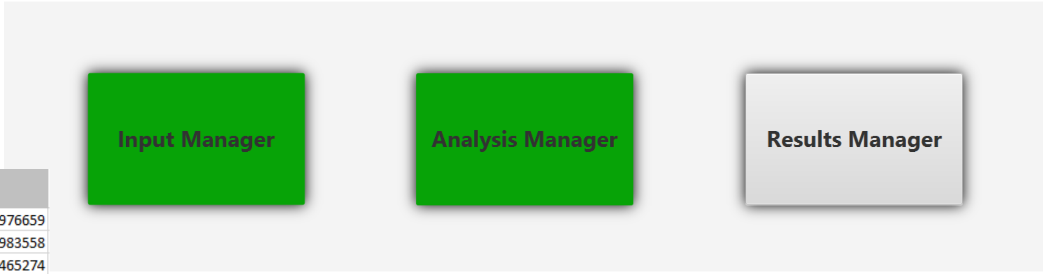


JPAD GUI OVERVIEW



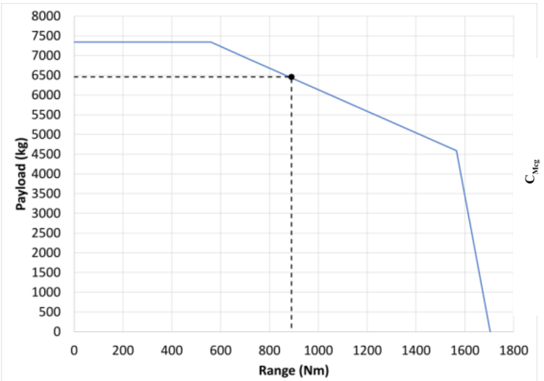


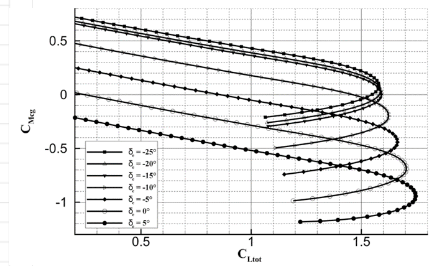
JPAD GUI OVERVIEW

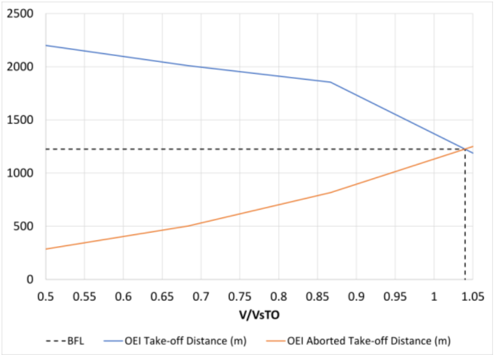


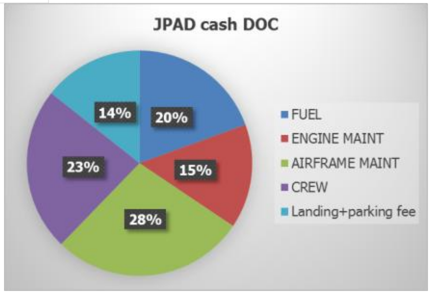
Description	Unit	Value
Ground roll distance	m	763.4976659
Rotation distance	m	165.4983558
Airborne distance	m	231.5465274
AEO take-off distance	m	1160.542549
FAR-25 take-off field length	m	1334.623931
Balanced field length	m	1225.663607
Ground roll distance	ft	2504.913602
Rotation distance	ft	542.9736083
Airborne distance	ft	759.6670847
AEO take-off distance	ft	3807.554295
FAR-25 take-off field length	ft	4378.687439
Balanced field length	ft	4021.20606
Stall speed take-off (VsTO)	m/s	53.67149021
Decision speed (V1)	m/s	55.82318509
Rotation speed (V_Rot)	m/s	56.35506473
Minimum control speed (VMC)	m/s	46.98027511
Lift-off speed (V_LO)	m/s	60.77409554
Take-off safety speed (V2)	m/s	63.95159767
Stall speed take-off (VsTO)	kn	104.3290307
Decision speed (V1)	kn	108.5115909
Rotation speed (V_Rot)	kn	109.5454822
Minimum control speed (VMC)	kn	91.32234902
Lift-off speed (V_LO)	kn	118.1353909
Take-off safety speed (V2)	kn	124.3119609
V1/VsTO		1.04
V_Rot/VsTO		1.05
VMC/VsTO		0.88
V_LO/VsTO		1.13
V2/VsTO		1.20
Take-off duration	s	31.51824683

TAKE-OFF | CLIMB | CRUISE | DESCENT | LANDING | MISSION PROFILE | PAYLOAD-RANGE





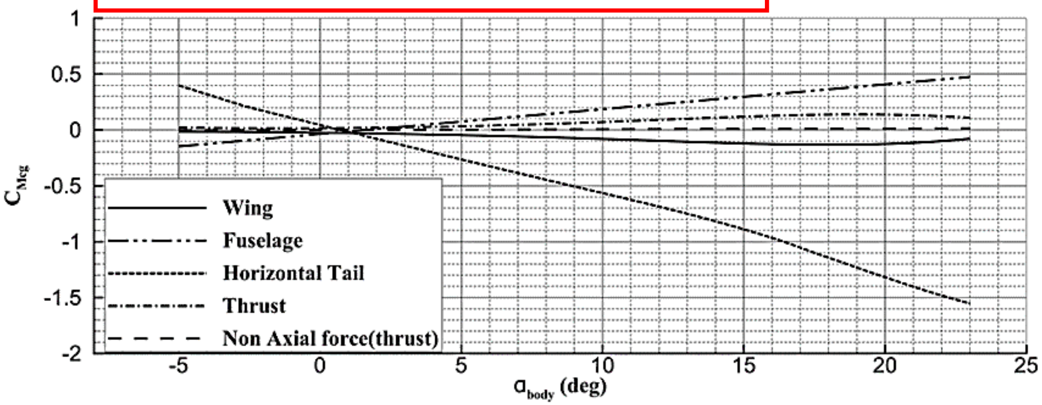




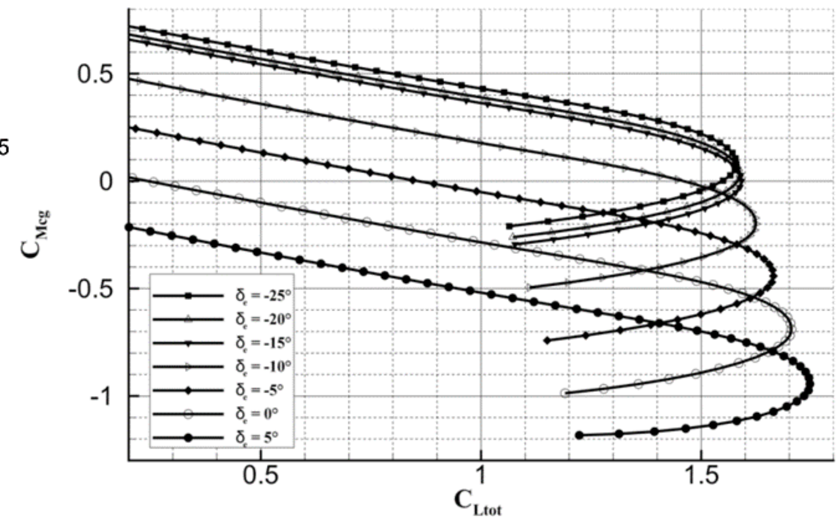
Case study: ATR 72

Aerodynamics and Longitudinal Stability

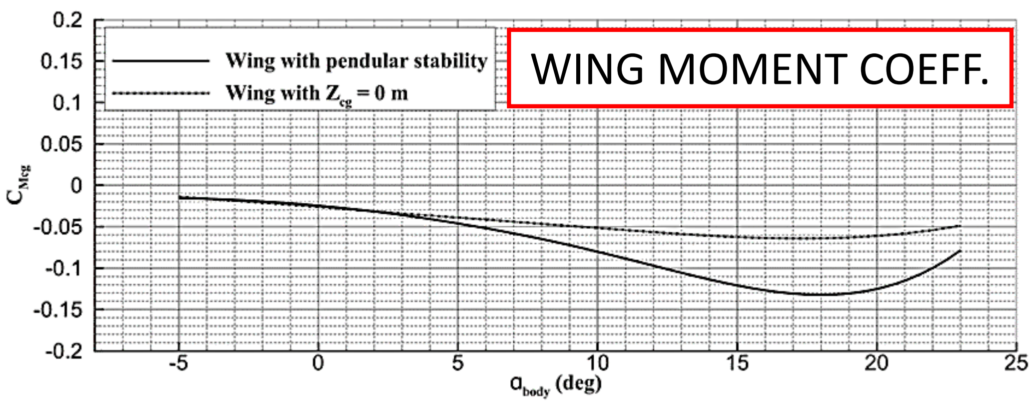
BREAKDOWN MOMENT COEFF.



MOMENT COEFF. Vs LIFT COEFF.
At different elevator deflections



WING MOMENT COEFF.

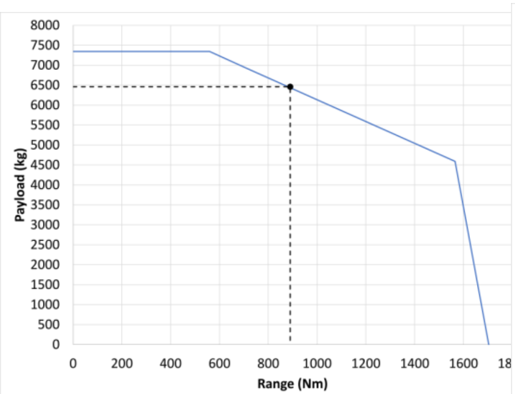


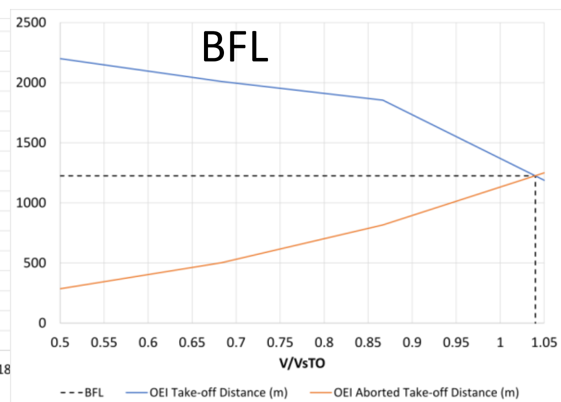
Case study: ATR 72

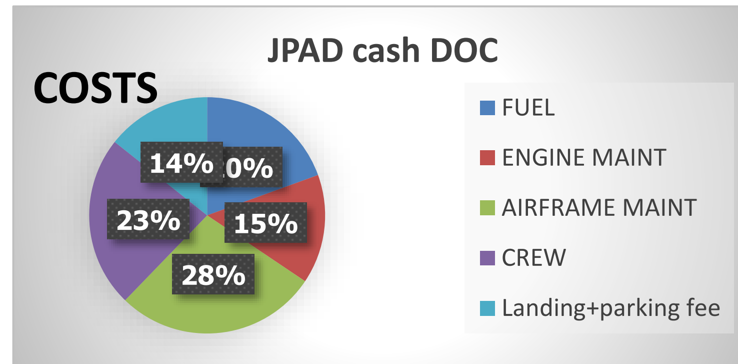
PERFORMANCE	JPAD	ATR-72	Difference
Design Range (with 68 passengers at 95kg)	890 Nm	890 Nm	<1.0%
Balanced Field Length	1225 m	1223 m	<1.0%
FAR-25 Landing Field Length	1162 m	1048 m	10.9%
Max cruise Mach number at 17kft	0.440	0.444	<1.0%
Service ceiling AEO	26709 ft	25000 ft	6.8%
Service ceiling OEI	14712 ft	14200 ft	3.6%

Performance

- Take-off
- Climb (AEO and OEI)
- Cruise
- Descent
- Landing
- Mission profile analysis
- Payload-Range
- Flight maneuvering and gust envelope







	ATR72 ($/trip)	JPAD ($/trip)
Fuel	182	183
Engine maintenance	120	148
Airframe maintenance	117	261
Crew	145	147
Landing fee	109	135
Total cash DOC	**673**	**868**

Aircraft Design and Software engineering

Deep link between research and education

- Students get involved in developing part of software often learn how to deal with new languages (i.e. Java) and how to develop software and solve technical problems with the help of computers (very useful competence for their future professional carrier)
- Research activities and academic education gain benefits from each other throughout the development of engineering software tools. Researchers can rely on the useful support of student (for thesis work) to continuously enhance the potentiality the tool and, as a consequence, a better tool may be used to achieve better research goals.

Aircraft Design and Software engineering

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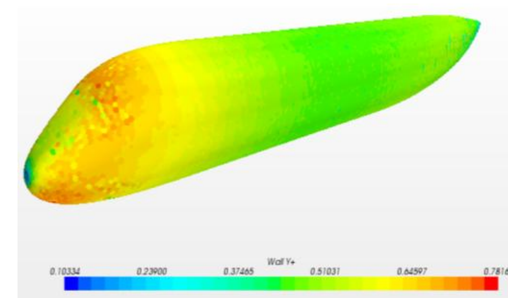
Aircraft Design Tools in-house development : WHY ?

- Research competitiveness (the possibility to customize and continuously integrate new knowledge from research activities in your own tool)
- Replace some modules and approaches with modern and more accurate ones
- Change approach and optimization algorithm
- Possibility to deal with new configurations, architectures and propulsive systems

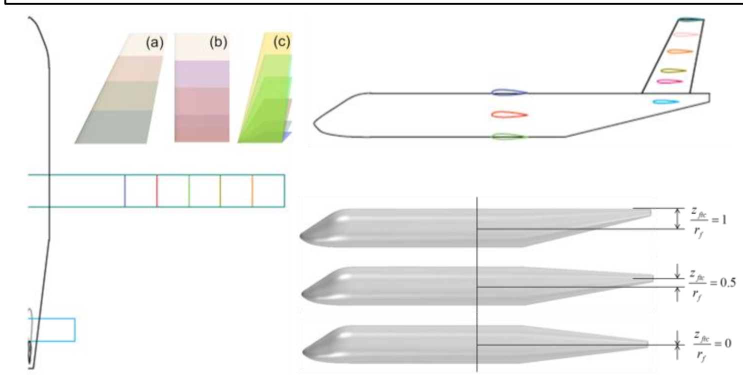
Development of New Improved Analysis Methodologies

Different aerodynamic prediction methodologies have been developed by the research group as results of several PhD and master theses. The methodologies have been implemented in JPAD increasing the library value in terms of results fidelity.

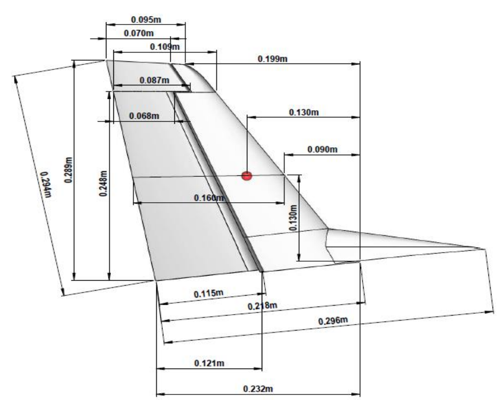
FusDes
Fuselage Design



VeDSC Vertical tail Design Stability and Control

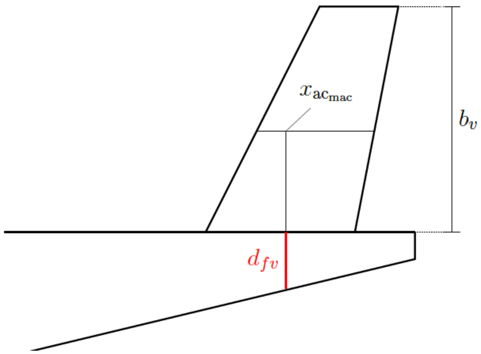


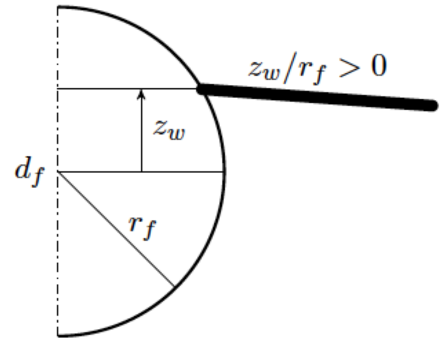
Rudder efficiency
(directional control)

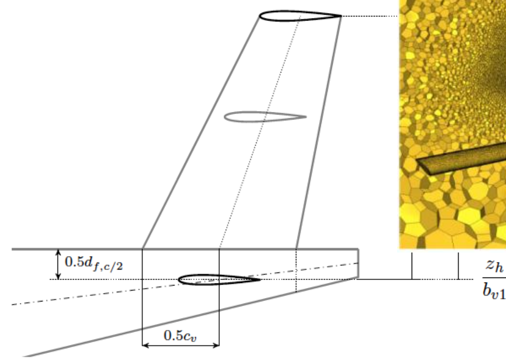


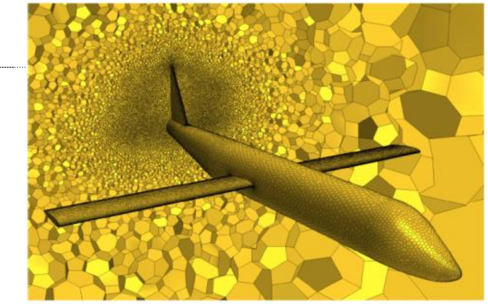
Hih-lift prediction (L1)

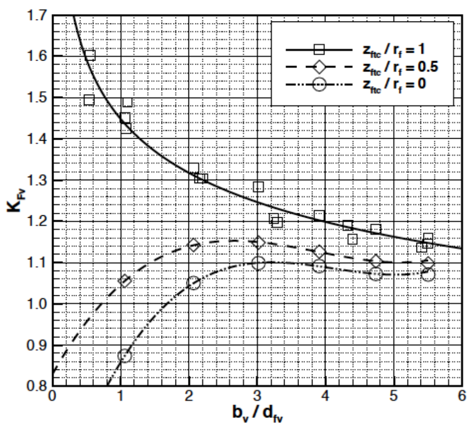
VeDSC - Vertical tail Design Stability and Control

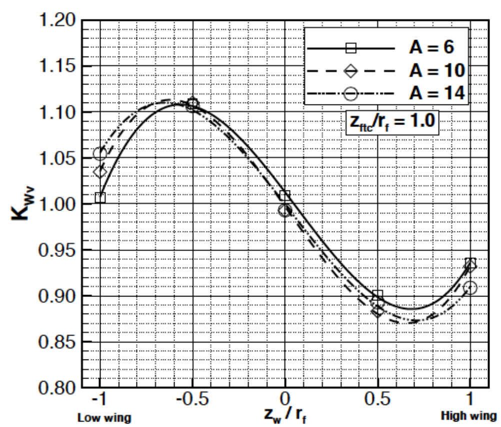


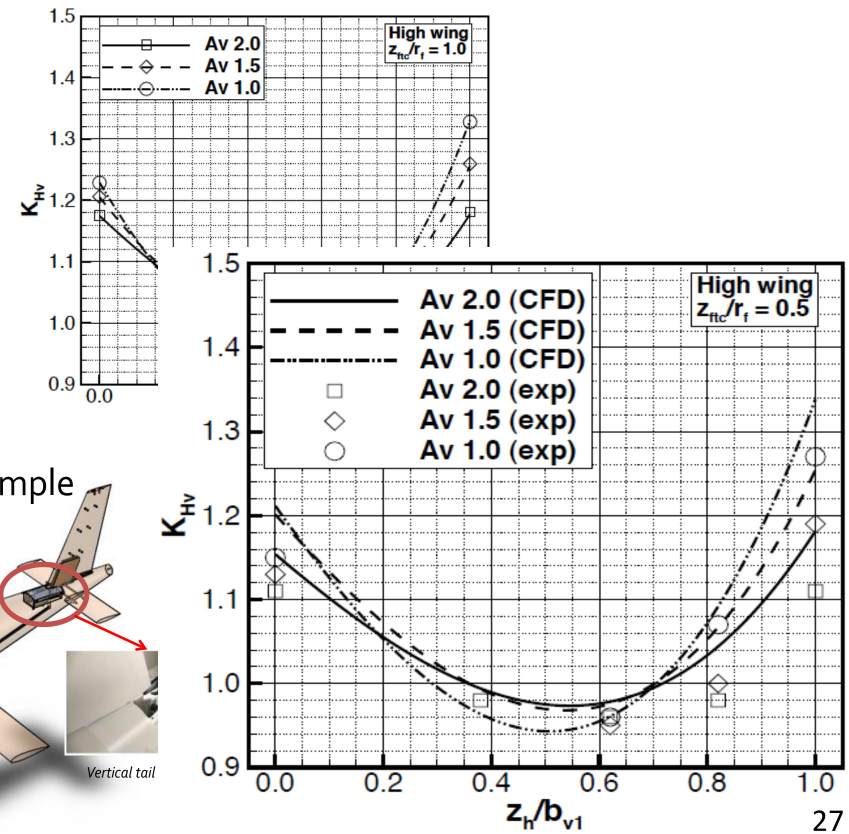


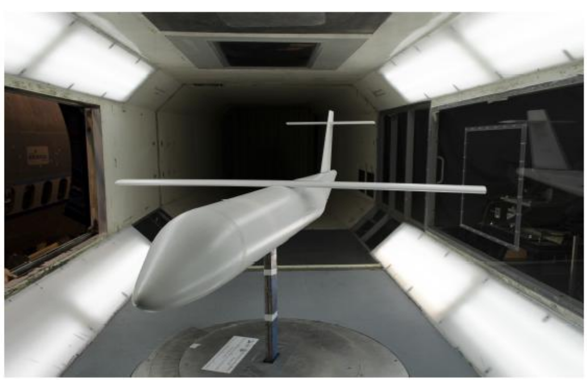




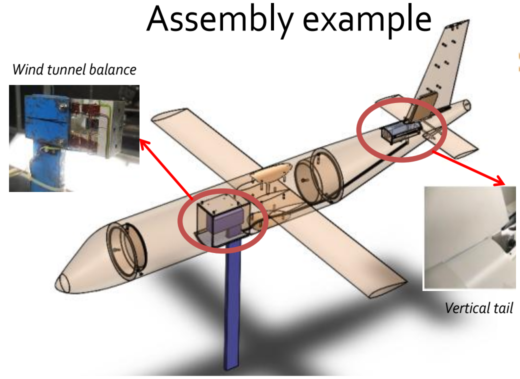




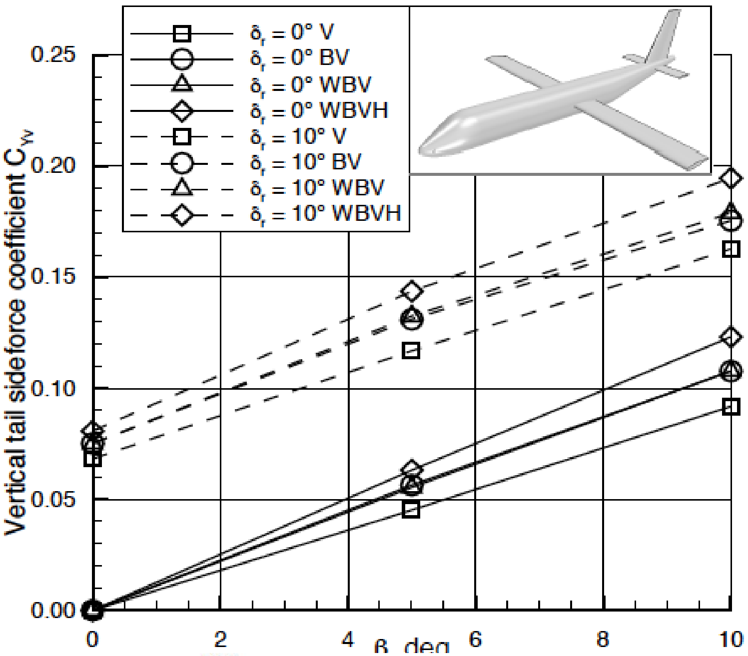


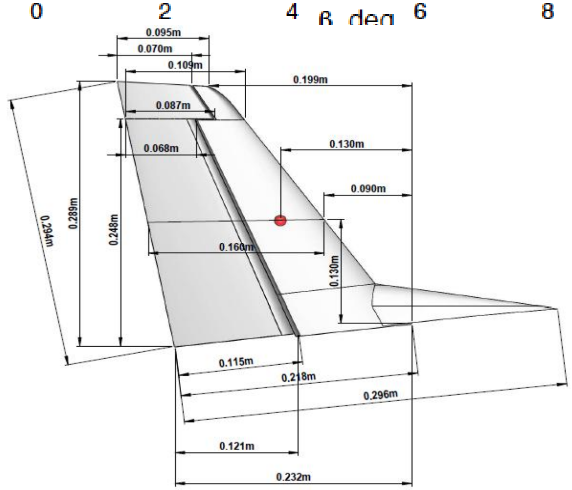


Assembly example

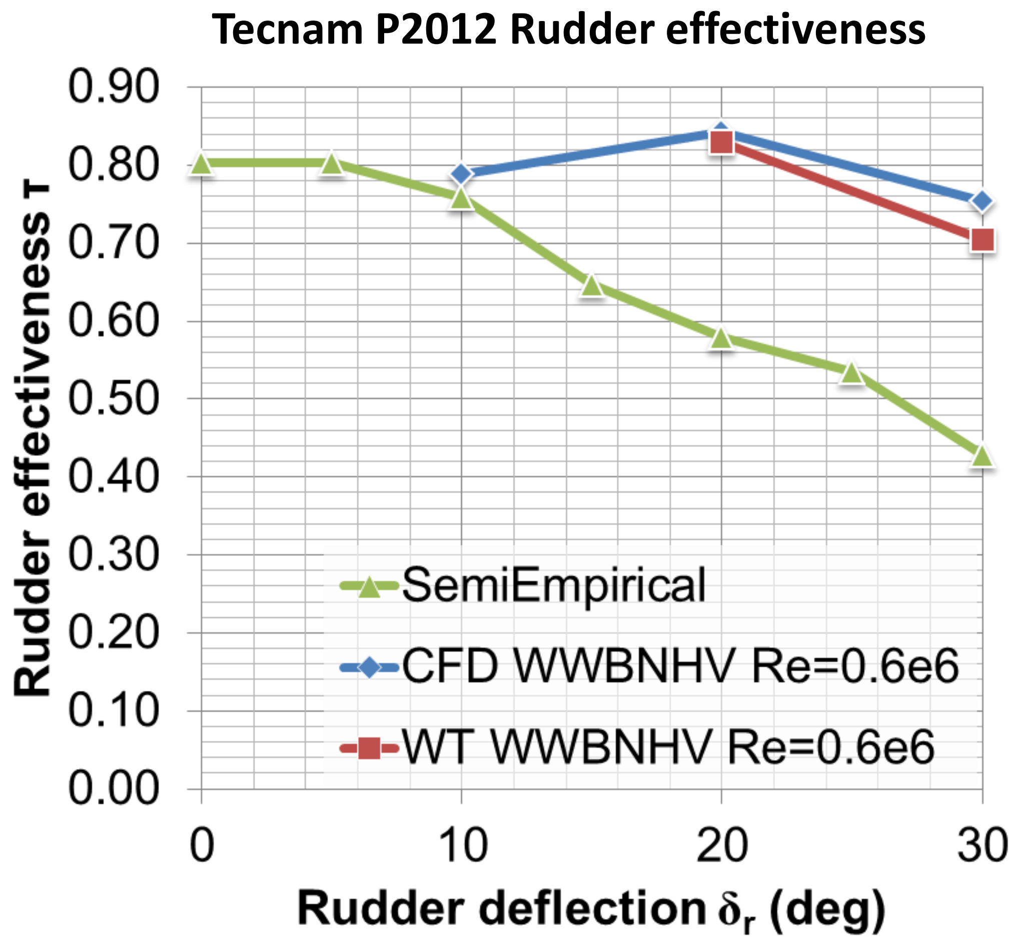


Directional control (directional control)

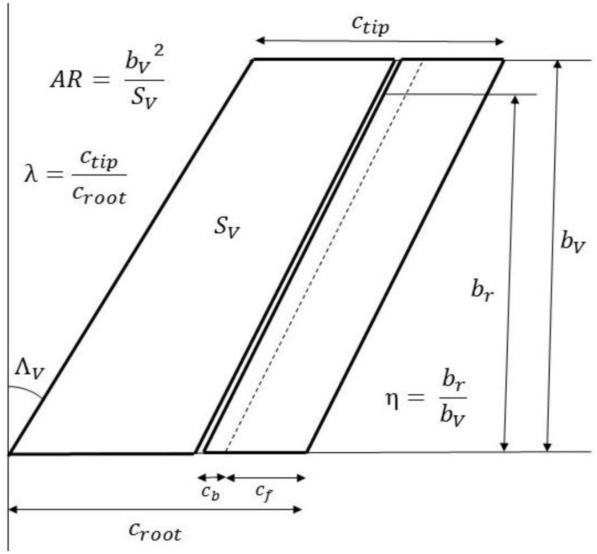


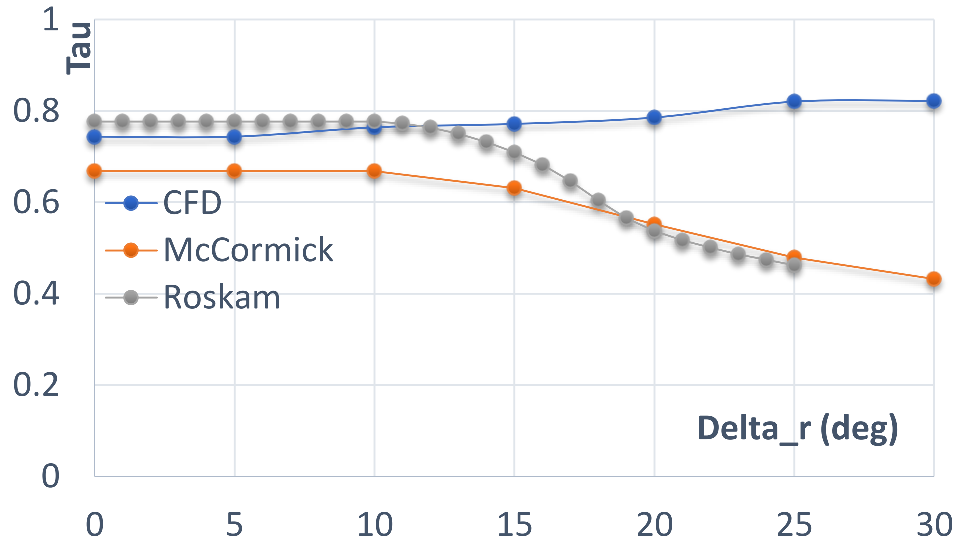


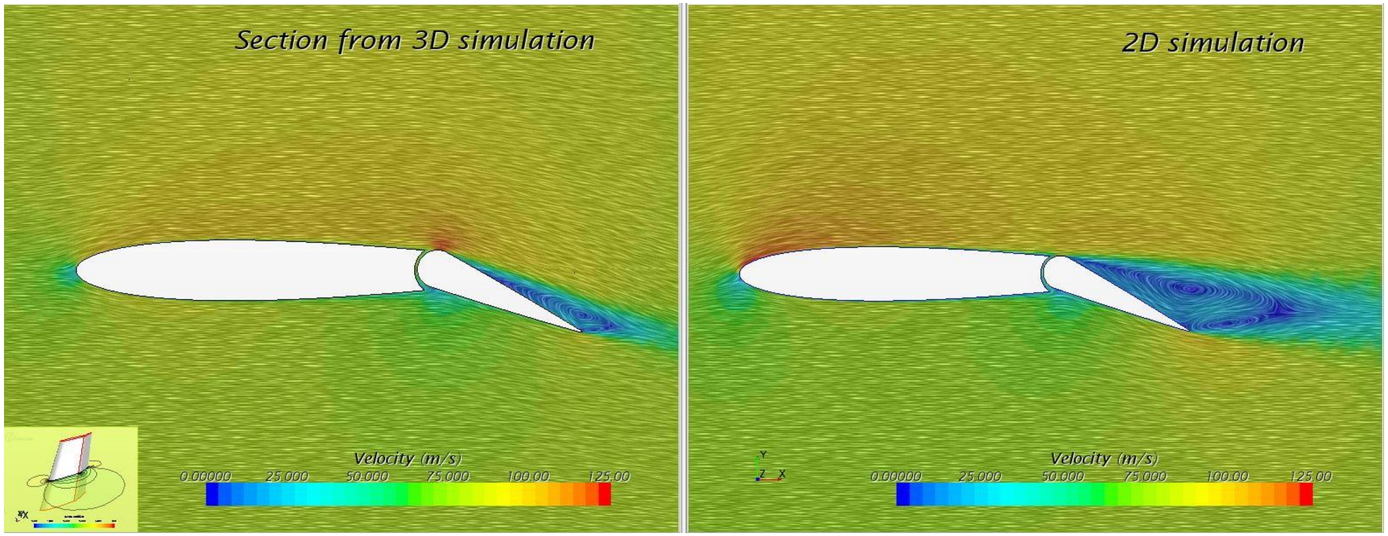
$$C_{N_{\delta_r}} = f\left[C_{L_{\alpha_v}}(A_{v\,eff}), \tau, K_{span}\right]$$



Directional control (directional control LOW AR lifting surface)



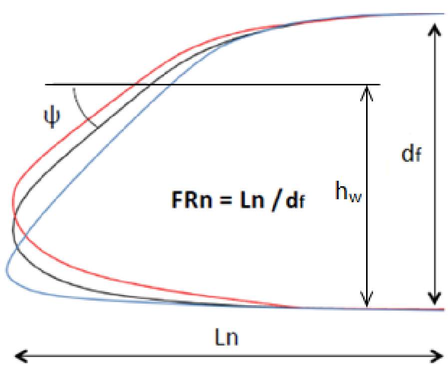


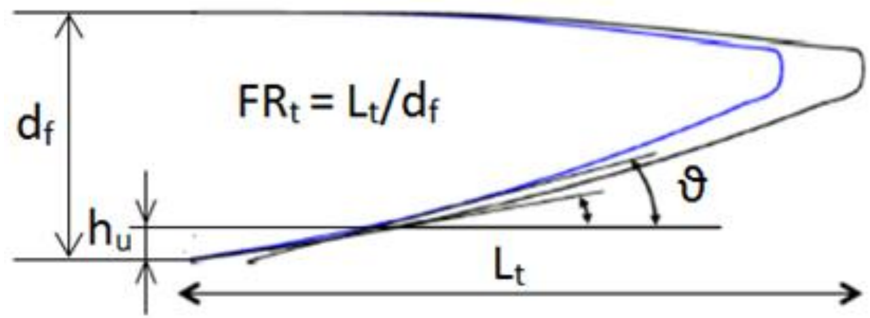


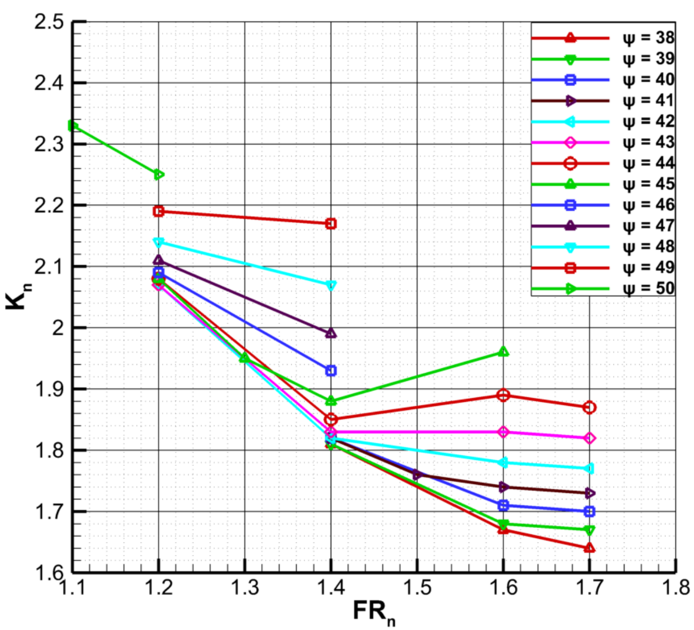
Fuselage aerodynamics (FUSDES)

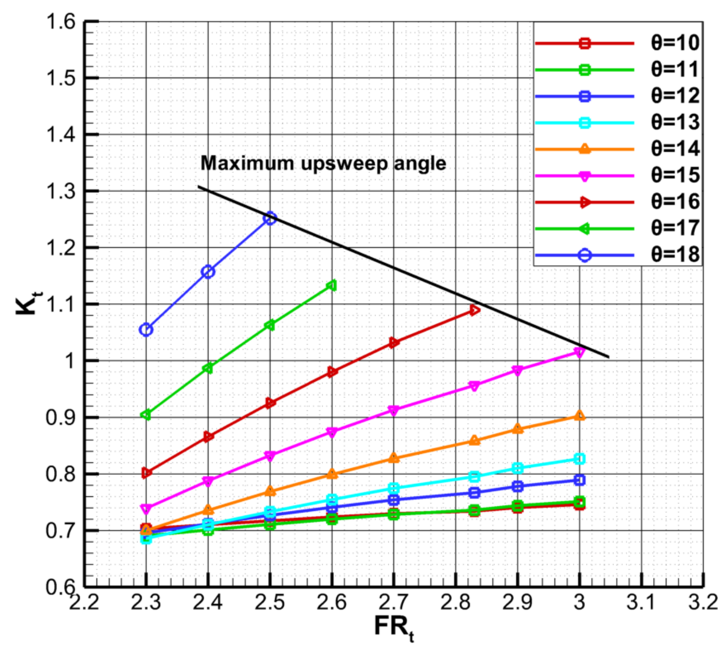
CD, CM(alpha), CN(beta)

$$C_{D\,fus} = \left(K_n \frac{S_{\text{wet nose}}}{S_{\text{wet}}} + K_c \frac{S_{\text{wet cabin}}}{S_{\text{wet}}} + K_t \frac{S_{\text{wet tail}}}{S_{\text{wet}}} \right) C_{D\,fp} \frac{S_{\text{wet}}}{S_{\text{front}}}$$

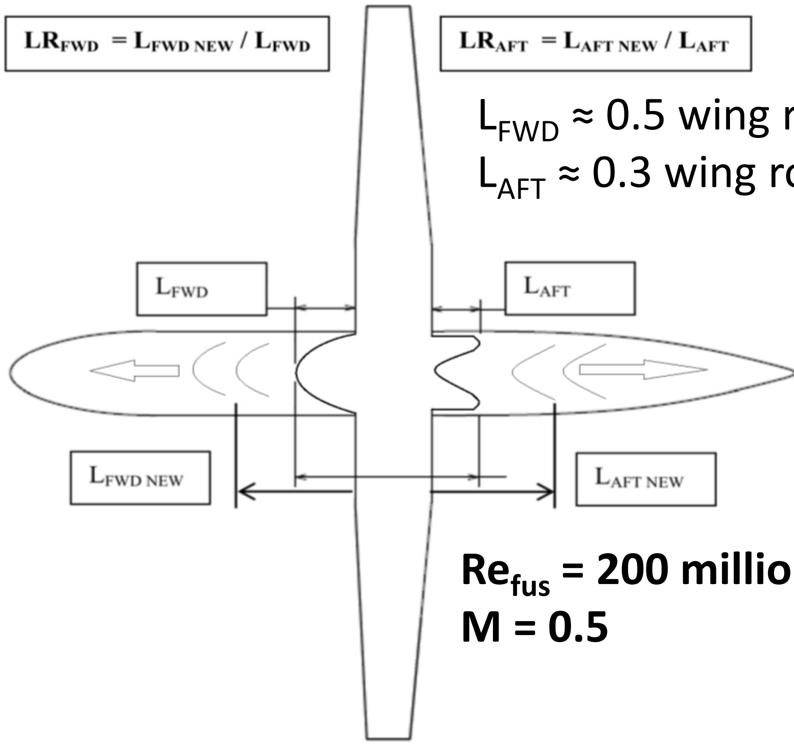




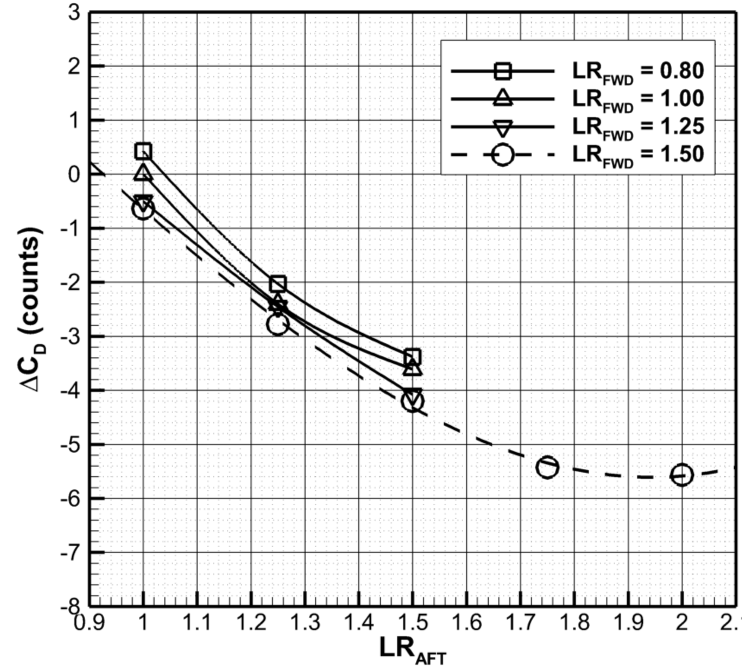




Karman design



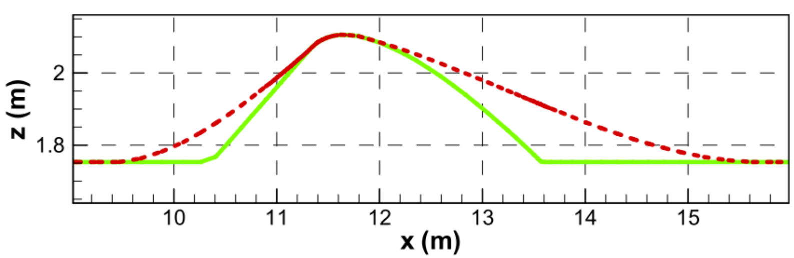
$L_{FWD} \approx 0.5$ wing root chord
$L_{AFT} \approx 0.3$ wing root chord

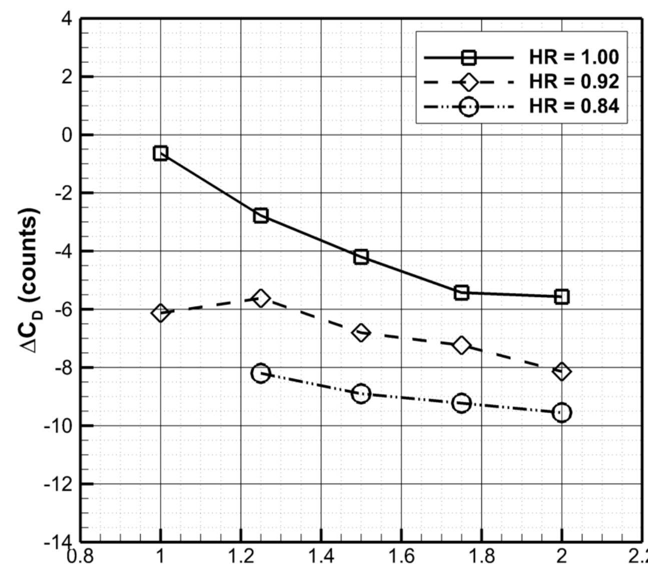


Re_{fus} = 200 million
M = 0.5

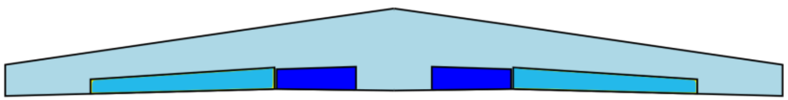
$HR = H_{NEW}/H_{REF}$

$H_{REF} \approx 0.2$ wing root chord

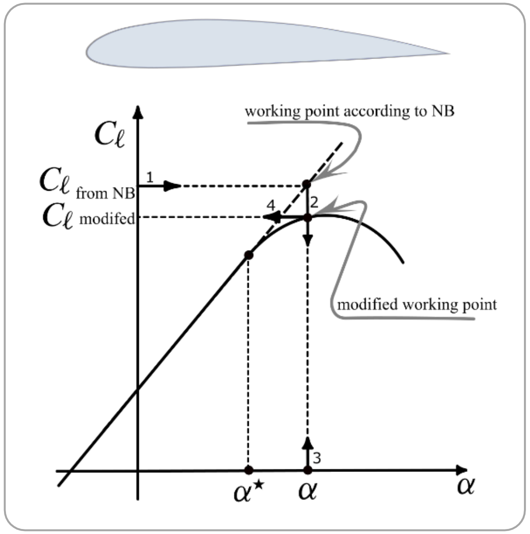


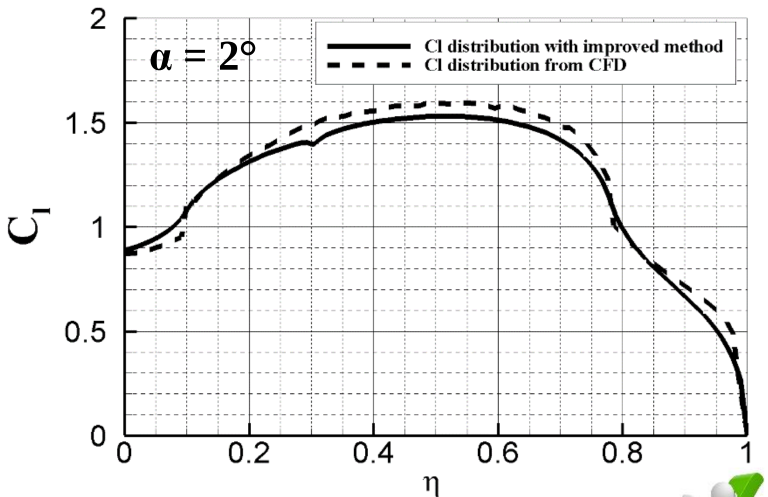


High-lift (wing max lift coeff. Prediction)

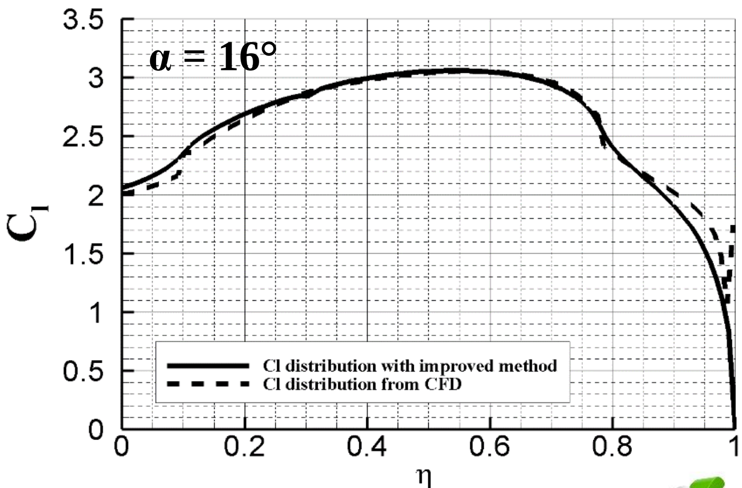


	ηin	ηout	δe	cf/c
flap 1	0.1	0.3	15°	0.29
flap 2	0.3	0.78	15°	0.32



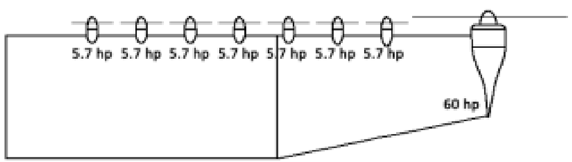


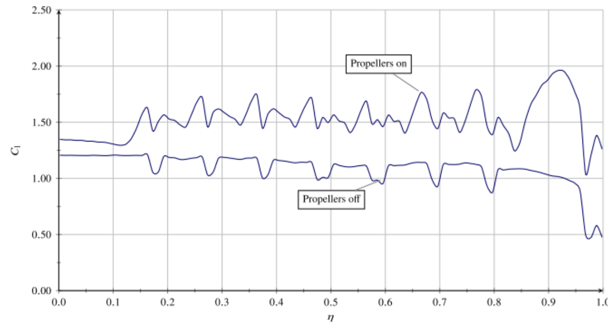
Mean ERR (%) = 4.94%

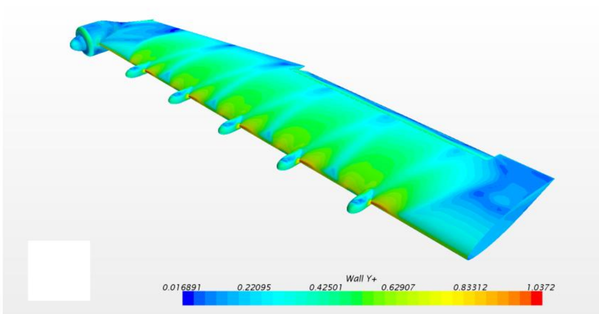


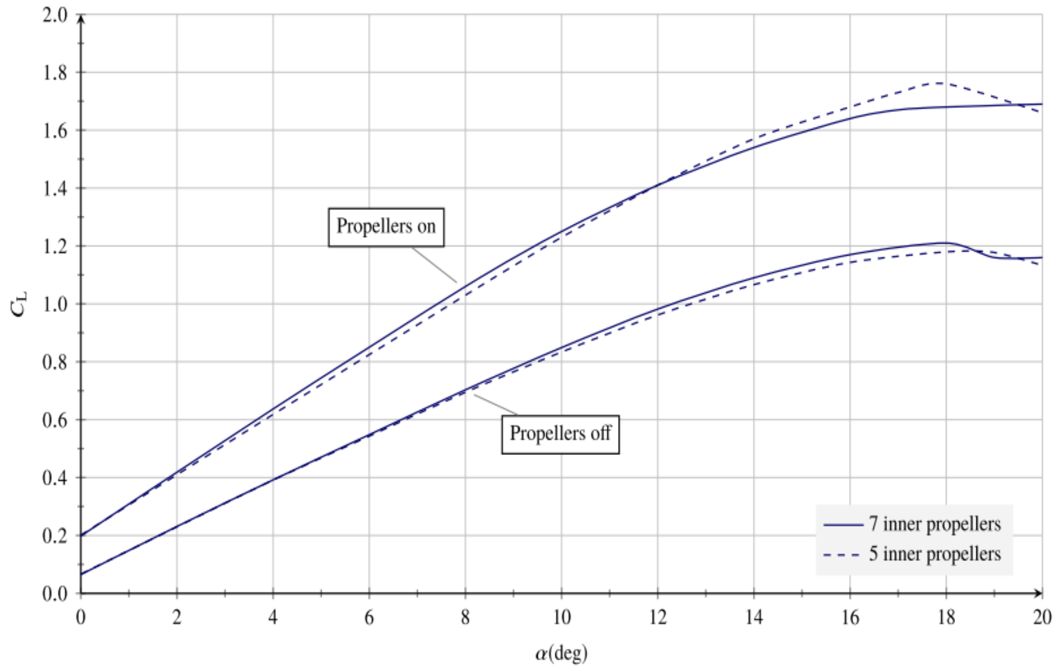
Mean ERR (%) = 2.78%

Analysis and modelling of Distributed Electric Propulsion









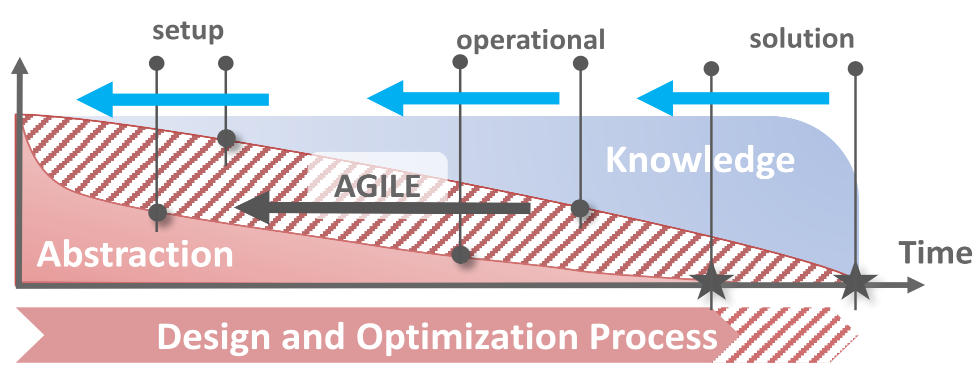
DAF group @ UNINA in AGILE project

AGILE Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts

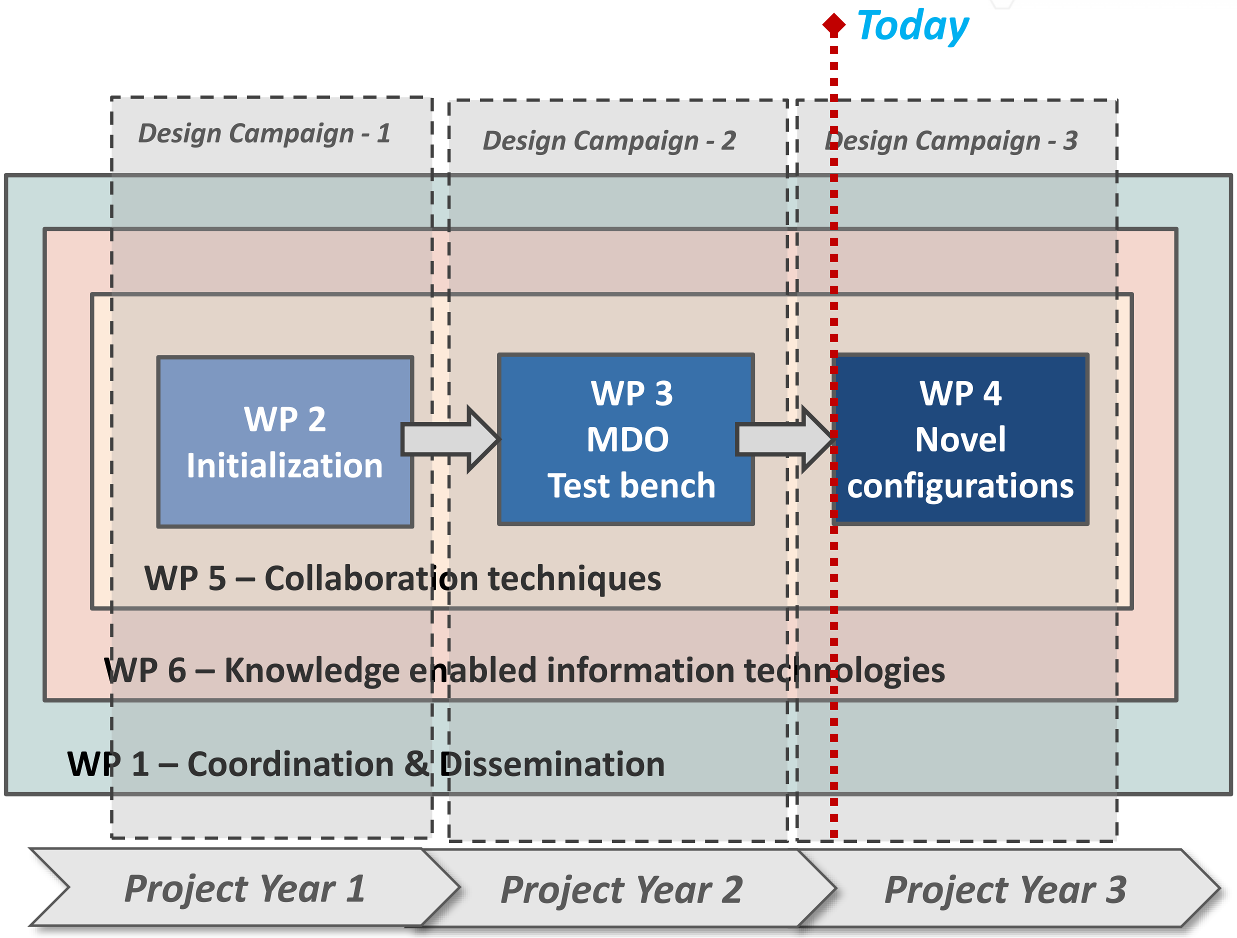
- H2020 3-years funded project
- 19 Partners involved

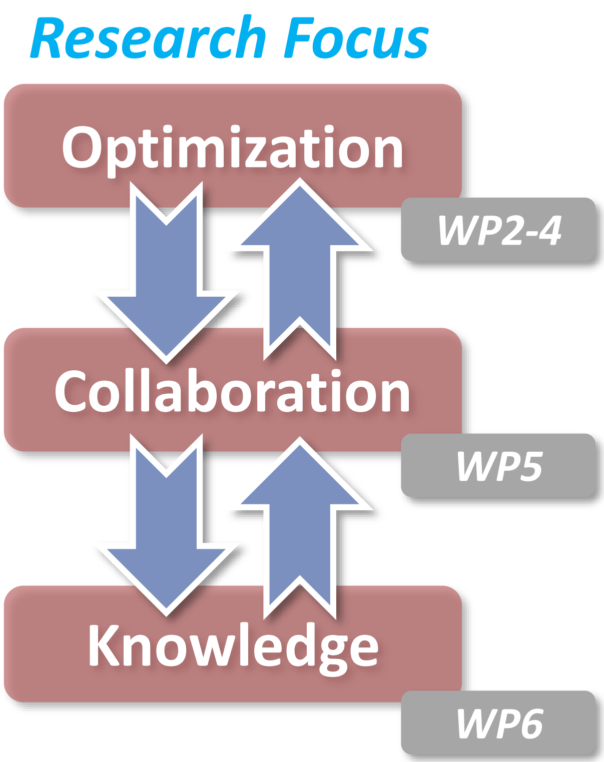
Objectives:

- *Realize the 3rd generation MDO*
- *Reducing aircraft development time\costs*
- *Enabling Collaborative Aircraft Design*



DAF group @ UNINA in AGILE project



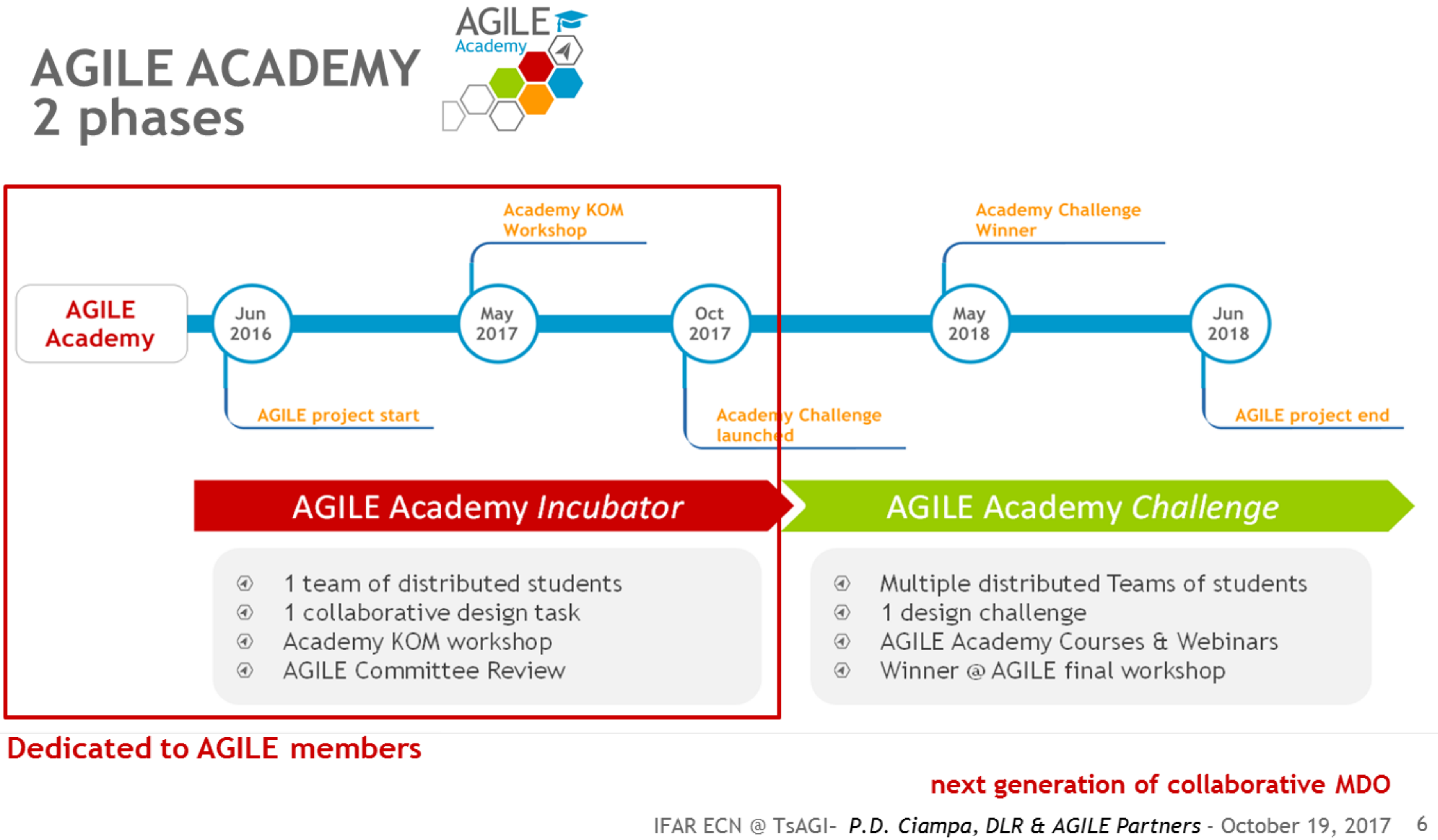


THE AGILE ACCADEMY

- Background:
  - Education on MDO State of the art is identified as a major need
  - MDO courses are available at limited Universities, and very diversified in contents

- Objectives of the Initiative:
  - Introduce the “AGILE Paradigm” and approach in Education\research
  - Disseminate\exploit AGILE results outside the Consortium
  - Deliver the AGILE “Open MDO suite” (one of the project main objectives)
  - Impact the MDO education → in Universities courses
  - A dedicated section on the AGILE portal

THE AGILE ACCADEMY

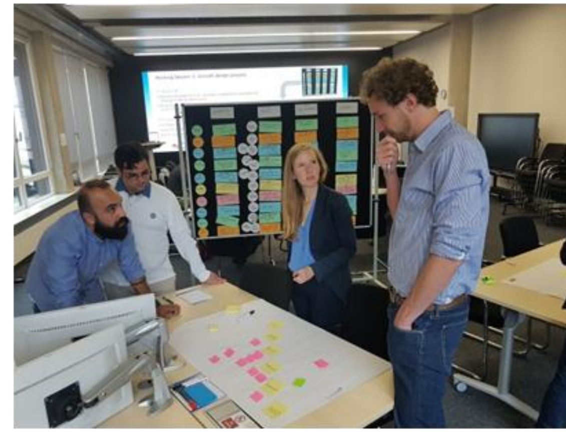


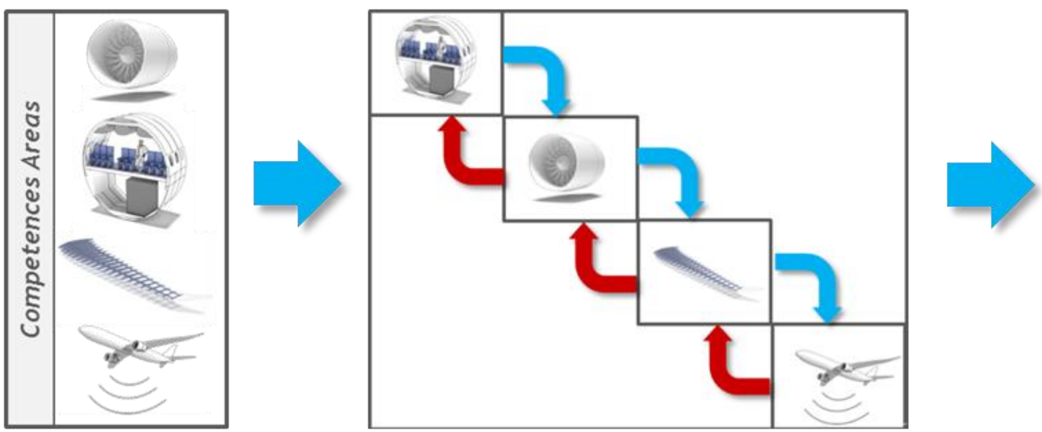
AGILE ACADEMY
Phase 1

1st AGILE Academy Workshop in Hamburg
https://agile-project.eu/agile-academy

Academy Incubator (May 2017- Sept 2017)

- Testing the **AGILE Paradigm** on students
- Quickly setup collaborative aircraft design among heterogeneous students





7

AGILE ACADEMY – Results of the Incubator

DC-2

Design Synthesis — Jonas Kaminski (DLR)

Aero — Giuseppe Torre (UNINA)

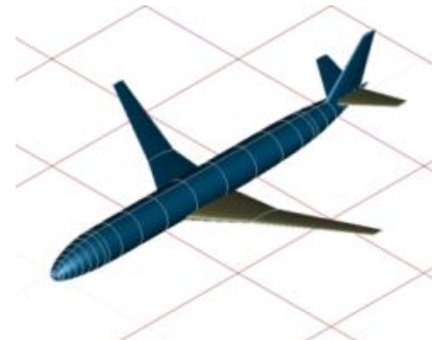
Structural Mass — Students TUD / DLR

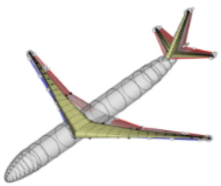
On Board Systems — Francesca Tomasella (POLITO)

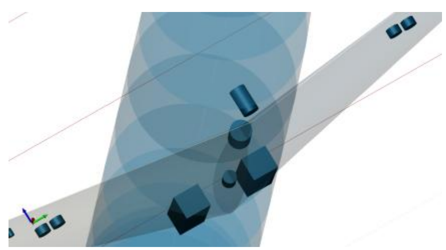
Engine Models — Maximilian Nollman (TUDELFT)

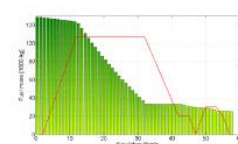
Mission Simulation — Nithin Rao (DLR)

Conventional DC 2 Aircraft









https://agile-project.eu/agile-academy

Incubator Activities (May-Sept 2017)

- Make use AGILE technologies
- Solve a collaborative aircraft design task
- ~2 months time
- 10 MSc students involved
- 3 Universities and 1 Research center
- Results at CEAS 2017

1st AGILE Academy Workshop in Hamburg

Academy Challenge (Oct 2017-May 2018)

- Release the AGILE technologies outside AGILE
- Establish collaborative distributed MDO teams
- Multiple aircraft MDO tasks, review by AGILE committee
- Challenge Winner @ AGILE final workshop

AGILE ACADEMY
Phase 2

Academy Challenge (Now- May 2018)

- Enable accessibility on AGILE technologies
- Establish **collaborative MDO Network**

1. Register https://agile-project.eu/agile-academy
2. Aircraft MDO Teams will be formed
3. MDO collaborative studies review by AGILE committee

- AGILE Technologies & Support (Webinars\Tutorials)
- Join activities with AGILE Consortium Partners
- Challenge Winner @ AGILE final workshop

Join the AGILE Challenge!!

For any information:
challenge@agile-project.eu

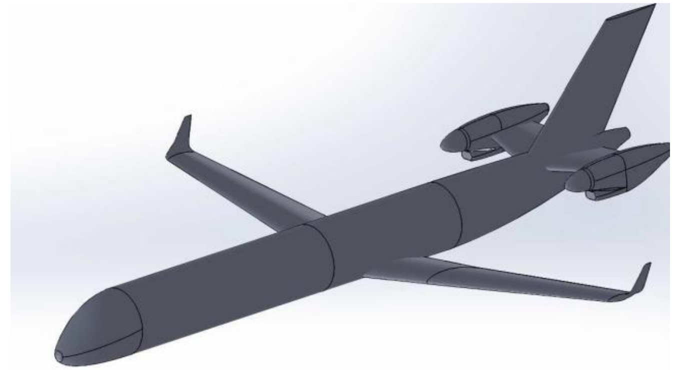
Presented @ CEAS

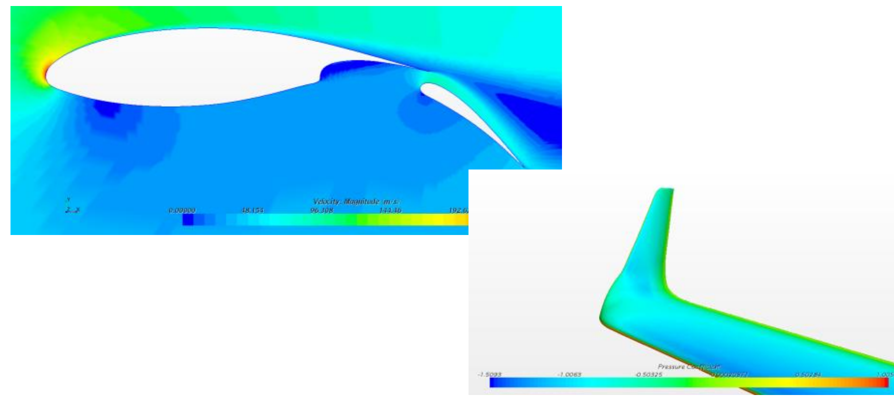
Thursday, October 19 , 2017
12:05 - 12:45 | Iorga Hall

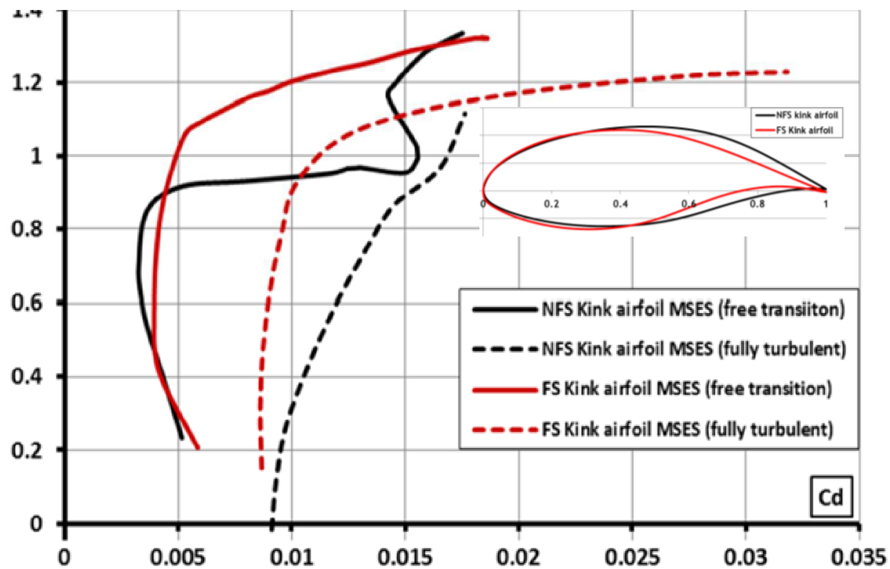
IRON Project

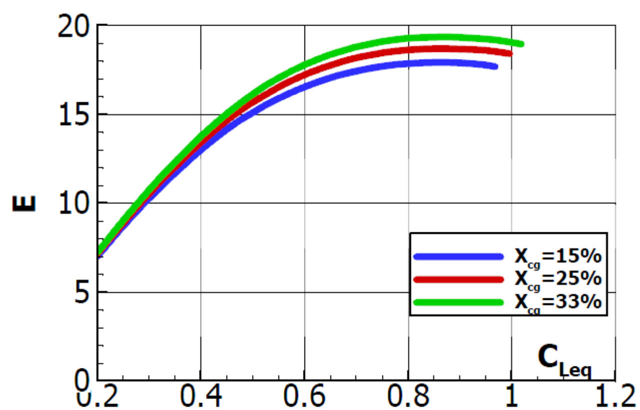
Design of an Innovative 130 pax Tprop A/C

- Aerodynamic design through several tools
- Deep use of several JPAD Modules
- Loop 1 completed









CONCLUSIONS

- Aircraft Design approach @ DAF group, UNINA
- Aircraft Design course and teaching and link with research
- Research activities and Industrial applications
- Innovative tools (software and framework)
- Improved analysis methods
- The activities in AGILE and the Agile Accademy