Dieter Scholz (Editor)

Proceedings

of the

11th European Workshop on Aircraft Design Education

EWADE 2013

17.-19.09.2013

Linköping, Sweden

Homepage of EWADE 2013:

http://EWADE2013.AircraftDesign.org

The presentation and papers listed here can be retrieved:

- http://ProceedingsEWADE2013.AircraftDesign.org
- https://zenodo.org/communities/ewade/search?q=ewade2013
- https://search.datacite.org/works?query=ewade2013

Each paper has its individual DOI (and link) as listed in the Table of Contents.

Table of Contents

EWADE 2 - Teaching and Research Activities in Aircraft Design

Adson Agrico de Paula	A Case Study in Aeronautical Engineering Education http://dx.doi.org/10.5281/zenodo.546420
Eike Stumpf	Aircraft Design Lectures at RWTH Aachen University, Germany http://dx.doi.org/10.5281/zenodo.546423
Sky Sartorius	The New Aircraft Design Course at the Technical University of Munich (TUM) http://dx.doi.org/10.5281/zenodo.546427
Dimo Zafirov, Hristian Panayotov	UAV Research and Development in Technical University – Sofia http://dx.doi.org/10.5281/zenodo.546431
Dieter Scholz	Open Access Publishing in Aerospace – Opportunities and Pitfalls http://dx.doi.org/10.5281/zenodo.18921 **Additional Full CEAS2013 Paper**

EWADE 3 - Aircraft Design Studies

G. La Rocca, P. van der Linden, M. Li	Conceptual Design of Passenger Aircraft for In-Flight Refueling Operations http://dx.doi.org/10.5281/zenodo.546442
Sergio Chiesa, Dieter Scholz, Giovanni A. di Meo, Marco Fioriti, Andrea Furlan	MARGARET: A Personal Transportation Aircraft of Tomorrow Used Today for Collaboration among Universities http://dx.doi.org/10.5281/zenodo.546443
G. La Rocca, M. Li, M. Chiozzi	Feasibility Study of a Nuclear Powered Blended Wing Body Aircraft for the Cruiser/Feeder Concept http://dx.doi.org/10.5281/zenodo.546482 **Additional Full CEAS2013 Paper**
R. De Roo, J. Verbeke, I. Becuwe	Development of UAS for Scientific Monitoring http://dx.doi.org/10.5281/zenodo.546608

EWADE 4 - Aircraft Design - Methods and Tools

Erwin Moerland, Richard-Gregor Becker, Björn Nagel	Collaborative Understanding of Disciplinary Correlations Using a Low-Fidelity Physics Based Aerospace Toolkit http://dx.doi.org/10.5281/zenodo.546610 **Additional Full CEAS2013 Paper**
Raghu Chaitanya.M.V, Ingo Staack, Petter Krus	Integrated Aircraft Design Network http://dx.doi.org/10.5281/zenodo.546612 **Additional Full CEAS2013 Paper**
Pier Davide Ciampa, Björn Nagel, Darwin Rajpal, Gianfranco La Rocca	Preliminary Design for Flexible Aircraft in a Collaborative Environment http://dx.doi.org/10.5281/zenodo.546615 **Additional Full CEAS2013 Paper**

EWADE 5 - Discussion about next EWADE and EWADE's role in CEAS

Gianfranco La Rocca	Aerospace Engineering at TU Delft http://dx.doi.org/10.5281/zenodo.546616

EWADE Contribution Presented in a CEAS Session

Dieter Scholz, Tahir Sousa	OpenVSP-Connect - Visualize YOUR Aircraft Sizing Results with NASA's Vehicle Sketch Pad http://dx.doi.org/10.5281/zenodo.546617

Introduction

General

In 2011 at the end of the workshop in Naples a short discussion followed by an acclamation by hand showed strong support and consensus to go to Kazan, Russia in May/June 2013. In December 2012 it became clear that this plan could no longer be followed. Prof. Petter Krus from Linköping University offered the possibility to integrate EWADE 2013 into the CEAS European Air & Space Conference 2013 (http://www.ceas2013.org).

For this reason **EWADE took place from 17th to 19th of September 2013** in the congress center located right in the heart of the city of Linköping, Sweden.

The workshop was organized by

- Prof. **Dieter Scholz**, Aircraft Design and Systems Group (AERO), Hamburg University of Applied Sciences, in close cooperation with
- Prof. **Petter Krus**, Head of the CEAS2013 Programme Committee and Head of the Division of Fluid and Mechatronic System, Linköping University and
- Dr. **Tomas Melin**, CEAS 2013 Programme Secretary and Research Associate in the Division of Fluid and Mechatronic System, Linköping University
- and of course the many people active in running the CEAS conference with coffee breaks, lunch, dinner, ...

LINKÖPINGS UNIVERSITET

Programme and Invitation

Day		Time	Activity
Tuesday	17 September 2013	09:30 - 11:30	EWADE 1 Presentations from EWADE Founders and Hosts
		13:00 - 15:00	EWADE 2 Teaching and Research Activities in Aircraft Design
		15:30 - 17:00	EWADE 3 Aircraft Design Studies
		evening	Gala Dinner
Wednesday	18 September 2013	10:30 - 12:30	EWADE 4 Collaboration, Methods and Tools
		14:30 - 16:00	EWADE 5 EWADE Roundtable: Discussion about next EWADE and EWADE's role in CEAS
Thursday	19 September 2013	all day	Technical Tours

There were 4 or 5 presentations scheduled for each session. See programme for details.

There were **2 options** for making a presentation: the "CEAS-Option" and the "EWADE-Option":

- "**CEAS-Option**": **Presentation with full paper**. The papers were published "open access" in the CEAS2013 Proceedings in DiVA - Academic Archive Online (the Swedish digital archive for research and student theses with long-term preservation) as:

  MELIN, Tomas; KRUS, Petter; VINTERHAV, Emil; ÖVREBÖ, Knut: *PROCEEDINGS of the 4th CEAS Conference in Linköping, 2013* (4th CEAS Air & Space Conference, 16. to 19.09.2013, Linköping, Sweden), ISBN 978-91-7519-519-3, http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-99581.

  This is unfortunately one big PDF (1005 pages) with all papers, but the CEAS papers related to presentations in an EWADE session can be found as a single paper at EWADE: http://proceedingsewade2013.aircraftdesign.org.

- "**EWADE-Option**": **Presentation without paper**. Only the presentations are provided online as PDF.

EWADE 2013

11th European Workshop on Aircraft Design Education

17 to 19 September 2013, Linköping University, Sweden

General Decision

In 2011 at the end of the workshop in Naples a short discussion followed by an acclamation by hand showed strong support and a general consensus to go to Kazan, Russia in May/June 2013. In December 2012 it became clear that this plan could no longer be followed. So Prof. Petter Krus from Linköping University offered the possibility to **integrate EWADE 2013 into the CEAS European Air & Space Conference 2013 taking place from 16th to 19th of September 2013 at Linköping University, Sweden**.

CEAS European Air & Space Conference

CEAS stands for "Council of European Aerospace Societies" (http://www.CEAS.org). The international and general CEAS conference is the "CEAS European Air & Space Conference". It takes place biannually and is always integrated within the national aerospace conference of one of the CEAS member societies. The 2011 CEAS conference in Venice, Italy organized by the Italian AIDAA - Associazione Italiana di Aeronautica e Astronautica will be followed in **2013** by the **CEAS conference in Linköping, Sweden organized by the Swedish Aeronautics and Astronautics Association FTF - FlygTekniska Föreningen together with the University Linköping** (http://www.CEAS2013.org).

EWADE Activities in CEAS

Since 2009 EWADE is linked to CEAS. This came naturally, since EWADE and CEAS are both European activities / organizations. EWADE carries the CEAS logo on its website (http://www.AircraftDesign.org) and the European Workshops on Aircraft Design Education are listed on the CEAS calendar of activities (http://www.ceas.org/calendar.php). Since 7th March 2013 CEAS has a "Technical Committee" called "Aircraft Design" (TCAD) with a section on education which is EWADE.

EWADE 2002 at Linköping

For those following EWADE activities for some time, Linköping is already well known: **The 5th European Workshop on Aircraft Design Education (EWADE 2002) took already place at the University of Linköping** (http://EWADE2002.AircraftDesign.org).

Organization of EWADE 2013

Since EWADE 2013 will be integrated into CEAS 2013, common activities are possible and EWADE has the chance to benefit from CEAS and the professional organization of the European Air & Space Conference. At the same time EWADE 2013 will maintain its character of a close-knit community of academics active in aircraft design education and research.

Preliminary Program of EWADE 2013
integrated into the CEAS European Air & Space Conference 2013

Day		Time	Activity
Tuesday	17 September 2013	evening	gala dinner
Wednesday	18 September 2013	morning	plenary event, technical sessions
		afternoon	plenary event, technical sessions, conclusions
Thursday	19 September	all day	tourist visits and industrial visits

Call for Presentations

Now after the CEAS deadline of the call for papers has past, there is only one option left to actively participate in EWADE. Traditionally EWADE offers the possibility to **give a presentation without the need to deliver a full paper**. There will be *several sessions organized by EWADE on Wednesday*. These sessions allow everyone

- to give an introduction to the activities of his/her university in aircraft design,
- to present recent advances of his/her university in aircraft design.

Presentations will be scheduled for 20 minutes with 10 minutes reserved for discussion at the end of each presentation. Presenters will have to submit the topic of the presentation for inclusion into the program by 15th May 2013 (this is already the extended deadline) to Prof. Dieter Scholz (info@ProfScholz.de).

Publication

- In any case your **presentation will be collected at the day of presentation and will be made public on the EWADE web site** (http://www.AircraftDesign.org) as known from previous workshops. In addition you have more ways for publication:
- If you want, you can deliver a one-page abstract on your EWADE presentation topic to tomas.melin@liu.se by 1st August 2013. If your abstract gets accepted, you can submit a full paper to be published in the **CEAS2013 proceedings**.
- If you want to have your EWADE presentation be published as a full paper in a **peer-reviewed journal**, we will present in Linköping at least one special possibility to do so.

2 Options for Registration

To facilitate the organization and to make full use of the activities of the European Air & Space Conference it is advised that EWADE participants consider taking fully part in CEAS 2013. In this way EWADE 2013 does not require additional spending on the part of the participant, if the participation in CEAS 2013 was considered anyway. The two options are:

a) **Full registration for the CEAS European Air & Space Conference 2013**: Fees are announced on http://www.ceas2013.redhammer.se/index.php/registration.

b) **EWADE presenters and EWADE participants** without presentations are offered a **one day registration (only Wednesday)**. The fee for one day will be 200 EUR. A single day registration includes CEAS conference amenities such as coffee, lunch and access to other presentation CEAS tracks. The exact details (price, rules, other things included in the price) will only be known once published on the CEAS web page (see above). If need arises, participants form former EWADE conferences may ask for a special financial arrangement on an individual bases on submission of an informal request to Prof. Petter Krus (petter.krus@liu.se).

The **technical visits** will be offered for EWADE participants as part of the CEAS conference on Thursday. The **gala dinner** for EWADE participants (also part of the general CEAS conference) will take place on Tuesday evening. Please contact the CEAS 2013 conference office (ceas2013@iei.liu.se) for details on technical visits and the gala dinner.

Note:

The **3rd Symposium on Collaboration in Aircraft Design** takes place from 19th to 20th September 2013 also in Linköping (Sweden). This is the activity of the research section of the "Technical Committee Aircraft Design" (TCAD) in CEAS. (Compare with "EWADE Activities in CEAS" on page 1).

Subject : **Invitation CEAS2013 with EWADE sessions**
From : Petter Krus
Date : Friday, January 18, 2013 2:50 PM
To : EWADE Mailing List

Dear All
We are pleased to announce that the "European Workshop on Aircraft Design and Education, EWADE", www.aircraftdesign.org, this year will be together with the CEAS2013 conference by co-hosting sessions during one day. More information on this can be found on www.AircraftDesign.org/2013/Invitation_EWADE2013.pdf.

The CEAS European Air & Space Conference 2013, CEAS2013, www.ceas2013.org, will take place in Linköping (Sweden), from 16 to 19 September 2013. Linköping is considered the aeronautics capital of Sweden, home of most of the important Swedish aviation industry and birthplace of Swedish aviation. This event will constitute a forum aimed at exchanging information in the wide field of aerospace, and also a unique forum and meeting place for socializing and networking among colleagues and friends from aerospace industry, institutions, academia and associations.

The CEAS conference was established by the Council of European Aerospace Societies (CEAS), to create a European forum for science and technology. It is aimed at being the major European aerospace conference. CEAS2013 will be the fourth CEAS Conference (after Berlin 2007, Manchester 2009 and Venice 2011) organized by the FTF and Linköping University, it will address all disciplines of aeronautics and aeronautical systems, including design, development and operations. Our hope is that this will be a truly international European conference. The central theme of the conference will be

'Innovative Europe'

To make a submission for the conference go to our website www.ceas2013.org.

Welcome!

Petter Krus
Professor, Linköping University
Chairman of the CEAS2013 program committee

Dieter Scholz
Professor, HAW Hamburg, info@ProfScholz.de
Co-organizer for the CEAS2013/EWADE sessions

11th EWADE, 2013

European Workshop on Aircraft Design Education
Integrated into CEAS 2013

Tuesday, September 17, 2013

Presentation	Presenter First Name	Last Name	Presenter Affiliation	Title	Other Contributors	Affiliation, long
EWADE 1	09:30 - 11:30, Verdefoajén					
Presentations from EWADE Founders and Hosts						
Chairperson:	Dieter	Scholz	HAW Hamburg			Hamburg University of Applied Sciences, Germany
EWADE 1	Egbert	Torenbeek	TUD (em.)	The New Textbook: "Advanced Aircraft Design - Conceptual Design, Technology and Optimization of Subsonic Civil Airplanes"		Delft University of Technology, Netherlands
EWADE 2	Marco	Fioriti	PoliTo	Contributions from Educational Activities to Researches about Hybrid Propulsion Opportunities for Light Aircaft	**Sergio Chiesa**, Giovanni Di Meo, Roberta Fusaro	Politecnico di Torino, Italy
CEAS 230	Christopher	Jouannet	LiU	Personal Jet - A Student Project	Patrick. Berry, Tomas Melin, David Lundström	Linköping University, Sweden
EWADE 14	Ed	Obert	TUD (em.)	The Relation between Aerodynamics and Control System Design - A case study: The F28 Rudder Control System		Delft University of Technology, Netherlands
EWADE 3	Fabricio	Nicolosi	UniNa	A New Vertical Tail Design Procedure for General Aviation and Turboprop Aircraft	P. Della Vecchia, D. Ciliberti	Università degli Studi di Napoli "Federico II", Italy
EWADE 2	13:00 - 15:00, Verdefoajén					
Teaching and Research Activities in Aircraft Design						
Chairperson:	Petter	Krus	LiU			Linköping University, Sweden
CEAS 210	Adson	Agrico de Paula	Uni Sao Paulo	A Case Study in Aeronautical Engineering Education		University of Sao Paulo, Brazil
EWADE 4	Eike	Stumpf	RWTH Aachen	Aircraft Design Lectures at RWTH Aachen University	Kristof Risse	RWTH Aachen University, Germany
EWADE 5	Sky	Satorius	TUM	Developing a New Aircraft Design Course at the Technical University of Munich		Technical University Munich, Germany
EWADE 8	Dimo	Zafirov	Uni Sofia	UAV Research and Development in the Plovdiv Branch of Technical University Sofia		Technical University Sofia, Branch of Plovdiv, Bulgaria
CEAS 236	Dieter	Scholz	HAW Hamburg	Open Access Publishing in Aerospace – Opportunities and Pitfalls		Hamburg University of Applied Sciences, Germany
EWADE 3	15:30 - 17:00, Verdefoajén					
Aircraft Design Studies						
Chairperson:	Adson	Agrico de Paula	Uni Sao Paulo			University of Sao Paulo, Brazil
EWADE 6	Gianfranco	La Rocca	TUD	Design Study of a Passenger Aircraft for In-Flight Refueling		Delft University of Technology, Netherlands
EWADE 9	Giovanni A.	Di Meo	PoliTo	MARGARET: A Personal Transportation Aircraft of Tomorrow used Today for Collaboration among Universities	Dieter Scholz *, Marco Fioriti, Andrea Furlan	Politecnico di Torino, Italy; * Hamburg University of Applied Sciences, Germany
CEAS 224	Gianfranco	La Rocca	TUD	Feasibility Study of a Nuclear Powered Blended Wing Body Aircraft for the Cruiser/Feeder Concept		Delft University of Technology, Netherlands
EWADE 7	Rob	De Roo	KHBO	Development of an Unmanned Aerial System (UAS) for Scientific Monitoring	Jon Verbeke, Ivan Becuwe	Katholieke Hogeschool Brugge - Oostende, Belgium

One EWADE presentation is in another CEAS session (parallel to EWADE 3)

Presentation	Presenter First Name	Last Name	Presenter Affiliation	Title	Other Contributors	Affiliation, long
Aircraft Design - Methods and Tools II, Musikalen						
EWADE 13	Dieter	Scholz	HAW Hamburg	**OpenVSP Connect** - Visualize Your Aircraft Sizing Results with NASA's Vehicle Sketch Pad	Tahir Sousa	Hamburg University of Applied Sciences, Germany

Wednesday, September 18, 2013

Presentation	Presenter First Name	Last Name	Presenter Affiliation	Title	Other Contributors	Affiliation, long
EWADE 4	10:30 - 12:30, Verdefoajén					
Collaboration, Methods and Tools						
Chairperson:	Egbert	Torenbeek	TUD (em.)			Delft University of Technology, Netherlands
CEAS 291	Erwin	Moerland	DLR	Collaborative understanding of disciplinary correlations using a low-fidelity physics based aerospace toolkit	Richard-Gregor Becker, Björn Nagel	Deutsches Zentrum für Luft- und Raumfahrt, Germany
CEAS 183	Raghu	Chaitanya	LiU	Integrated Aircraft Design Network	Ingo Staack, Petter Krus	Linköping University, Sweden
CEAS 233	Christopher	Jouannet	LiU	Aircraft Conceptual Design Optimization Based on Direct Simulation	Ingo Staack, Raghu Chaitanya, Tomas Melin, David Lundström	Linköping University, Sweden
CEAS 199	Pier Davide	Ciampa	DLR	Preliminary Design for Flexible Aircraft in a Collaborative Environment	Björn Nagel	Deutsches Zentrum für Luft- und Raumfahrt, Germany
CEAS 187	Ingo	Staack	LiU	Integration of On-Board Power Systems Simulation in Conceptual Aircraft Design		Linköping University, Sweden
EWADE 5	14:30 - 16:00, Verdefoajén					
EWADE Roundtable						
Chairperson:	Dieter	Scholz	HAW Hamburg			Hamburg University of Applied Sciences, Germany

Discussion about next EWADE and EWADE's role in CEAS

Discussion about EWADE's Future

There was an EWADE registration option at CEAS for single days. To register for **two days (Tuesday and Wednesday) was sufficient if someone just wanted to go to EWADE**. A single day registration included CEAS conference amenities such as coffee, lunch and access to other presentation tracks. A two day registration included also the gala dinner. The fee for two days was 4750 SEK (about 500 EUR) incl. VAT (25%) - instead of the regular CEAS fee of 7125 SEK.

Background about fees for EWADE participants:

- 1 day participation: 1900 SKR (220 EUR). EWADE sessions only.
- 2 day participation: 4750 SKR (500 EUR). This included conference dinner and technical tour.
- 3 day participation: 5700 SKR (670 EUR). This was 425 SKR (50 EUR) less than CEAS standard price.

For the first time EWADE was **co-located with anther conference**. At this EWADE participants had the possibility to go to parallel sessions and select the EWADE session or another session from the CEAS conference. This enabled a choice between many different presentations, but limited the experience of EWADE as a meeting among friends. For this reason it was not even possible to track who on site was an EWADE participant. Accordingly the idea to make an "EWADE 2013 group picture" of participants was skipped. The financial structure made it necessary to ask participants to pay full or partial conference fees depending on the number of days participating. Also **paying conference fees** was a novum for EWADE and made it unfortunately impossible for several people to attend.

The **discussion** in EWADE Session 5 showed controversial views **about EWADE's link to CEAS** and its role in CEAS. There was however agreement that EWADE should be acting as the Education Section in the new CEAS Technical Committee on Aircraft Design (CEAS TCAD). EWADE being part of the CEAS TCAD would enhance its visibility. EWADE will continue to act independently based on a discussion at each EWADE. It will not take orders related to its activities from CEAS bodies.

A presentation and **invitation for 2015** by Dr. Gianfranco La Rocca from Delft University of Technology was well received. An acclamation by hand showed strong support and a general consensus to go to Delft, Netherlands for the **12th EWADE** with the plan to convene in May/June 2015. This timing was later changed to enable **co-location** of EWADE **with CEAS2015**.

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.*18916*

The New Textbook ”Advanced Aircraft Design – Conceptual Design, Technology and Optimization of Subsonic Civil Airplanes“

Egbert Torenbeek

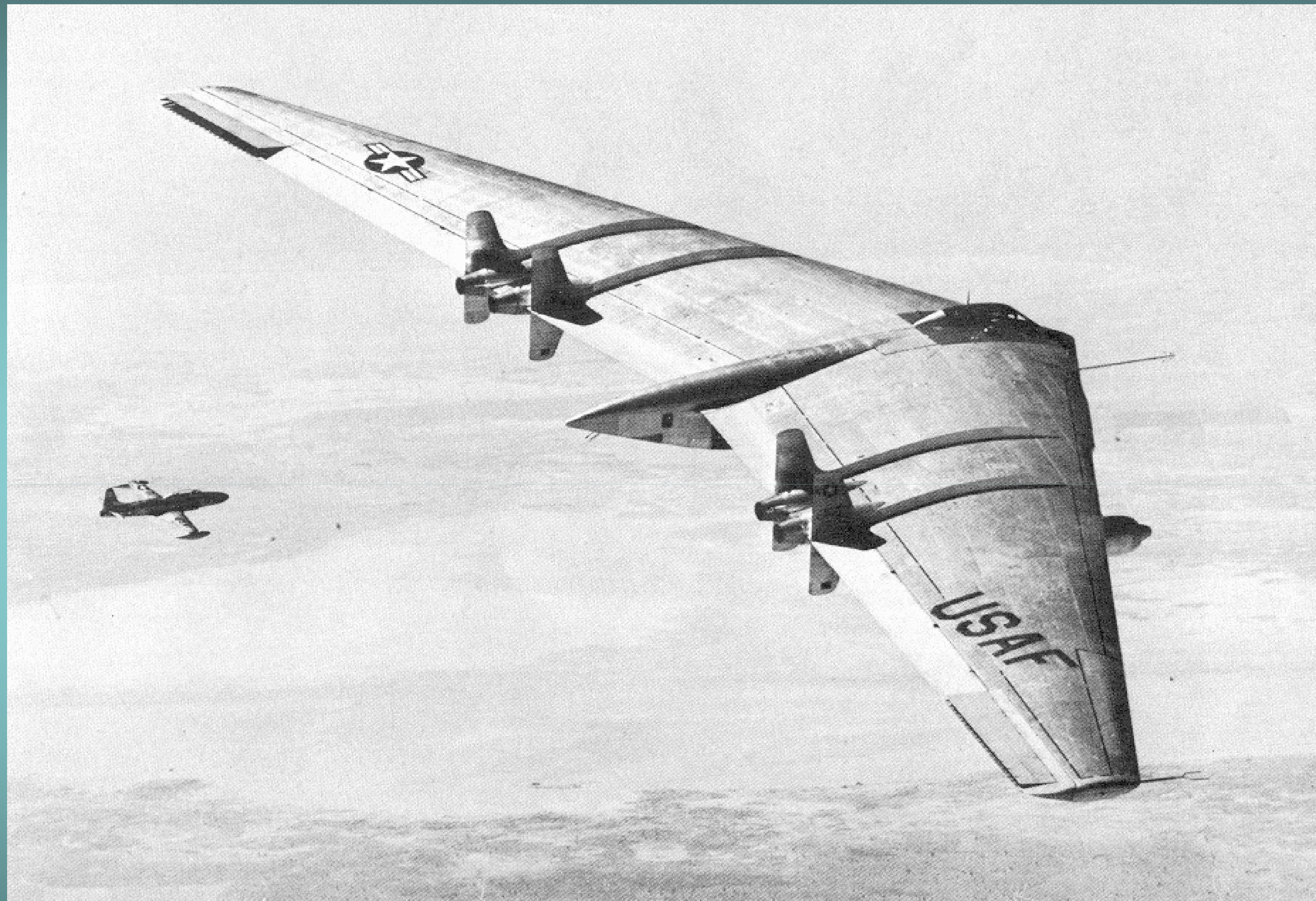
11th EWADE, 2013
European Workshop on Aircraft Design Education
17th to 19th September 2013
Linköping, Sweden

ADVANCED AIRCRAFT DESIGN

Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes

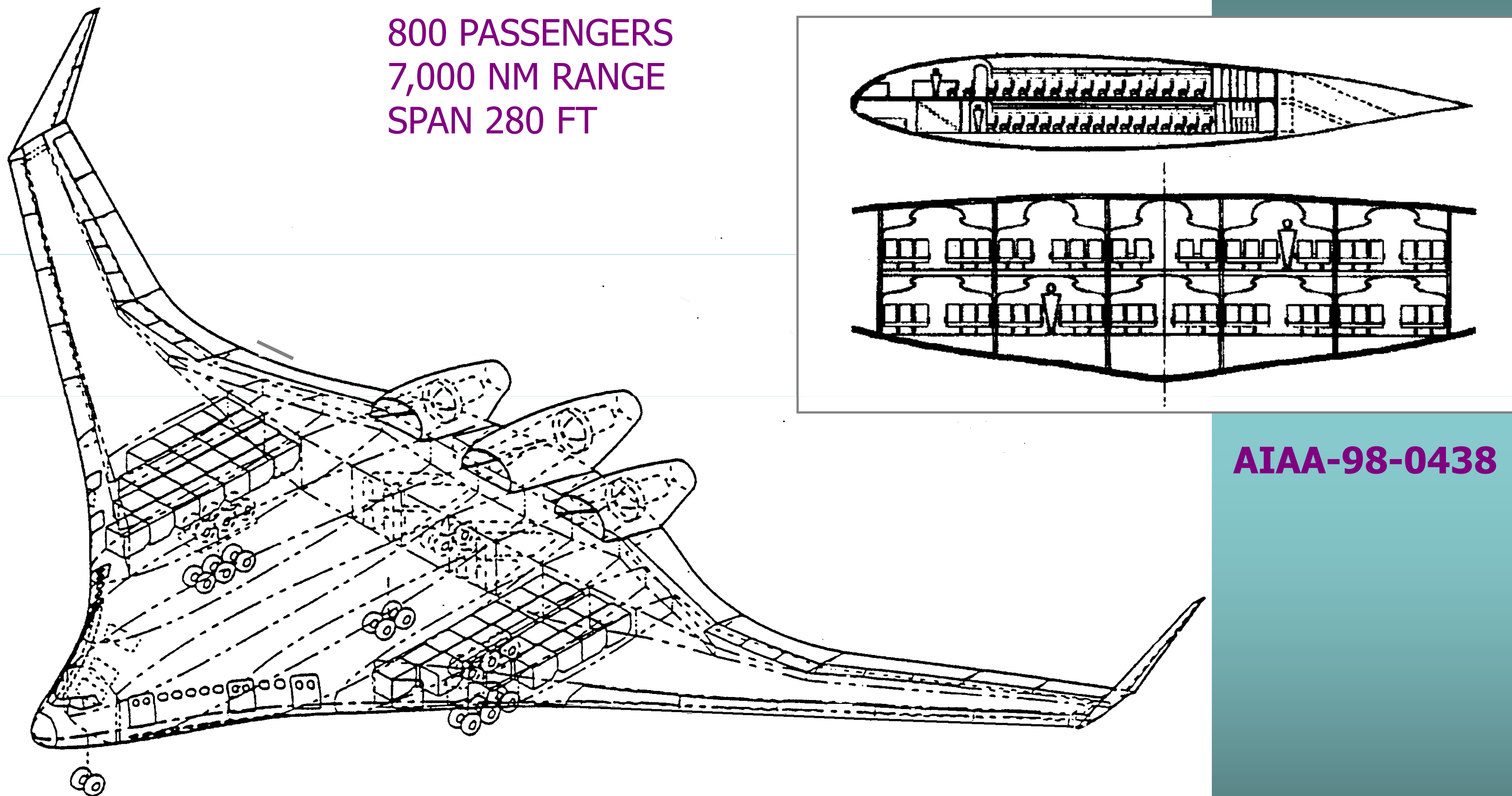
1. Design of the Well-Tempered Aircraft
2. Early Conceptual Design
3. Propulsion and Engine Technology
4. Aerodynamic Drag and its Reduction
5. From Tube and Wing to Flying Wing
6. Clean Sheet Design
7. Aircraft Design Optimizations
8. Theory of Optimum Weight
9. Matching Engines and Airframe
10. Elements of Aerodynamic Wing Design
11. The Wing Structure and its Weight
12. Unified Cruise Performance

NORTHROP YRB - 49A (1950)



It has long been recognized that the flying wing, when jet propelled, is a poor choice for an aircraft configuration intended to achieve long range (J.V.Foa 1984)

EARLY MDD BWB DESIGN



AIAA-98-0438

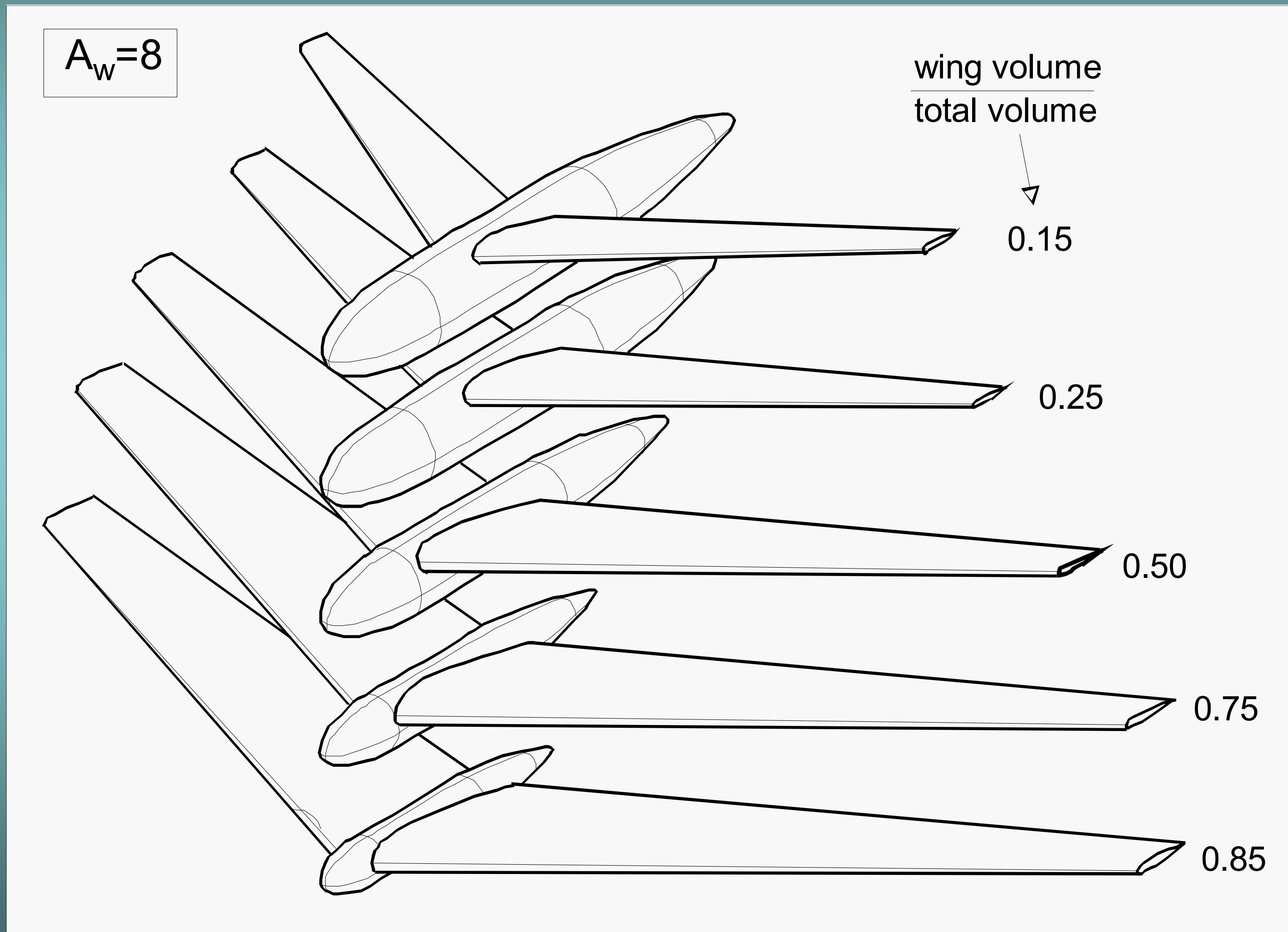
BOEING BWB-450 DESIGN HAS PASSENGER SEATS ON UPPER DECK, BAGGAGE ON LOWER DECK

SYNERGY OF BASIC DISCIPLINES IN BWB

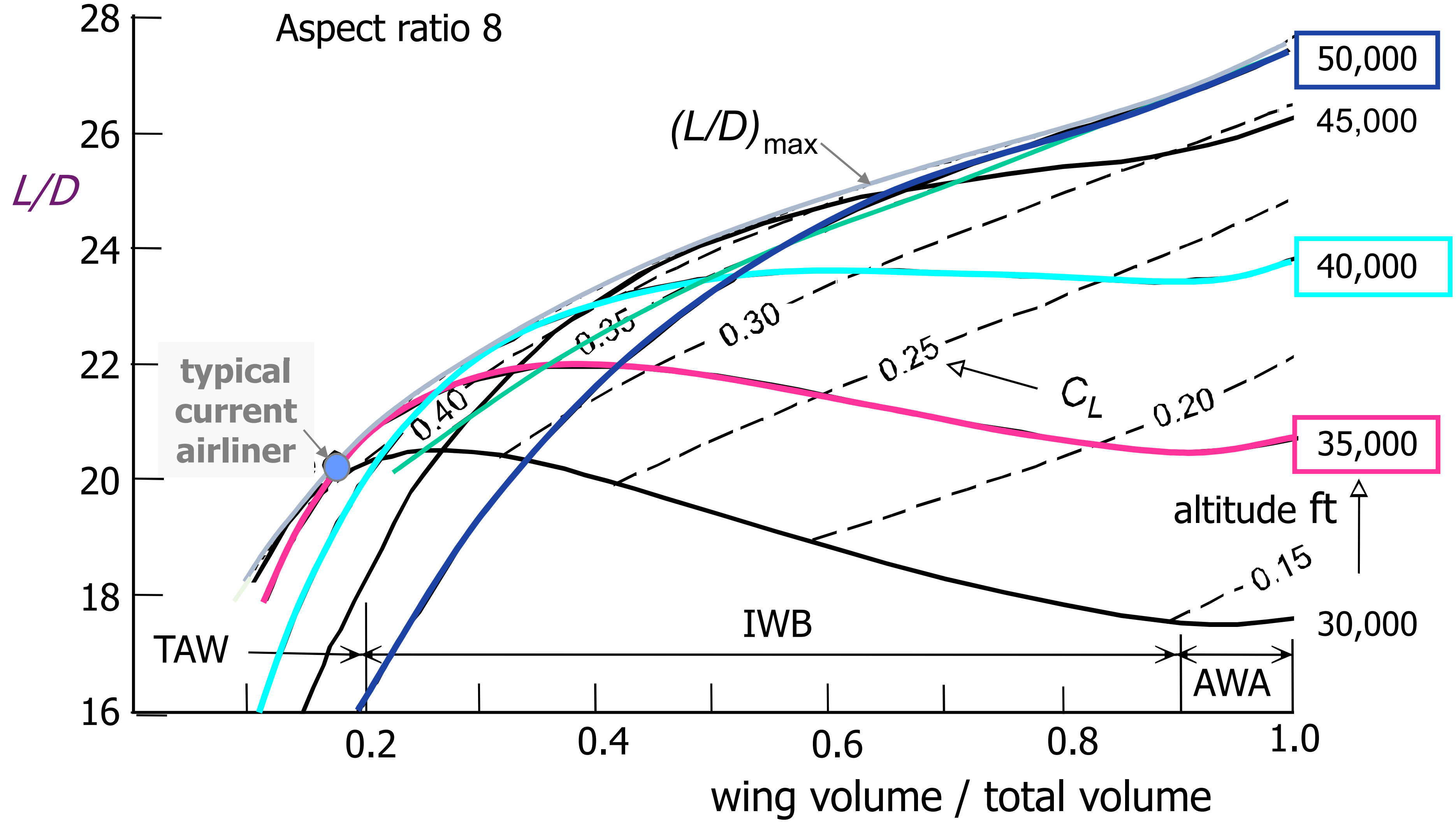
- VERTICALS PROVIDE DIRECTIONAL STABILITY AND ACT AS WINGLETS
- THE FUSELAGE IS ALSO A WING, AN ENGINE INLET AND A PITCH CONTROL SURFACE
- TOTAL WETTED AREA IS REDUCED BY 33% RELATIVE TO CONVENTIONAL LAYOUT

- INTERACTION OF THE BASIC DISCIPLINES IS UNUSUALLY STRONG; CONVENTIONAL DESIGN INTUITION AND APPROACH ARE CHALLENGED
- A SMALL CHANGE IN PLANFORM LEADS TO RECONFIGURATION OF THE ENTIRE VEHICLE

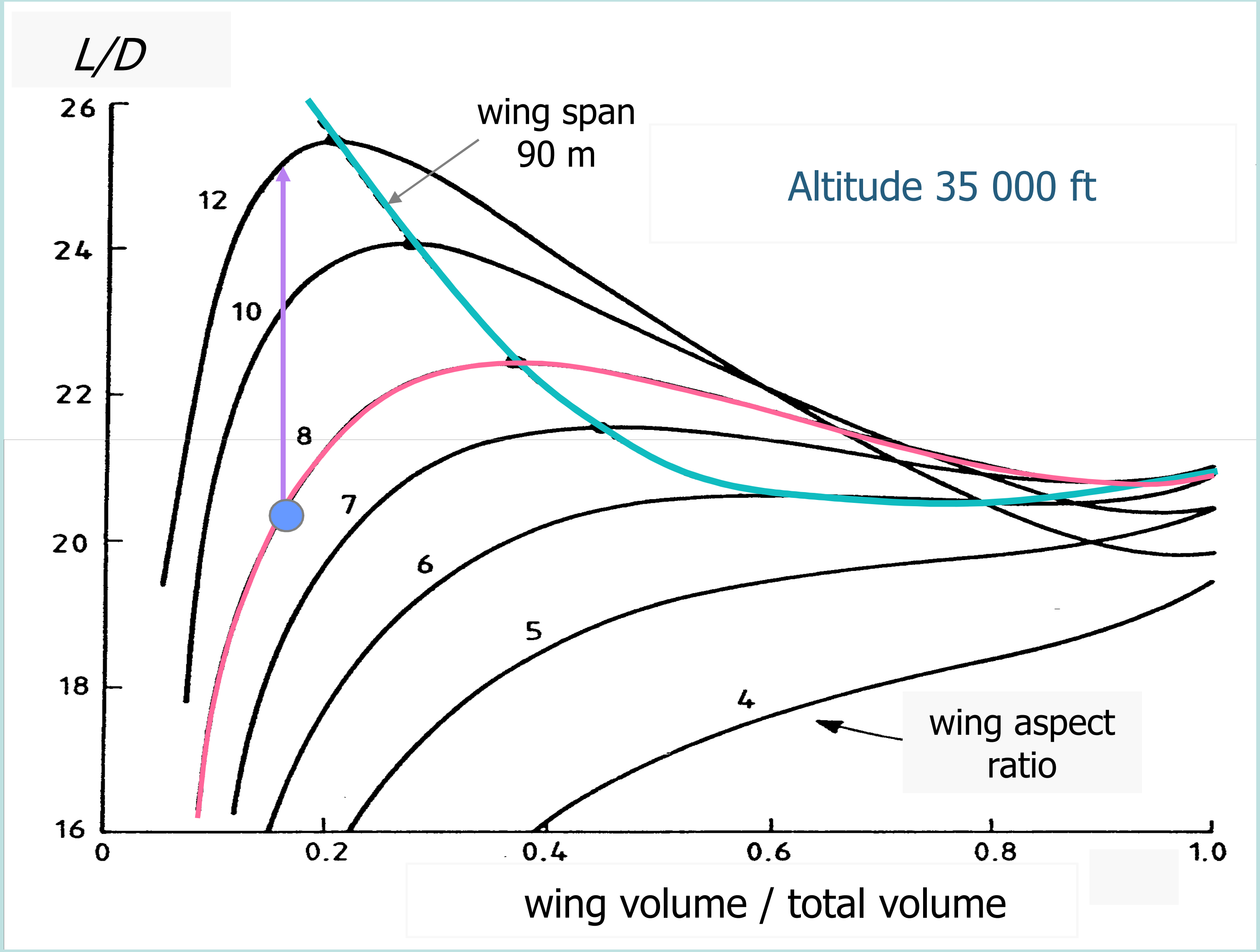
WING / BODY CONFIGURATIONS
WITH EQUAL TOTAL VOLUME



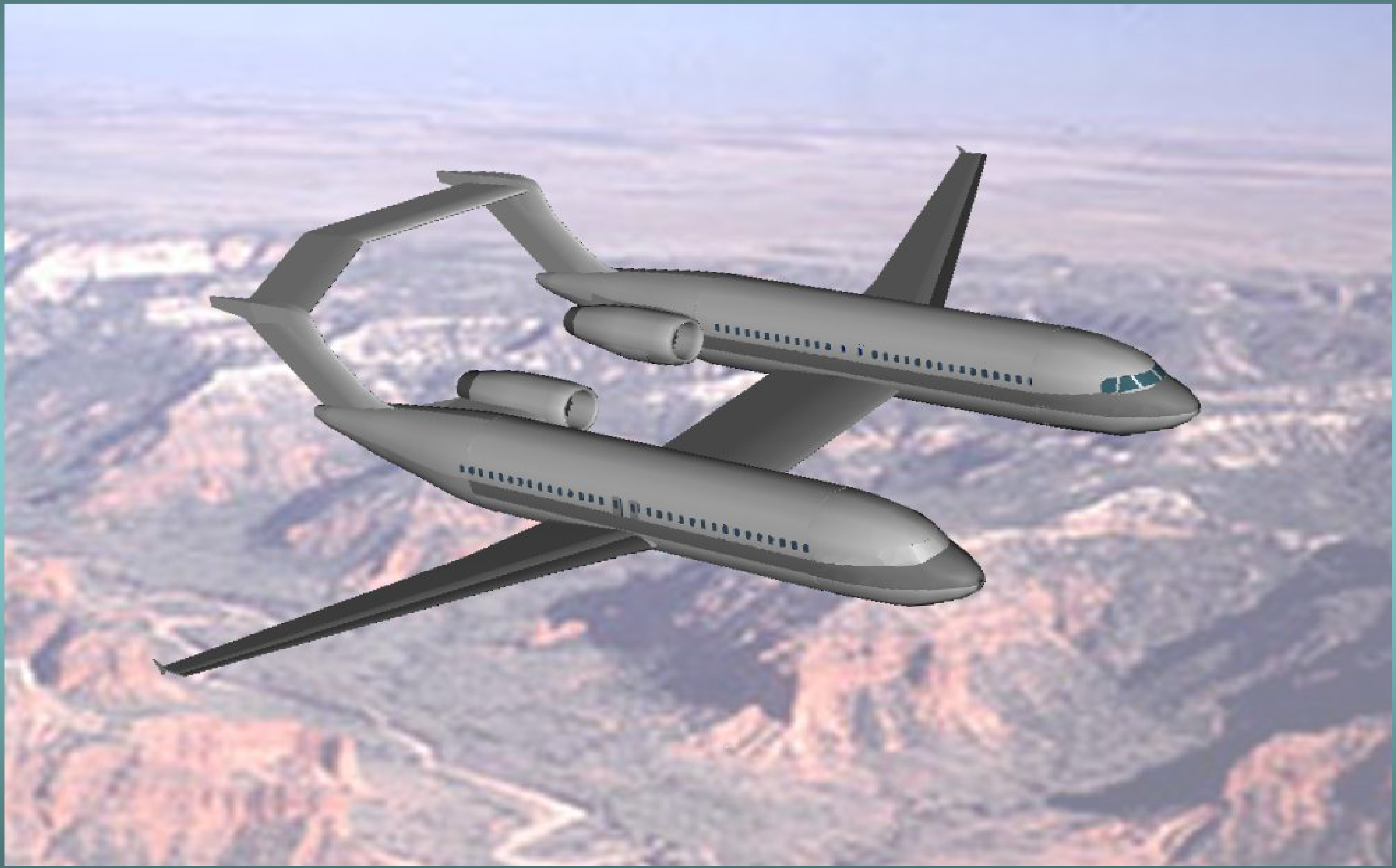
AERO. EFFICIENCY AFFECTED BY ALTITUDE



AERO. EFFICIENCY AFFECTED BY ASPECT RATIO



AIRBUS 300/310 SUCCESSOR ?

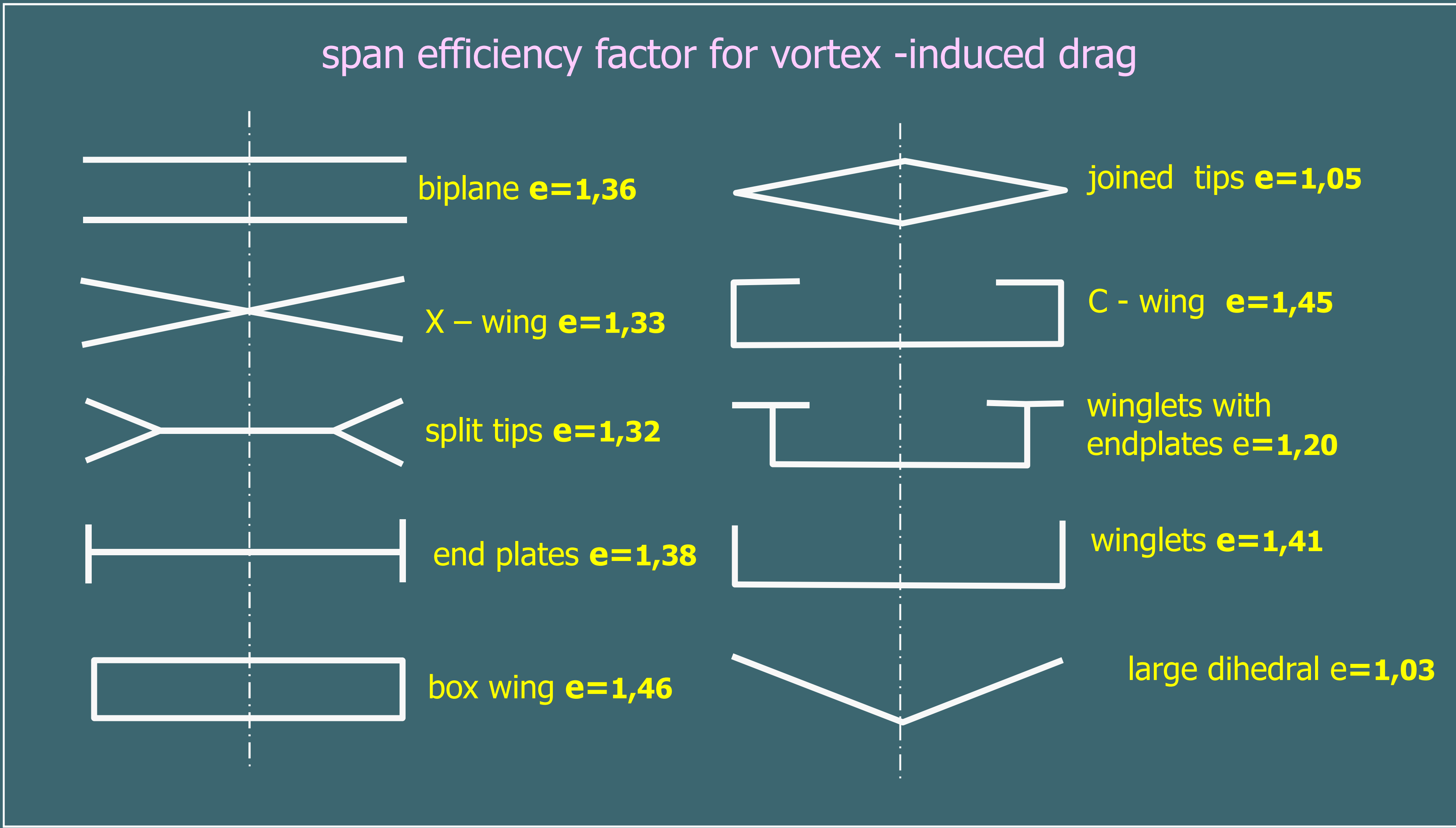


E. JESSE / E. TORENBEEK (2002)

TWIN FUSELAGE WEIGHT ADVANTAGES

Design mass, kg	conventional	twin fuselage	Δ %
MTOW	155,000	134,000	-13.5
MLW	128,000	113,000	-11.7
MZFW	120,000	106,000	-11.7
OEW	84,000	70,000	-16.7
Payload (structural limit)	36,000	36,000	0
Block fuel for 8,000 km	40,715	34,245	-15.9

WING SHAPE AND SPAN EFFICIENCY FACTOR

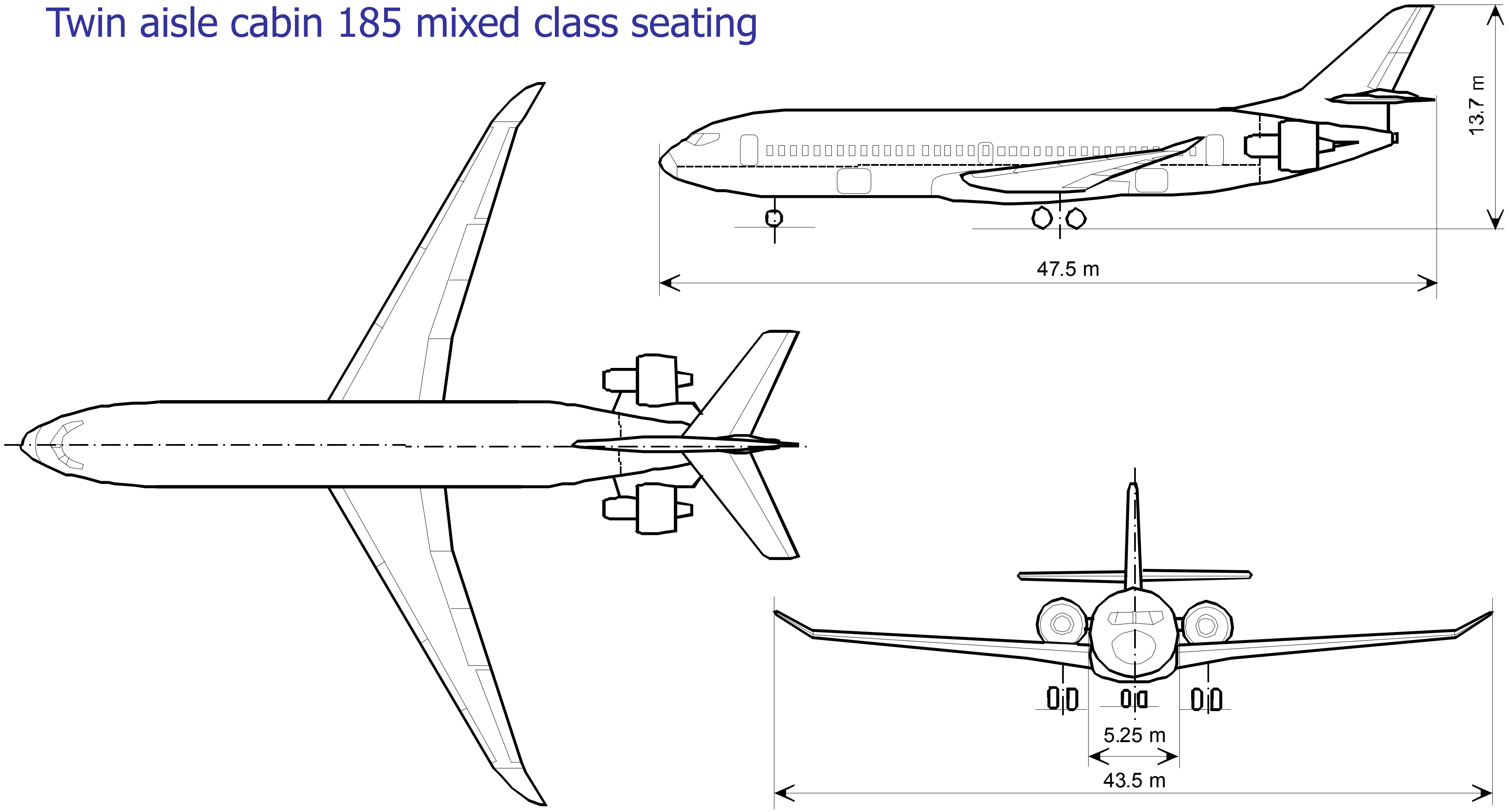


PROBLEMETIC ISSUES OF RADICAL CONCEPTS

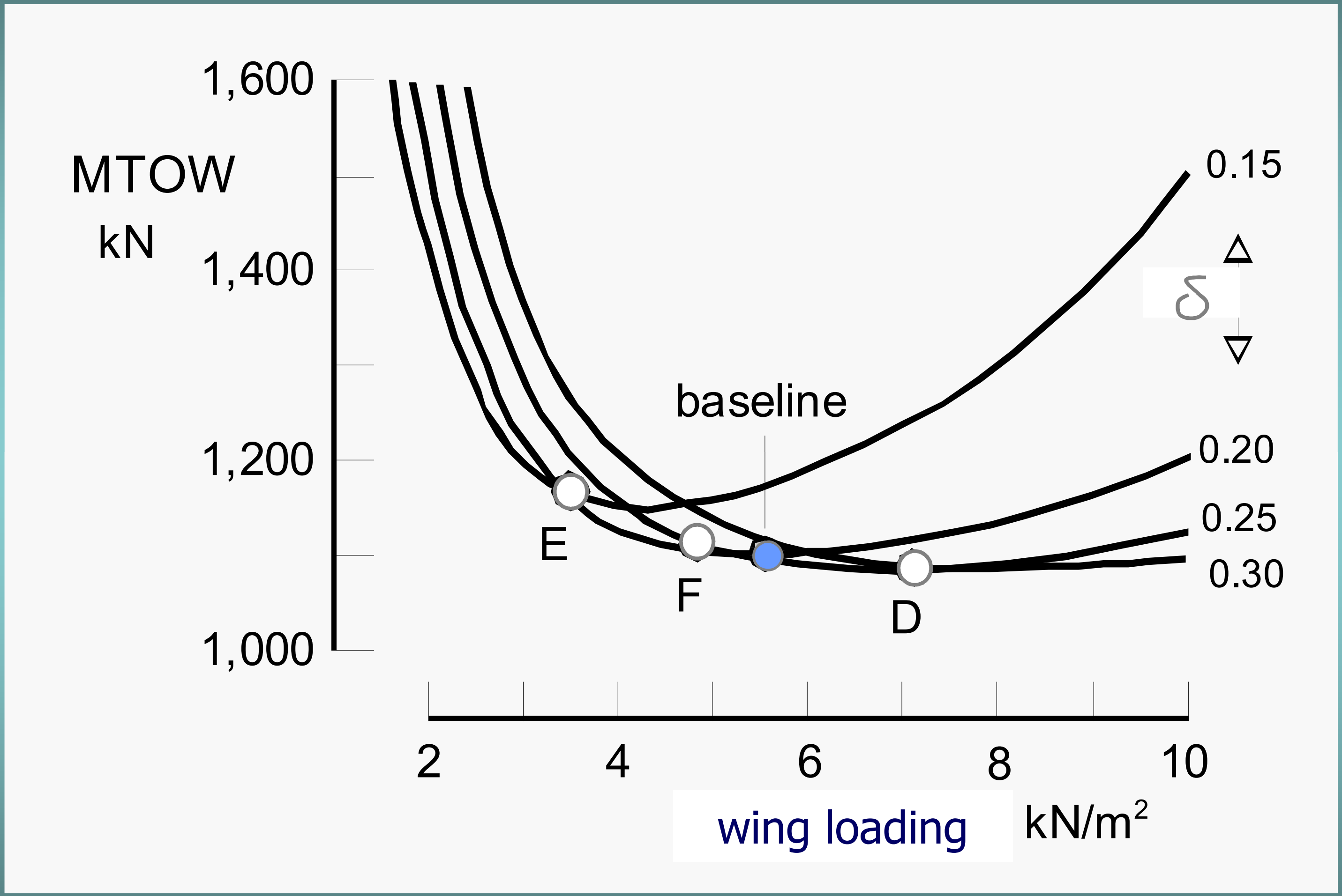
- IT IS DIFFICULT TO PREDICT THE SENSITIVITY OF ECONOMIC PERFORMANCE TO VARIATION OF UNUSUAL DESIGN CHARACTERISTICS
- RADICAL DESIGNS MAY HAVE OBJECTIONABLE INHERENT AEROELASTIC BEHAVIOR
- SOME DEGREE OF PASSENGER DISCOMFORT MAY BE DIFFICULT TO AVOID

BASELINE DESIGN OF A MEDIUM RANGE AIRLINER

Twin aisle cabin 185 mixed class seating



DESIGN SENSITIVITY OF MTOW



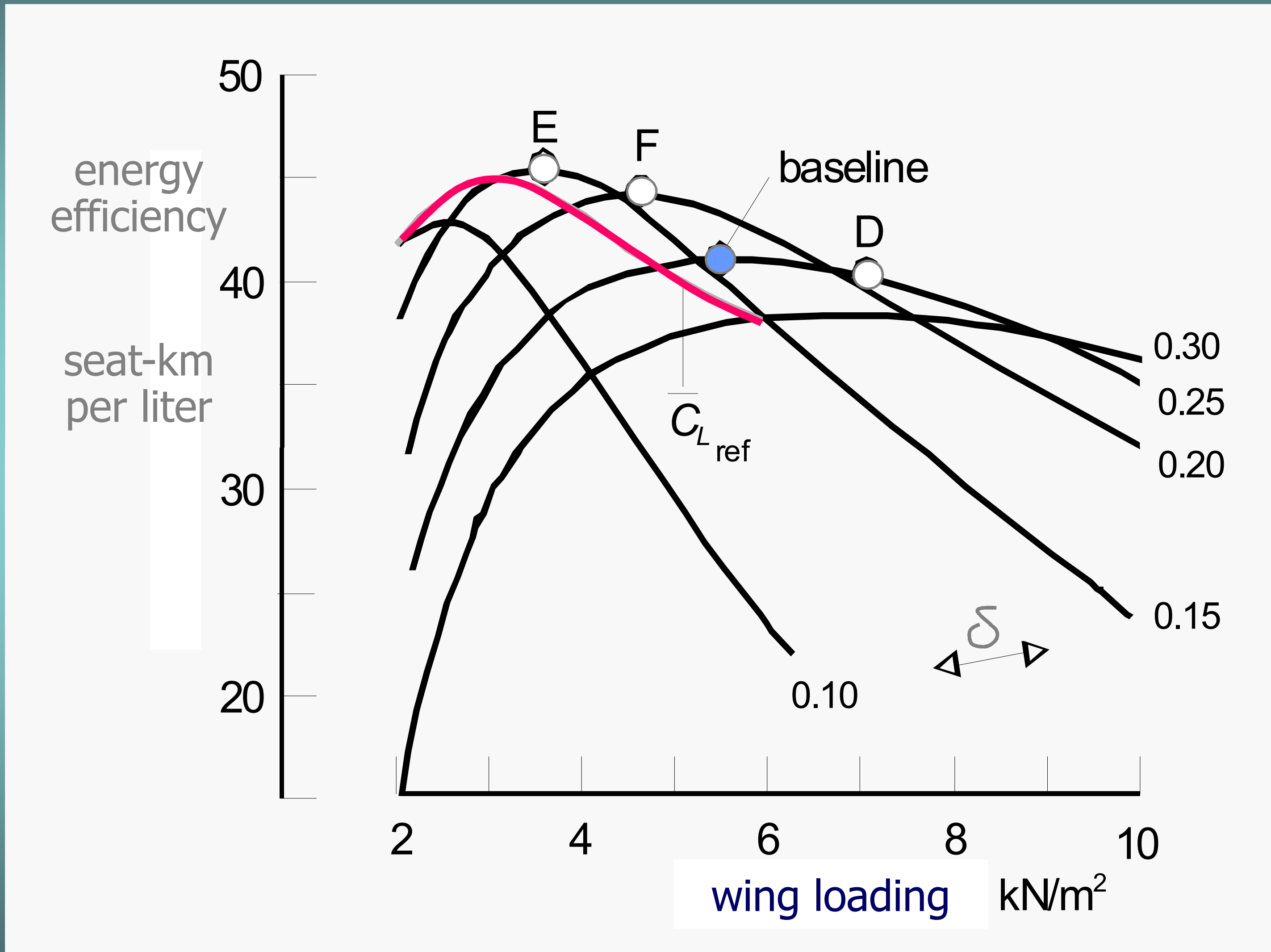
OPTIMUM DESIGNS

D: minimum MTOW

E: maximum fuel efficiency

F: minimum fuel + engine weight

DESIGN SENSITIVITY OF ENERGY EFFIFIENCY



OPTIMUM DESIGNS

D: minimum MTOW

E: maximum fuel efficiency

F: minimum fuel + engine weight

OPTIMIZATION: OBSERVATIONS AND PROBLEMS

- OPTIMIZATION BY MEANS OF CFD IS A POPULAR SUBJECT OF CFD SPECIALISTS. HOWEVER, OFF-DESIGN PROPERTIES SUCH AS BUFFETING AND STALL PROPERTIES ARE OFTEN NEGLECTED
- THE EARLIER THE DESIGN STAGE, THE MORE VARIABLES ARE SUBJECT TO OPTIMIZATION. THIS LEADS TO A MULTI – FIDELITY APPROACH
- SENSITIVITY OF EMPTY WEIGHT TO PRIMARY SELECTION VARIABLES IS HARD TO OBTAIN. THE TERM ***VALUE OF A POUND*** IS ALMOST FORGOTTEN.
- AND NOBODY KNOWS THE ***VALUE OF A COUNT***.
- LET US RELY ON THE FOLLOWING EARLY DEFINITION OF A GOOD PRODUCT:

PRIZE THAT WHICH IS BEST IN THE UNIVERSE;

AND THIS IS THAT WHICH

USETH EVERYTHING AND ORDERETH EVERYTHING

Marcus Aurelius (AD 121-180) Meditations, v. 21.

A THING OF BEAUTY IS A JOY FOR EXTRA

www.extraaircraft.com

EWADE 2013

11th European Workshop on Aircraft Design Education

17 to 19 September 2013, Linköping University, Sweden

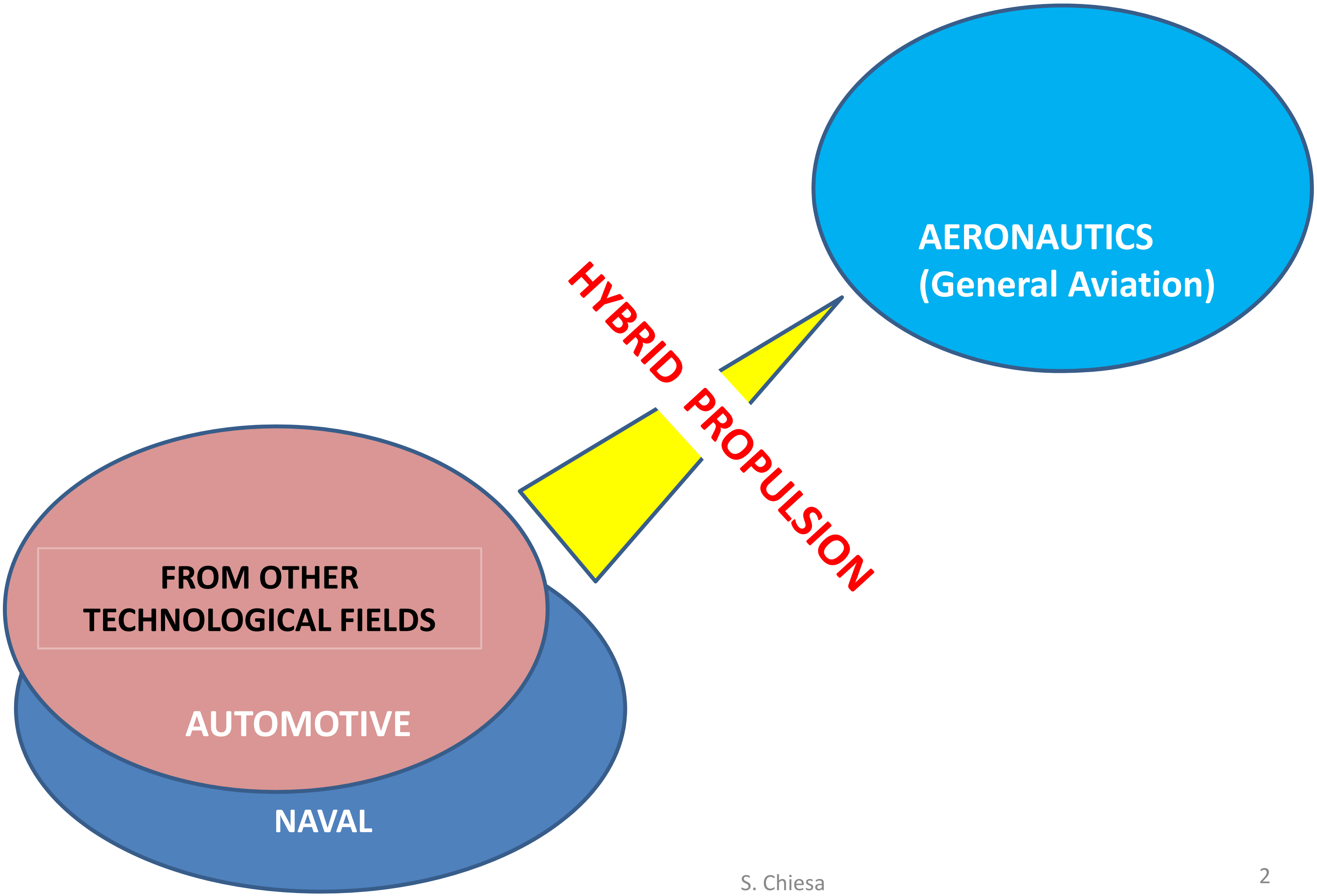
CONTRIBUTIONS FROM EDUCATIONAL ACTIVITIES TO RESEARCHES ABOUT HYBRID PROPULSION OPPORTUNITIES FOR LIGHT AIRCAFT

Sergio CHIESA, Giovanni DI MEO, Marco FIORITI, Roberta FUSARO
(ASSET GROUP, DIMEAS, POLITECNICO di TORINO - ITALY)

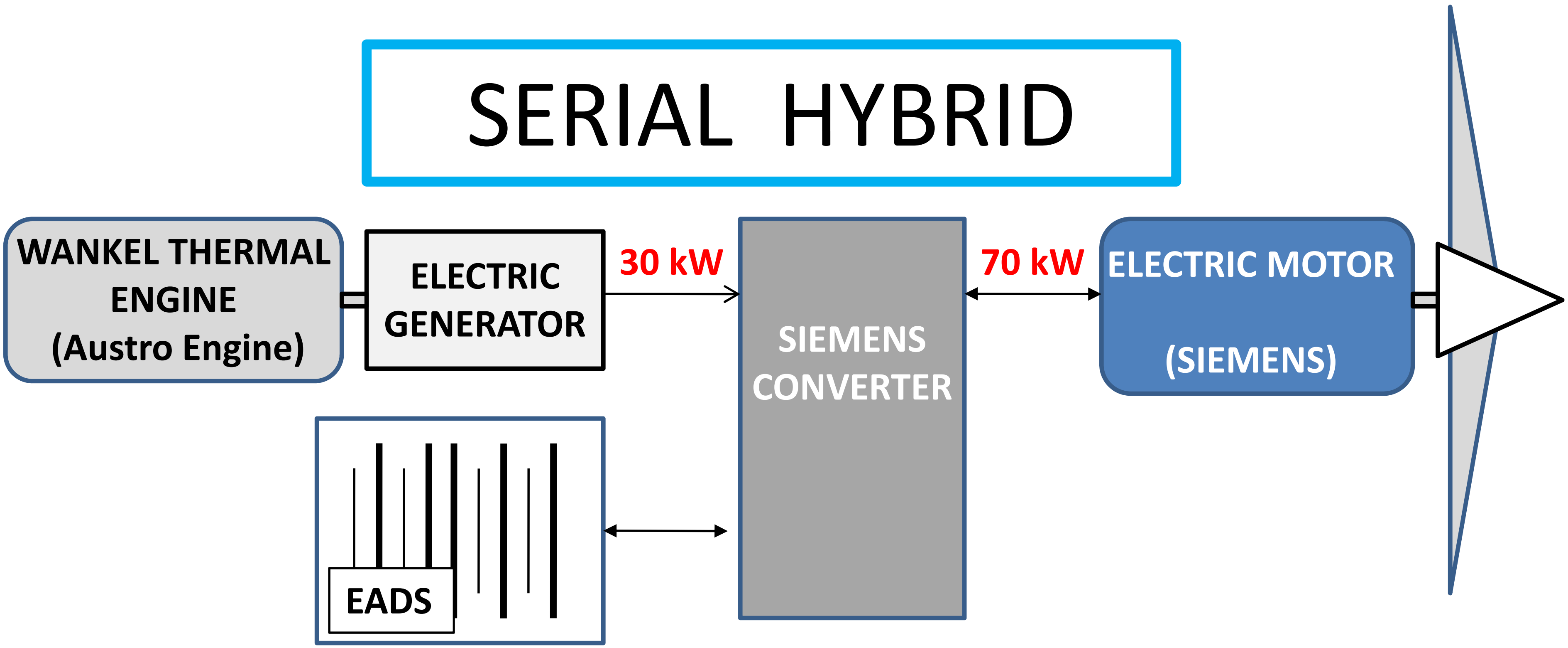
A: Aero
S: Space
S: System
E:Engineering
T:Team

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.21440

A new TREND in Aeronautics

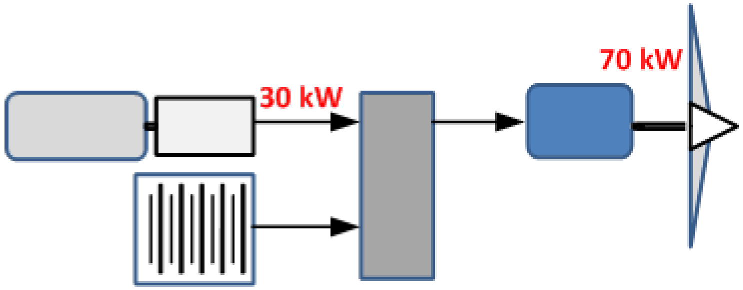


SERIAL HYBRID

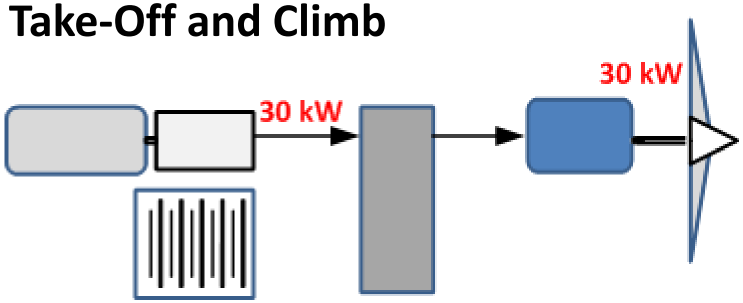


World's first serial **hybrid** electric aircraft to fly at Le Bourget 2011

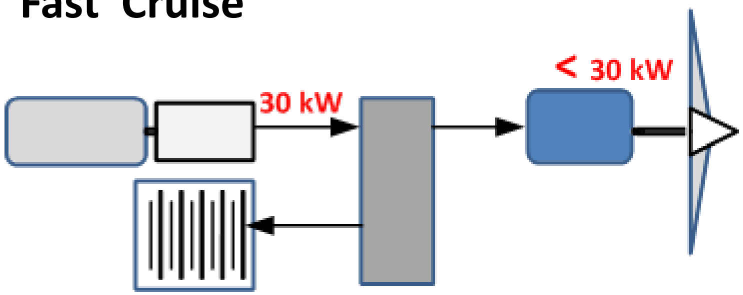
A motor glider, which is based on Diamond Aircraft's HK36 Super Dimona, is the first to use a so-called serial hybrid electric drive.



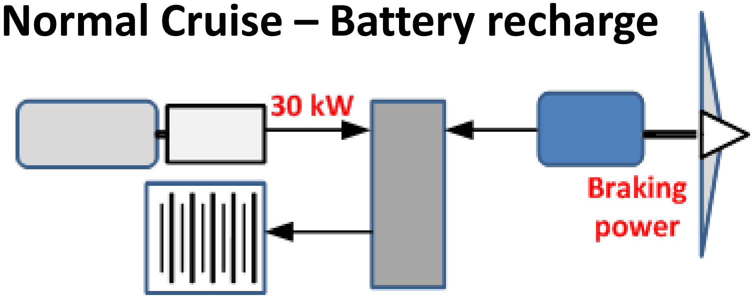
Take-Off and Climb



Fast Cruise



Normal Cruise – Battery recharge

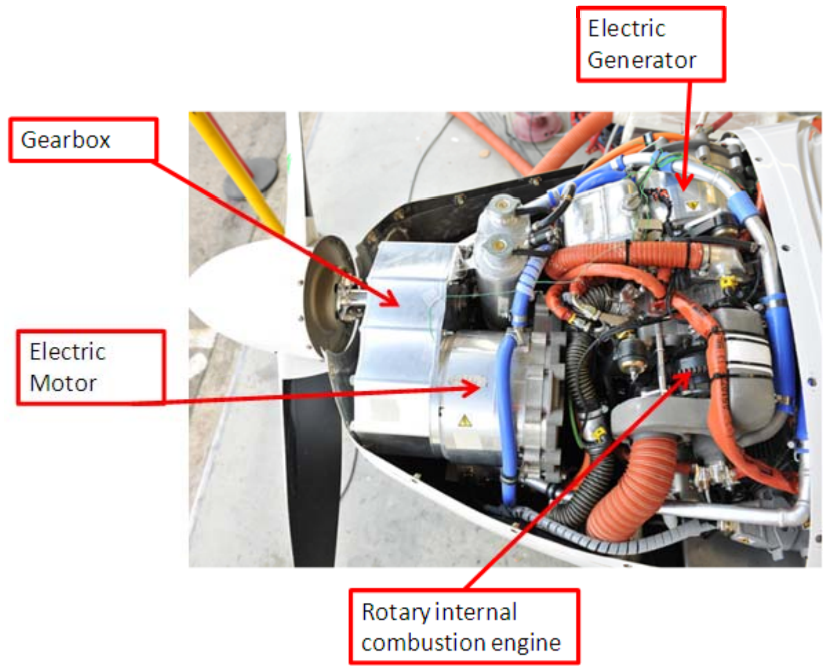


Descent and Landing – Battery recharge

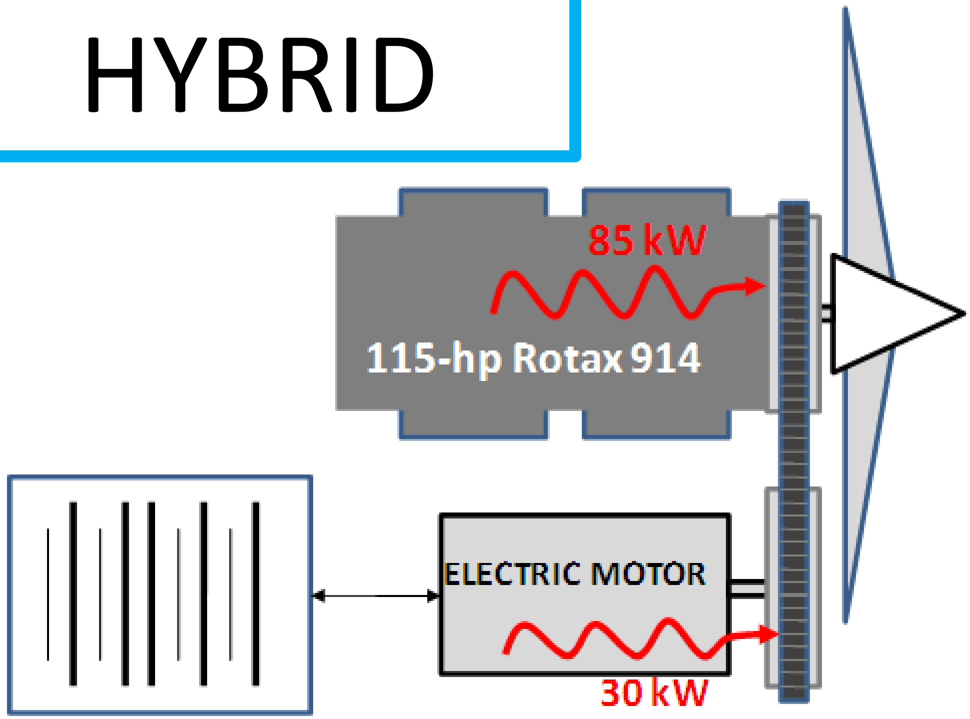
Alternative "Green and Quite" Take-Off is possible, only using batteries

In cruise the recharge of batteries is possible. The costant ratio of running of Thermal engine / generator, offers reduced fuel consumption

The system is regenerative, with possibility of recovering energy during descent and landing



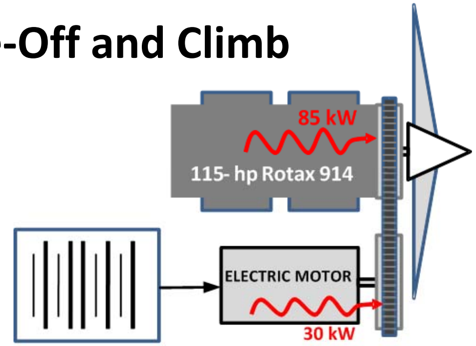
PARALLEL HYBRID



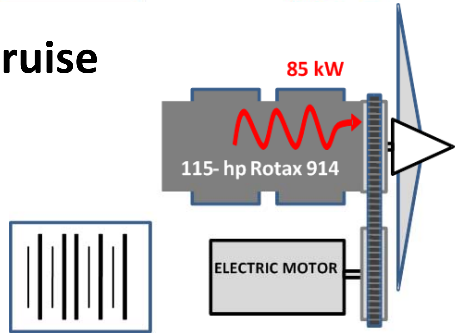
Flight Design, a producer of light aircraft , proposes a parallel Hybrid base on well known ROTAX Engine

Particularly interesting is the possibility of OVER-BOOST, i.e. the sum of thermal and electric powers

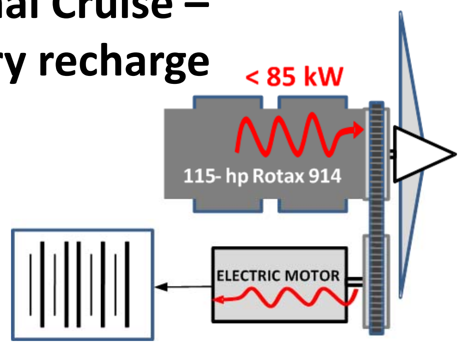
Take-Off and Climb



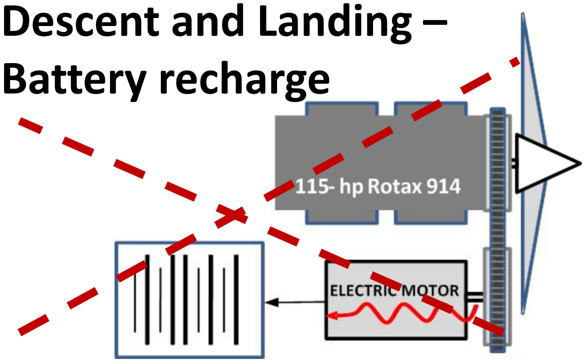
Fast Cruise



Normal Cruise – Battery recharge



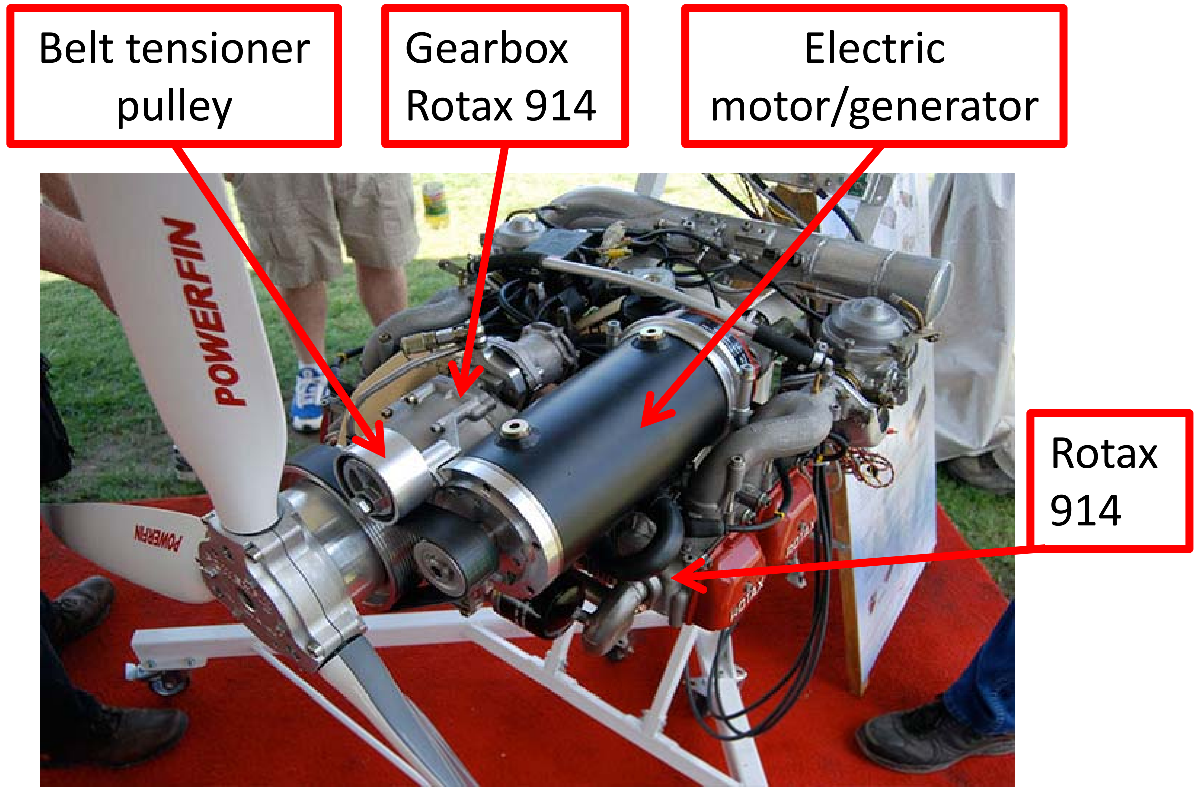
Descent and Landing – Battery recharge



Over-boost, given by electric motor, can be useful, other than in Take-Off and Climb, FOR every other contingencies

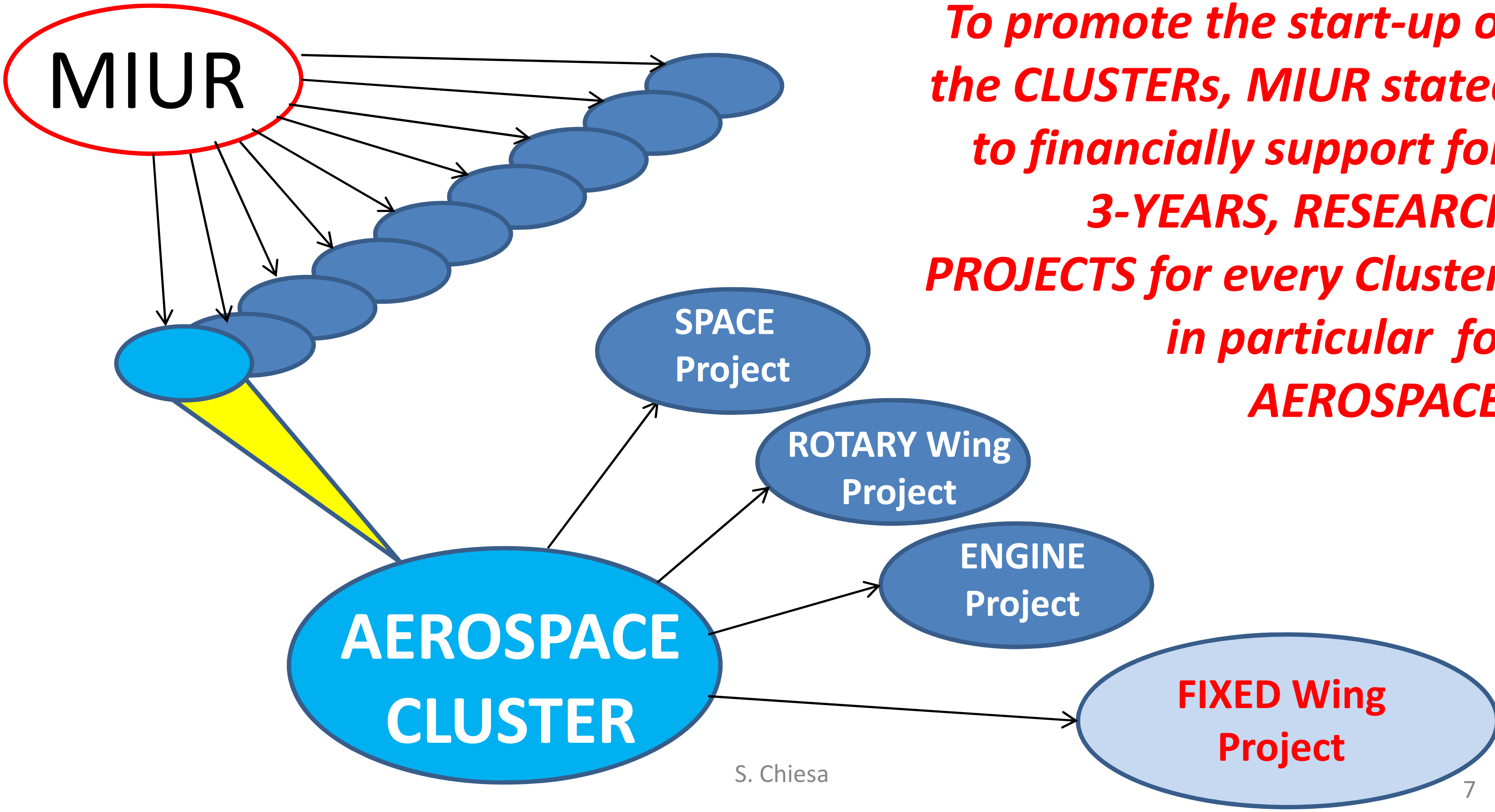
The only electric motor Power can add Safety in the case of Main engine failure

The system is regenerative, with possibility of recovering energy during descent and landing



In 2012 the Italian University and Research Ministry (MIUR) promoted the establishment of TECHNOLOGICAL CLUSTERS (Groups of Research Centres, Universities, Big Industries, SME) in 9 fields considered "Strategic" for future development of the Country

To promote the start-up of the CLUSTERs, MIUR stated to financially support for, 3-YEARS, RESEARCH PROJECTS for every Cluster; in particular for AEROSPACE:

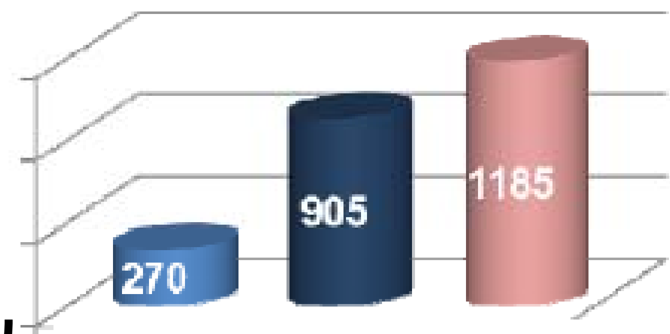


FIXED Wing Project

TIVANO

Tecnologie **I**nnovative per **V**elivoli di **A**viazione Generale di **N**uova Generazi**O**ne
(Innovative Technologies for General Aviation airplane)

MOTIVATIONS



General Aviation but also Initial Trainers /Screeners and possible platform for UAS

FIXED Wing Project

TIVANO

Tecnologie **I**nnovative per **V**elivoli di **A**viazione Generale di **N**uova Generazi**O**ne

(Innovative General Aviation Technologies)

STRATEGY

ALENIA-AERMACCHI SF 260

A continuous success over half a century

?

2013: SOLD SN “900”

TIVANO

1964: FIRST FLIGHT

FIXED Wing Project

TIVANO

Tecnologie **I**nnovative per **V**elivoli di **A**viazione Generale di **N**uova Generazi**O**ne
(Innovative General Aviation Technologies)

PARTICIPANTS - ACTIVITIES

ALENIA-AERMACCHI Leader

- POLIMI
- North Italy S.M.E.

Aerodynamic Configuration, New System – Electric brakes

- POLITO
- A.S.E. (SME) electric motor

Advanced, affordable and Green Propulsion System; Hybrid opportunities

- UNINA
- South Italy S.M.E.

Low Cost , efficient composite structures

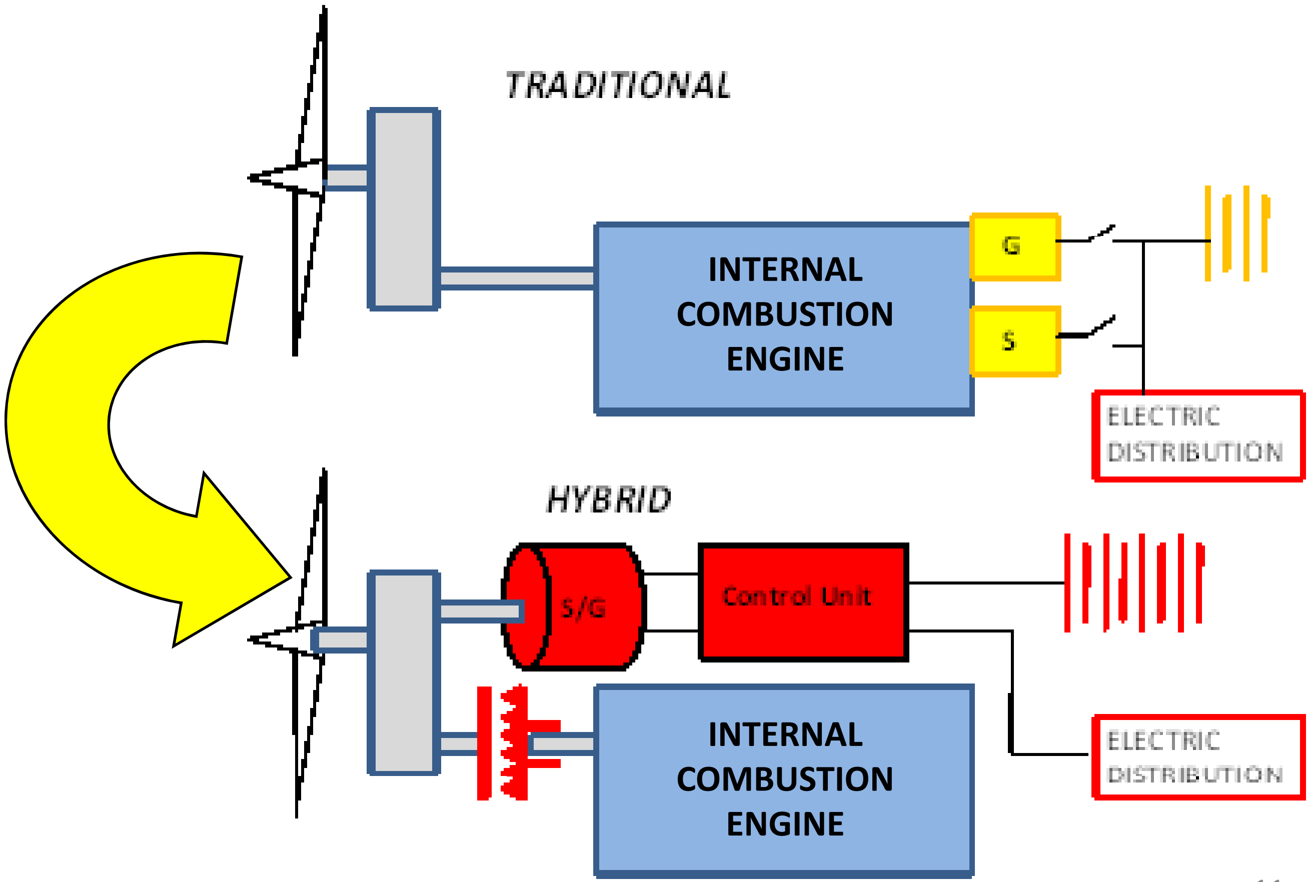
POLITO

ALENIA-AERMACCHI

A.S.E. (SME) electric motor

Advanced, affordable and Green Propulsion System; Hybrid opportunities

BASIC IDEA:



POLITO

ALENIA-AERMACCHI

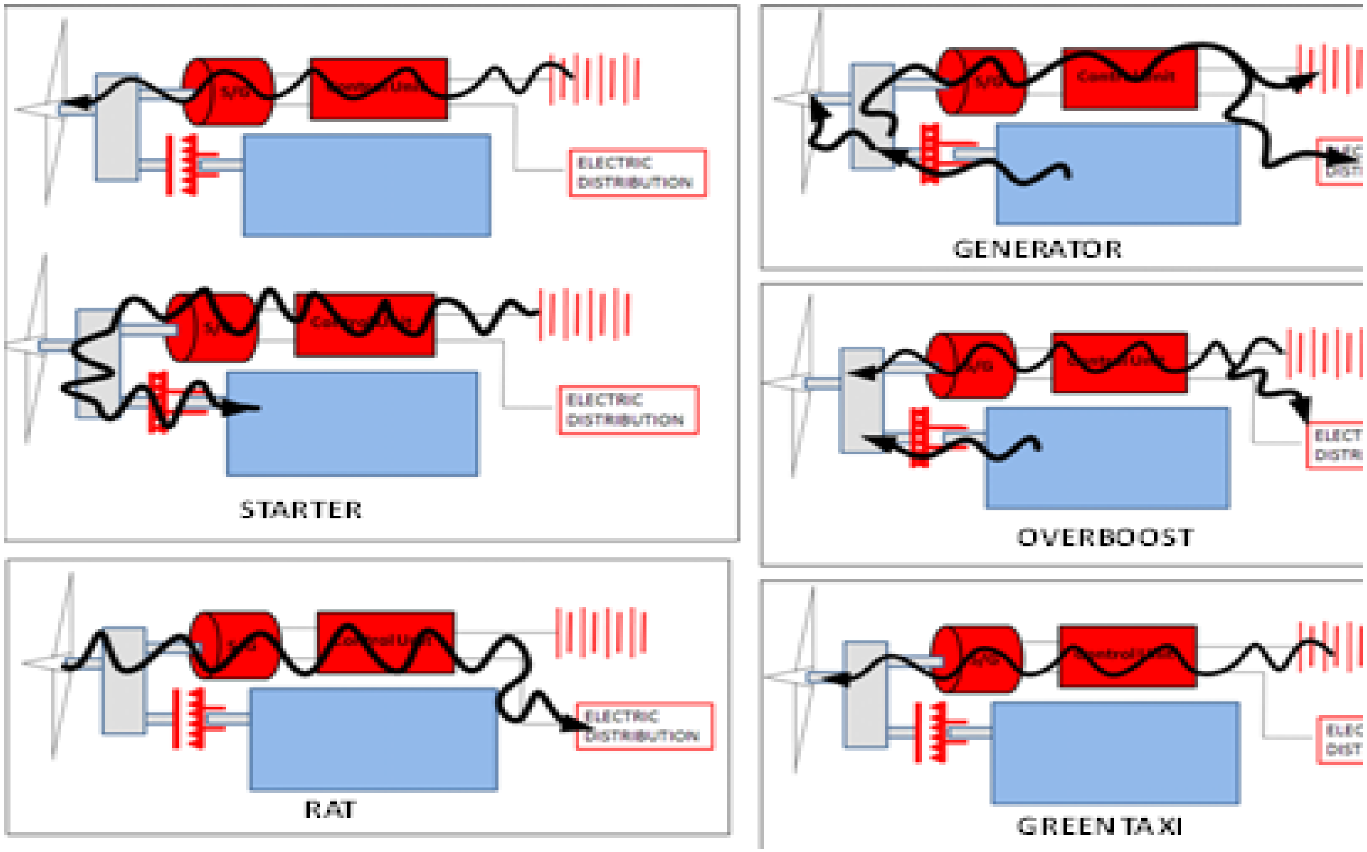
A.S.E. (SME)
electric motor

Advanced, affordable and Green Propulsion System; Hybrid opportunities

OPPORTUNITIES:

Engine starting

Ram Air Turbine



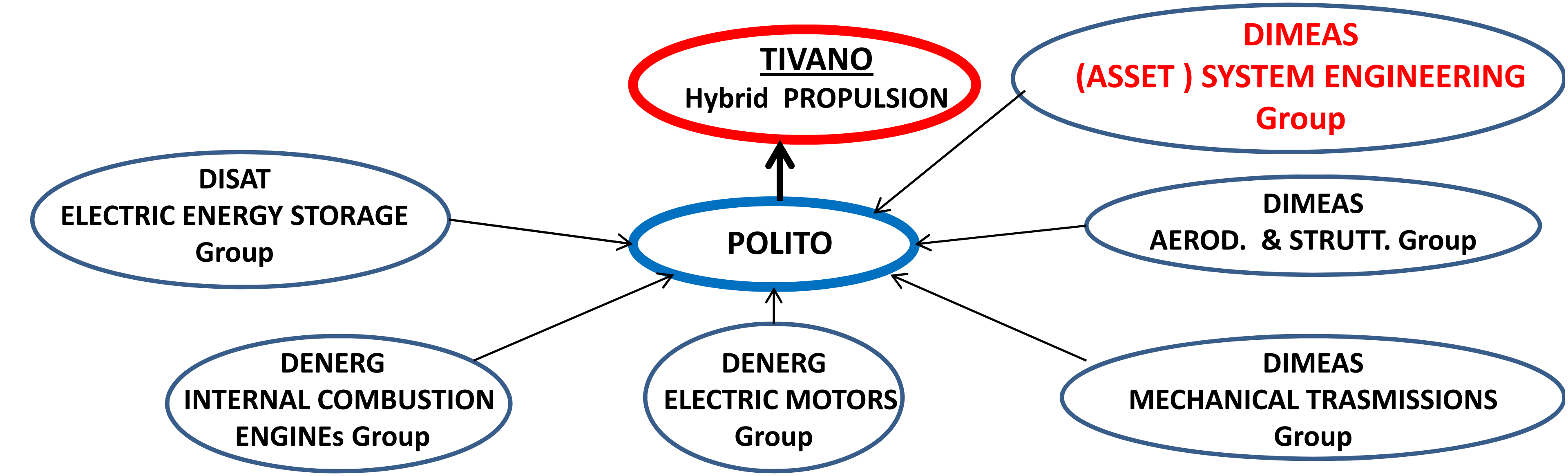
Cruise

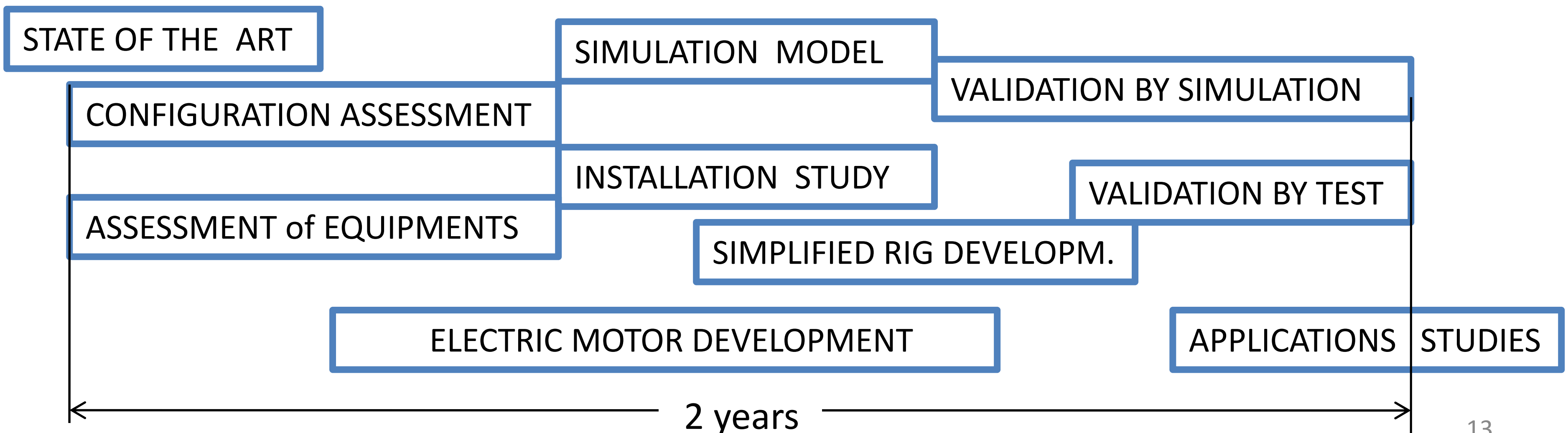
Take-off and climb

Green taxi

POLITO

ACTIVITIES & SCHEDULE



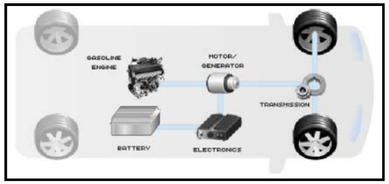


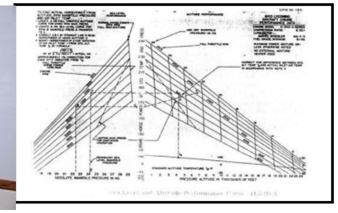
EDUCATIONAL ACTIVITIES AIMED TO TIVANO

(ASSET) SYSTEM ENGINEERING Group

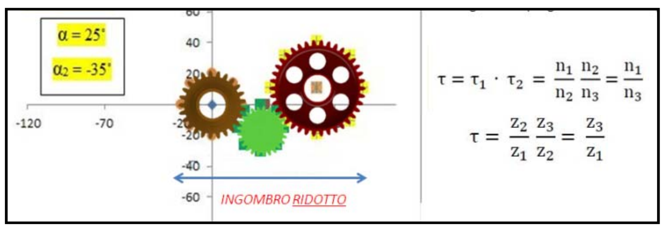
a) PREPARATION PHASE

1) Franco Zurletti ***"HYBRID PROPULSION SYSTEMS ANALYSIS"*** Degree Thesis in Aerospace Engineering –POLITECNICO di TORINO, December 2012

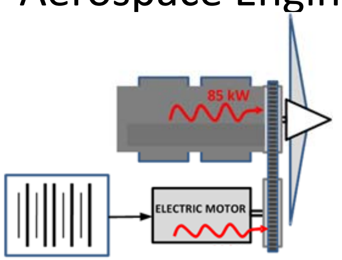


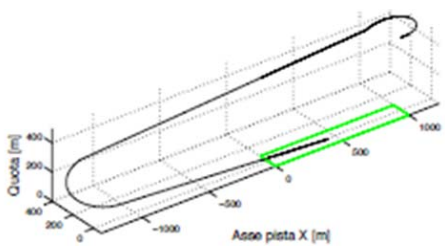



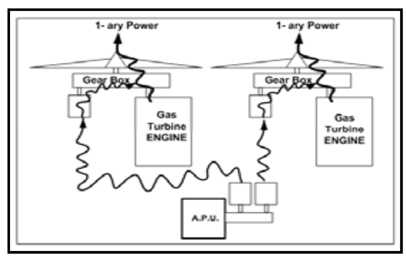
2) Andrea Buscemi "***METHODOLOGY FOR MECHANICAL TRANSMISSIONS IN AERONAUTIC DEFINITION*** " *Master* Degree Thesis in Aerospace Engineering –POLITECNICO di TORINO, July 2013

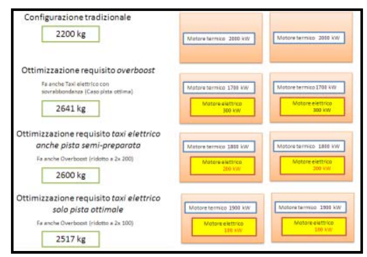



3) Roberta Fusaro "***HYBRID PROPULSION IN AERONAUTICS"*** *Master* Degree Thesis in Aerospace Engineering –POLITECNICO di TORINO, (in progress…)









EDUCATIONAL ACTIVITIES AIMED TO TIVANO

(ASSET) SYSTEM ENGINEERING Group

b)IN FUTURE, during development of the Project

The MIUR stated that all the Research Project of the Cluster must be comprehensive of an “Educational Program” (about 10% of the total amount of every Project)

So TIVANO will pay five grants for Ph D Students that will work for three years on the Project both in Industry and at University. The Tutor will be Academic

POLITO will account three of the aforesaid PhD Students in the Team that will work on the previous described activities

We hope that at EWADE 2015 these Ph D Students will present the progress of their works!

MidJet a personal Jet

A student project

Christopher Jouannet Ph.D

11th European Workshop on Aircraft Design Education, Linköping, 17.-19.09.2013

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546412

LiU EXPANDING REALITY

LiU EXPANDING REALITY

Contents

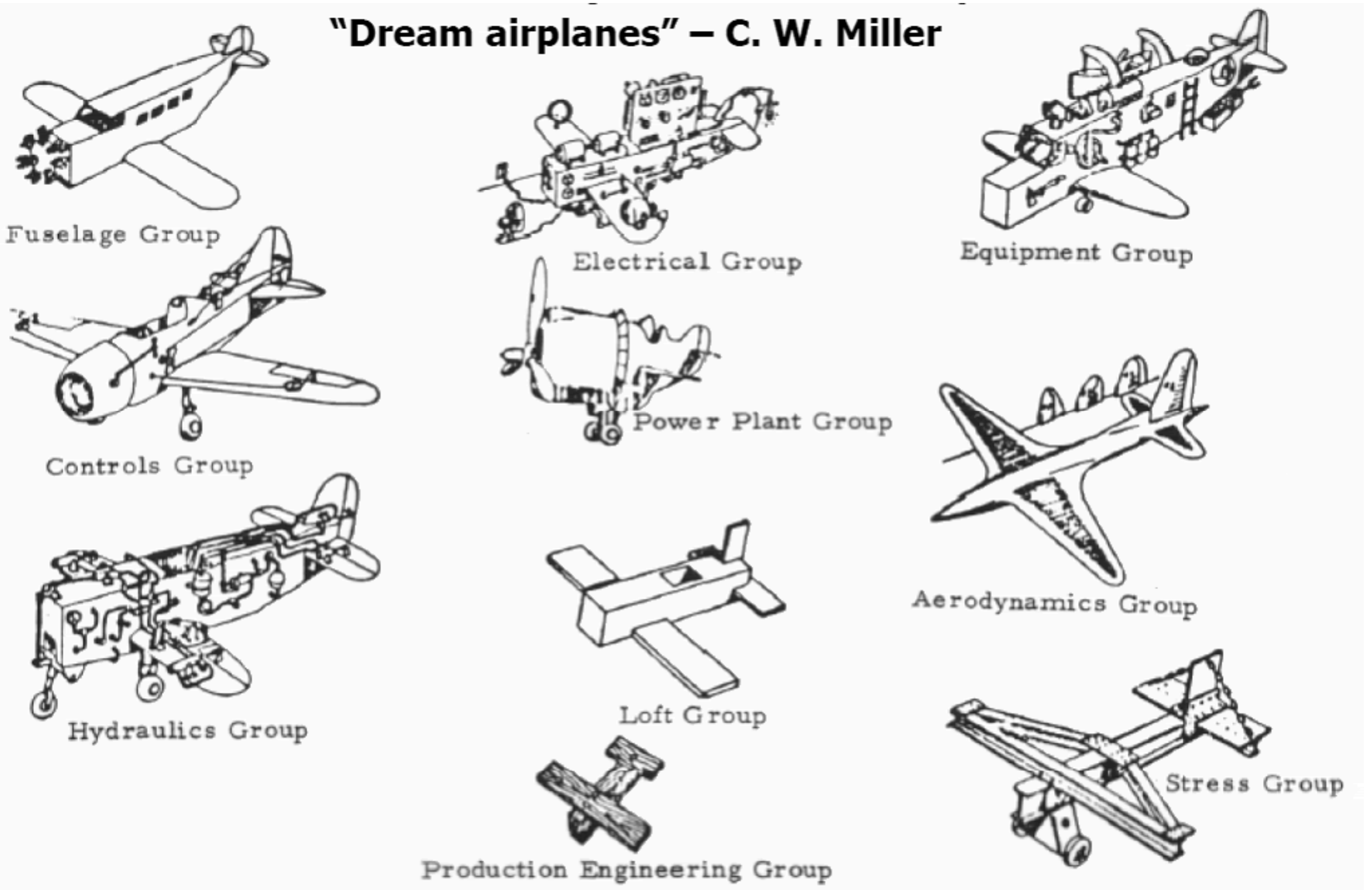
- Challenges within Aircraft design
- Students project, why?
- Project requirements
- Concepts
- Design
- Manufacturing
- First fly…

Time Span	Aircraft projects
1950-1980	XP-5Y, A-2D, XC-120, F-4D, F-3H, B-52, A-3D, X-3, S-2F, X2, F-10F, F-2Y, F-100,B-57, F-102, R-3Y1, F-104, A-4D, B-66, F-11F, C-130, F-101, T-37, XFY, F-8U, F-6M, U-2, XY-3, F-105, X-13, C-133, F-107, B-58, F-106, F-5D, X-14, C-140, T-2, F-4, A-5, T-39, T-38, AQ-1, X-15, F-5A, X-1B...
1960-1990	A-6, SR-71, SC-4A, X-21, X-19, C-141, B-70, XC-142, F-111, A-7, OV-10, X-22, X-26B, X-5, X-24
1970-2000	F-14, S-8, YA-9, A-10, F-15, F-18, YF-17, B-1B, YC-15, YC-14, AV-8B, F/A-18
1980-2010	F-117, F-20, X-29, T-46, T-45, B-2, V-22
1990-2020	YF-22, YF-23, JSF, C-17
2000-2030	UCAV, B-3?...

Challenges within Aircraft design

- Aircraft designers are:
  - Broad specialists…
  - Will unfortunately only participate to a few number of project during is career…should have been born in the 40's
  - High number of disciplines involved
  - Need experience

Aircraft Design



Students project, why?

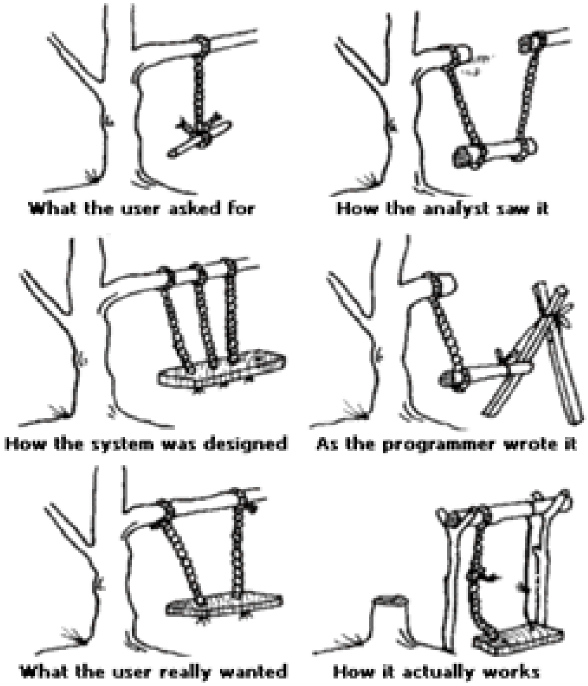
- Educate
- Give a broad view
- Educate generalist and not specialist
- A chance to see a product from requirement to first flight
- Have fun and be proud
- Team work

LiU EXPANDING REALITY

Project requirements

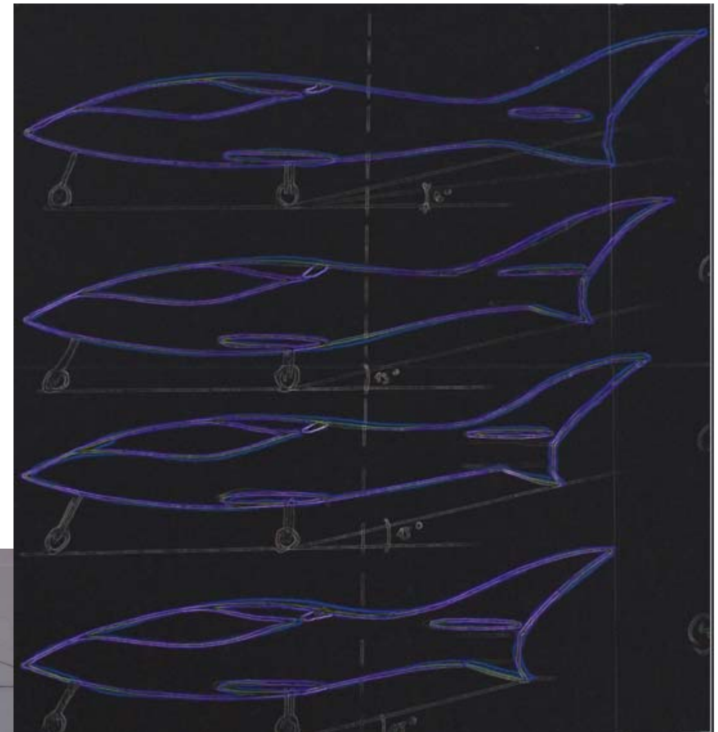
- Need to be stimulating
- Need to be a challenge
- Need to show interaction between the different disciplines
- Need to be something new…or old…
- Need to

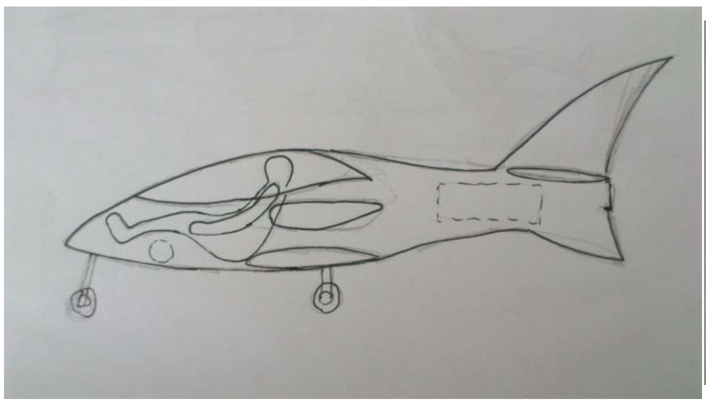
MidJet Requirements



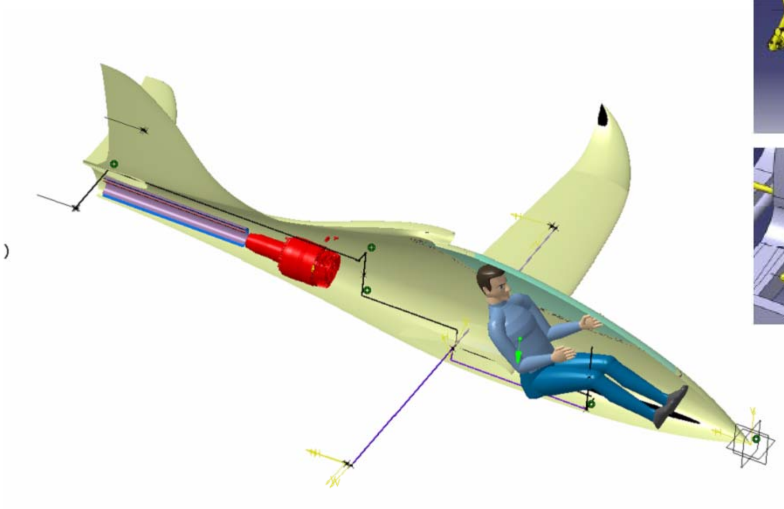
- Replacement of the outdated BD5J
- Appealing design
- Good handling qualities
- Performance level similar to BD5J
- Defined under which certification this aircraft can be certified

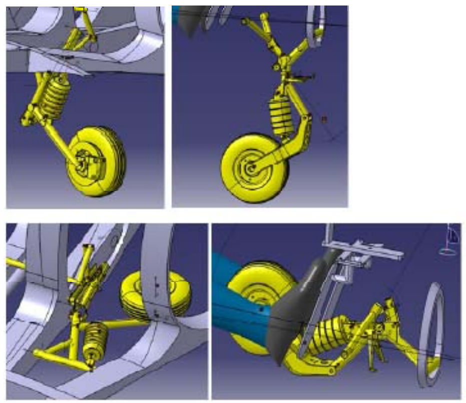
Concepts

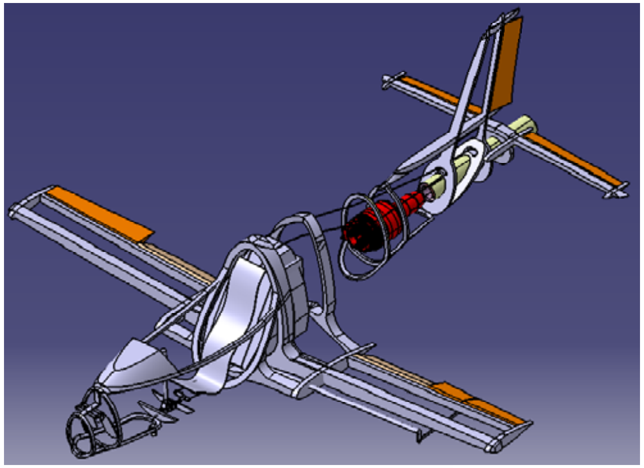


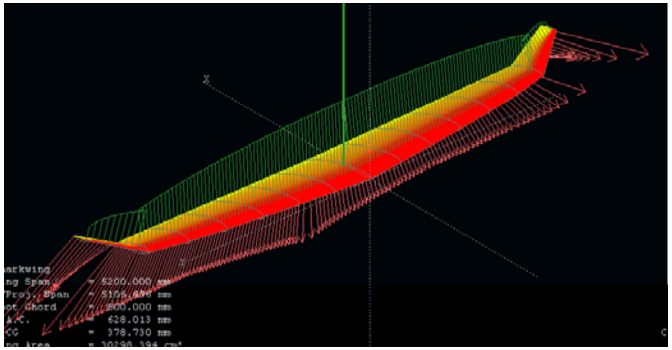


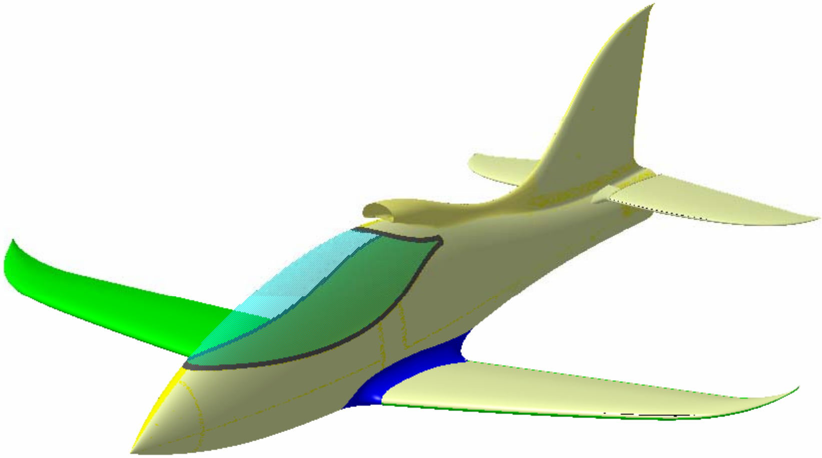
Design



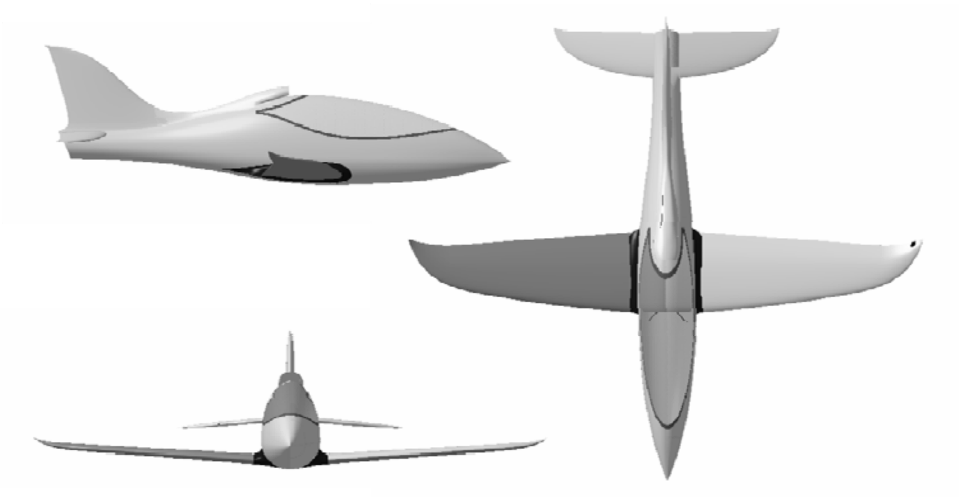








Characteristics

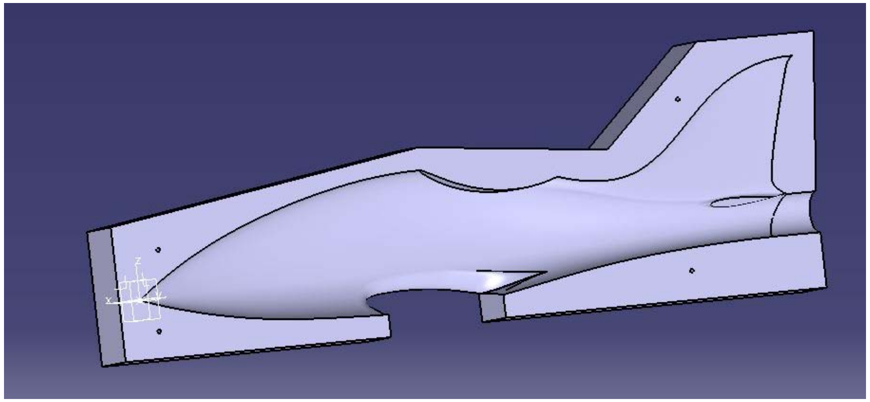


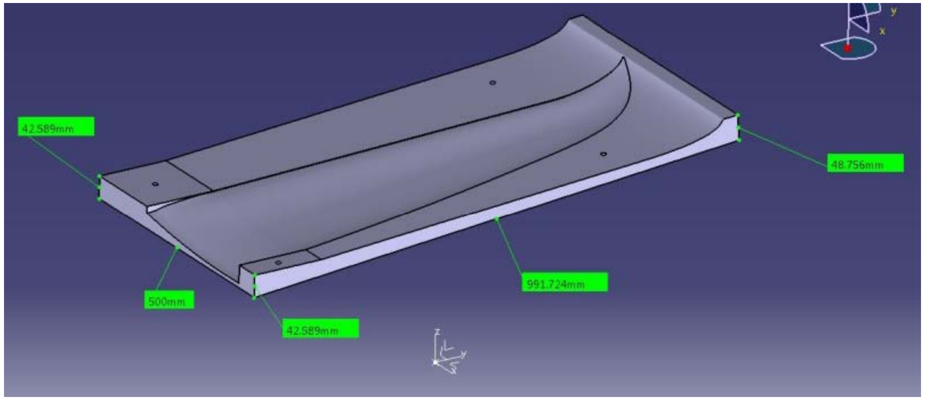
	MidJet	BD5J
MTOW [kg]	320	386
OEW [kg]	146	163
Vcruise [km/h]	437	386
Stall speed [km/h]	104	107
Wing loading [kg/m2]	100	137
Sref [m2]	3,2	2,8
Wing span [m]	5,2	4,36
Length [m]	4,8	3,6
Height [m]	1,46	1,68

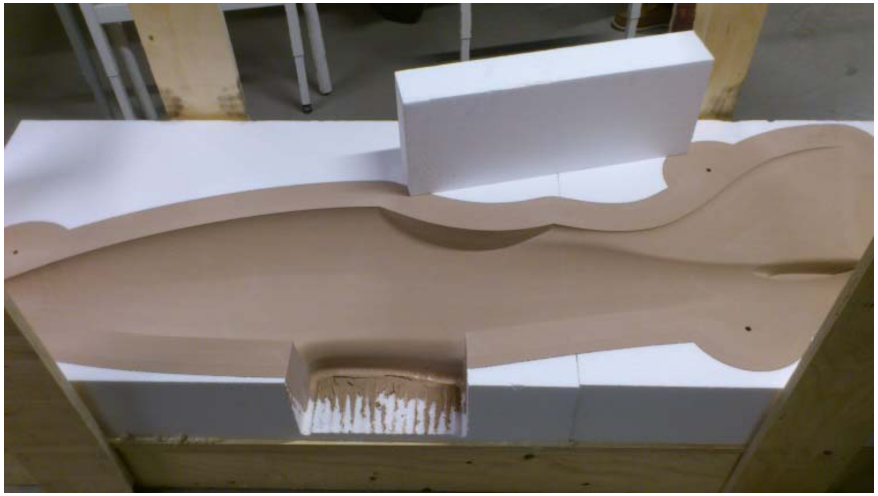
CS-23 used as certification base

TJ 100
1200 N

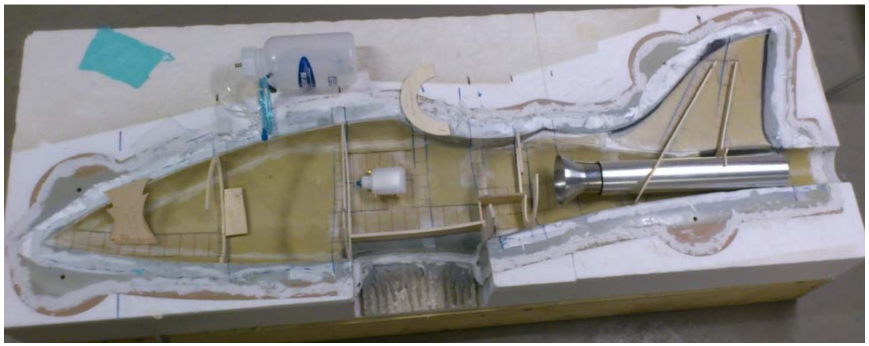
Manufacturing

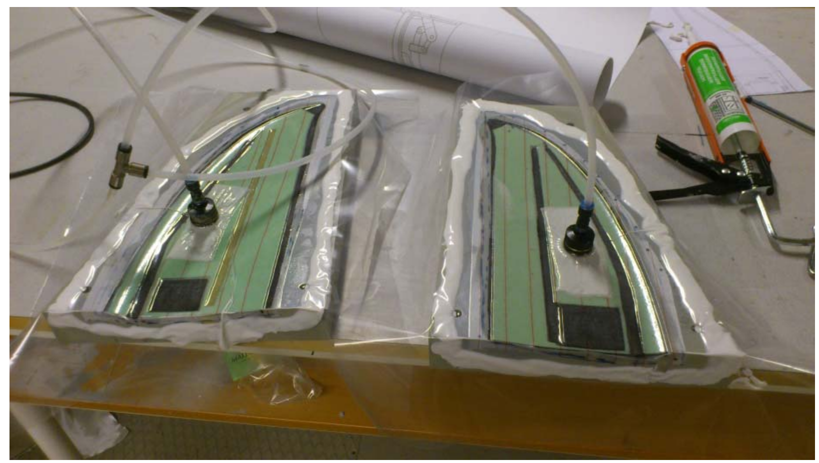




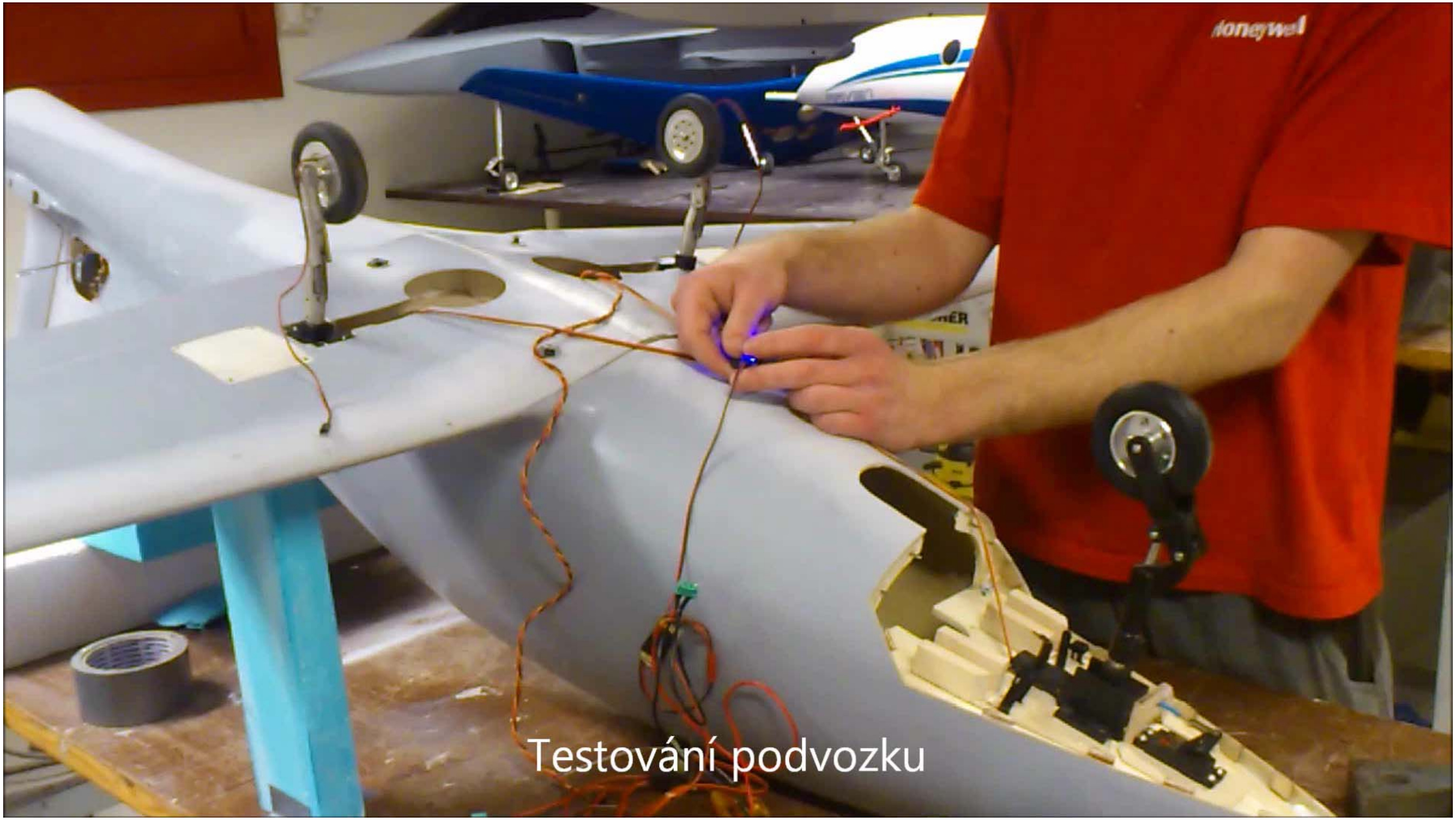


Manufacturing





Roll out



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Questions?

Linköpings universitet

expanding reality

www.liu.se

FOKKER-VFW B.V.

NETHERLANDS AIRCRAFT FACTORIES FOKKER-VFW B.V.

RAPPORT ÷ REPORT

AFDELING / DEPARTMENT: CB-AP	UITGAVE / ISSUE: 1	RAPPORT NR. / REPORT NO.: A-128
RUBRICERING / SECURITY CLASS:	DATUM / DATE: 1979 – 2013	BLAD / PAGE: 1

ONDERWERP / SUBJECT: **Static Directional Stability and Control of Transport Aircraft**

SAMENVATTING / SUMMARY

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546414

An analysis is described of side-force and yawing-moment-in-sideslip of conventional transport aircraft based on available wind tunnel and full-size aircraft data.
After a chapter on general design requirements the analysis is divided in a part which describes the tail-off characteristics and a part which describes the contribution of the tail surfaces to side-force and yawing-moment-due-to- sideslip. Particular attention is paid to the different contributions to the sidewash as experienced by the tail surfaces.
Also rudder characteristics are discussed.

OPGESTELD / PREPARED: E.Obert

GEKONTROLEERD / CHECKED:

UITGAVE / ISSUE	DATUM / DATE	INTERN AKKOORD / INTERNAL APPROVED	EXTERN AKKOORD / EXTERNAL APPROVED	BEWAAKTE KOPIE / CONTROLLED COPY

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AANTAL BLADEN / NUMBER OF PAGES x A4 x A3 x A

Contents **Pages**

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.21443

Notation

A	Aspect ratio
A_H	Horizontal tailplane aspect ratio $b_H{}^2 / S_H$
A_V	Vertical tailplane aspect ratio $b_V{}^2 / S_V$
A_W	Wing aspect ratio $b_W{}^2 / S_W$
b_{FL}, b_{fl}	Wing flap span
b_H	Horizontal tailplane span
b_V	Vertical tailplane span (see page I-19)
b_W	Wing span
C	Cross force perpendicular to the X-Z plane, positive to the left.
$C_C\,(=-C_Y)$	Cross force coefficient C / qS_W
c_H	Horizontal tailplane chord
C_{L_W}	Wing (or tail-off) lift coefficient L / qS_W
$C_{L_{T-O}}, (C_L)_{T-O}$	Tail-off lift coefficient
c_{l_α}	2-dimensional lift gradient due to angle-of-attack
c_{l_δ}	2-dimensional lift gradient due to control surface deflection
C_{l_β}	Rolling-moment-due-to-sideslip derivative
$(C_{l_\beta})_{T-O}$	Tail-off rolling-moment-due-to-sideslip derivative
$(C_{l_\beta})_\Gamma$	Contribution to rolling-moment-due-to-sideslip derivative due to wing dihedral
$C_{L\alpha}$	Lift-due-to-angle-of-attack gradient (Lift curve slope)
$C_{L\alpha_V}$	Vertical tailplane lift-due-to-angle-of-attack gradient (Also $(C_{L\beta})_V$,)
$C_{L\alpha_{Vest}}$	Estimated <u>isolated</u> vertical tailplane lift-due-to-angle-of-attack gradient

$C_{L\alpha_{V+H}}$, $C_{L\alpha_T}$	Vertical tailplane (including horizontal tailplane endplate effect) lift-due-to-angle-of-attack gradient. (Also $\left(C_{L\beta}\right)_{V+H}$.)
$C_{L\alpha_{V+Hest}}$	Estimated isolated vertical tailplane (including horizontal tailplane endplate effect) lift-due-to-angle-of-attack gradient
$C_{L_{\delta_r}}$	Vertical tailplane (including horizontal tailplane endplate effect) lift-due-to-rudder-deflection gradient
C_{L_β}	Rolling moment coefficient due to sideslip
$\left(C_{L_\beta}\right)_{V+H}$	See $C_{L\alpha_{V+H}}$
C_l	Rolling moment coefficient £ / $qS_W b$
$\left(C_{l_\beta}\right)_{T-O}$	Tail-off rolling moment coefficient due to sideslip.
C_n	Yawing moment coefficient $N / qS_W b$
$C_{n_{30}}$	Yawing moment coefficient with moment reference centre at $x = 0.30\overline{c_W}$.
$\left(\Delta C_{n_{30}}\right)_{V+H}$	Tail contribution to yawing moment coefficient with moment reference centre at $x = 0.30\overline{c_W}$.
C_{n_β}	Yawing-moment-due-to-sideslip derivative
$\left(\Delta C_{n_\beta}\right)_{FL}$	Contribution to yawing-moment-due-to-sideslip derivative due to flap deflection
$\left(C_{n_\beta}\right)_{tail-off}$	Tail-off yawing-moment-due-to-sideslip derivative (Also $\left(C_{n_\beta}\right)_{T-O}$ and $\left(C_{n_\beta}\right)_{WF}$ or $\left(C_{n_\beta}\right)_{WFN}$.)
$\left(\Delta C_{n_\beta}\right)_T$, $\left(\Delta C_{n_\beta}\right)_{V+H}$	Tail contribution to yawing-moment-due-to-sideslip derivative (Also $\left(C_{n_\beta}\right)_T$)
$C_{n_{\delta_r}}$	Yawing-moment-due-to-rudder-deflection derivative
c_r	Rudder chord
c_{R_V}	Vertical tailplane root chord
$c_{R_{V\,exposed}}$	Exposed vertical tailplane root chord (see page I-53)

c_V	Vertical tailplane chord
$\overline{c_V}$	Vertical tailplane mean aerodynamic chord.
$\overline{c_W}$, $\overline{c_{ref}}$	Wing mean aerodynamic chord.
C_Y	Side force coefficient Y / qS_W
C_{Y_β}	Side-force-due-to-sideslip derivative
$\left(\Delta C_{y_\beta}\right)_{est}$	Estimated tail contribution to side-force-due-to-sideslip derivative (See pages II-1 to II- 65)
$\left(C_{y_\beta}\right)_{tail-off}$	Tail-off side-force-due-to-sideslip derivative (Also $\left(C_{y_\beta}\right)_{T-O}$ and $\left(C_{y_\beta}\right)_{WF}$ or $\left(C_{y_\beta}\right)_{WFN}$).
$\left(\Delta C_{y_\beta}\right)_{FL}$	Contribution to side-force derivative due to flap deflection
$\left(\Delta C_{y_\beta}\right)_{nac}$	Contribution to side-force derivative due to engine nacelles
$\left(\Delta C_{y_\beta}\right)_T$, $\left(\Delta C_{y_\beta}\right)_{V+H}$	Tail contribution to side-force-due-to-sideslip derivative (Also $\left(C_{y_\beta}\right)_T$ or $\left(\Delta C_{y_\beta}\right)_{VH}$).
$\left(\Delta C_{y_\beta}\right)_\Gamma$	Contribution to side-force-due-to-sideslip derivative due to wing dihedral.
$C_{Y_{\delta_r}}$	Side-force-due-to-rudder-deflection derivative
$\left(C_{y_{\delta_R}}\right)_{S_V}$	Side-force-due-to-rudder-deflection derivative for a full-vertical-tailplane-span rudder derived from side-force data, $Y_{\delta_R} / q \frac{S_V}{S_W} S_W$
$\left(C^*_{y_{\delta_R}}\right)_{S_V}$	Side-force-due-to-rudder-deflection derivative for a full-vertical-tailplane-span rudder derived from yawing moment data, $N_{\delta_R} / q \frac{S_V}{S_W} \frac{l_{VR+(DF)}}{b_W} S_W b_w$
$D_{f_{max}}$, D_{fus} , d	Maximum fuselage diameter
d_V , D_V	Fuselage height as defined on page I-19

$\frac{d\sigma}{d\beta}$	Sidewash-angle-to-sideslip-angle ratio
E	Rudder-chord-to-fin-chord ratio c_r / c_v
h_W , Δh_W	Wing root height relative to fuselage centre line. Positive when wing is above the fuselage centre line.
i_h	Horizontal tailplane angle-of-incidence.
i_V	Vertical tailplane angle-of-incidence
K_i	Empirical factor defined on page I-15
K_N	Empirical factor defined on page I-16
K_{FV}	Fuselage-vertical-tailplane lift carry-over effect
K_{VH}	Horizontal-to-vertical tailplane endplate effect
$K_{VH_{est}}$	Estimated horizontal-to-vertical tailplane endplate effect
L	Lift
l_B	Fuselage length (see page I-16)
$l_V , l_{V_{30}} , l_V^*$	Vertical tailplane yawing moment arm measured from $x = 0.30\overline{c_W}$ .or $x = 0.25\overline{c_W}$.
l_{V+dfn}^*	Effective vertical tailplane yawing moment arm including dorsal fin n. (n=2,3,4,5) For Fokker models measured from $x = 0.30\overline{c_W}$. (Also l_{V+DF})
$l_{V_{ref}}$	Vertical tailplane moment arm related to reference (=exposed) vertical tailplane area
£	Rolling moment
N	Yawing moment
n_{nac}	Number of engine nacelles
q	Free-stream dynamic pressure $q = ½\rho V^2$
q_V	Average dynamic pressure at the vertical tailplane

R_{TL}	Tail moment arm ratio (Tail length ratio) $R_{TL} = \left(\Delta C_{n_\beta}\right)_T / -\left(\Delta C_{y_\beta}\right)_T * \frac{l_V}{b_W}$
S_{B_S}	Body side area (see page I-16)
S_{dfn}	Area of dorsal fin n (n =2,3,4,5) (Also S_{DF})
$S_{fus.cross}$	Maximum fuselage cross section.
S_H	Horizontal tailplane are
S_V	Vertical tailplane area (see page I-19)
S_{V_r}	Part of vertical tailplane area affected by the rudder (see page I-19).
$S_{V_{ref}}$	Reference (=exposed) vertical tailplane area
S_W ,	Wing area
$S_{W_{ref}}$	Reference wing area
$S_{W\,trap}$	Wing area of trapezoidal wing
V	Free stream velocity
$\overline{V_{V_{30}}}$	Vertical tailplane volume coefficient with moment centre at $x = 0.30\overline{c_W}$.
$\overline{y^*}$	Spanwise position of the centroid of span loading as a fraction of the semispan.
x	Distance along fuselage centre line from fuselage nose
x_{ac_V}	Distance from fuselage nose of vertical tailplane aerodynamic centre including dorsal fin.
x_{exh}	Longitudinal position of engine exhausts (see page I-53)
x_{R_V}	0% x_{R_V} = longitudinal position of vertical tailplane root chord
Y	Side force perpendicular to the X-Z plane, positive to the right.
$z_{CL_{nac}}$	Vertical position of engine-nacelle centre line
z_H	Vertical position of the horizontal tailplane (see page I-19)

$z_w \, (= -h_W)$	Wing root height relative to fuselage centre line. Positive when wing is below the fuselage centre line (see page I-15).
$\alpha \, , \alpha_R$	aircraft angle-of-attack
α_h	Horizontal tailplane angle-of-attack
α_h^*	Horizontal tailplane zero-lift angle-of-attack relative to tailplane reference plane
α_V	Effective vertical tailplane angle-of-attack
$\dfrac{\Delta\alpha_0}{\Delta\delta}$	2-dimensional control surface effectiveness $\dfrac{c_{l_\delta}}{c_{l\alpha_0}}$ (see page I-116)
β	Sideslip angle
Γ_W	Wing dihedral angle
δ_f	Flap angle
δ_s	Slat angle
$\delta\sigma / \delta\beta \, , \dfrac{\delta\sigma}{\delta\beta}, \dfrac{d\sigma}{d\beta}$	Sidewash-angle-to-sideslip-angle ratio
$\left(\dfrac{\delta\sigma}{\delta\beta}\right)_{FV}$	Fuselage-vertical-tailplane interference factor
$\left(\Delta\dfrac{\delta\sigma}{\delta\beta}\right)_{h_W}$	Effect of relative wing height on the fuselage on the sidewash-angle-to-sideslip-angle ratio
$\left(\Delta\dfrac{\delta\sigma}{\delta\beta}\right)_{\Gamma}$	Effect of wing dihedral on the sidewash-angle-to-sideslip-angle ratio
$\left(\Delta\dfrac{\delta\sigma}{\delta\beta}\right)_{FL}$	Effect of wing flap deflection on the sidewash-angle-to-sideslip-angle ratio.
$\left(\Delta\dfrac{\delta\sigma}{\delta\beta}\right)_{FL,ldg}$	Effect of wing flap deflection to the landing position on the sidewash-angle-to-sideslip-angle ratio.

$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{Cl\beta}$ Effect of rolling moment due to sideslip on the sidewash-angle-to-sideslip-angle ratio.

the sidewash-angle-to-sideslip-angle ratio

$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{NF}$ Effect of rear-fuselage engine nacelles on the sidewash-angle--to-sideslip-angle ratio

$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{NW}$ Effect of engine-nacelles-on-the-wing on the sidewash-angle-to-sideslip-angle ratio

ε	Downwash angle
λ	Taper ratio
λ_H	Horizontal tailplane taper ratio
λ_V	Vertical tailplane taper ratio
λ_W	Wing taper ratio
$\Lambda_{1/4 c_H}$	Horizontal tailplane quarter-chord sweep angle
$\Lambda_{1/4 c_V}$	Vertical tailplane quarter-chord sweep angle
$\Lambda_{1/4 c_W}$	Wing quarter-chord sweep angle
ρ	air density
σ	Sidewash angle

Model or aircraft components

W , V	wing
F , R	fuselage
N_f, G	engine nacelles on the rear fuselage
N_w,	engine nacelles on the wing
V	vertical tailplane
H	horizontal tailplane
DR	dorsal fin

All dimensions are measured in m, in, m^2 or in^2.

Unless otherwise indicated all angles are measured in degrees (deg).

Static Directional Stability and Control of Jet Transport Aircraft

Introduction

Static directional stability and control of transport aircraft is primarily determined by the forward fuselage and the vertical tailplane or fin and the rudder with some secondary effects due to the wing and wing-fuselage interference.
For preliminary design purposes the contribution of the forward fuselage can be determined with the standard design manual methods. However, these manuals do not consider the effect of angle-of-attack or high-lift devices on tail-off side force or yawing moment. This effect is addressed in the present report.
Determining the characteristics of the vertical tail surface and rudder is a more complex process. This is due to the vertical tail being positioned in a flow field affected by all other major aircraft components. In a sideslip the fuselage, wing, engine nacelles and even the horizontal tailplane create all different, often non-linear, cross flows, also depending on their relative position. (High - or low - wing, engine nacelles on the wing or on the rear – fuselage, high or low horizontal tailplane.) Furthermore modern transport aircraft have swept wings and highly efficient high-lift systems. This tends to produce large variations in the rolling-moment-due to-sideslip at varying angle-of-attack which in turn produces significant variations in cross flow at the tail.
Standard design manuals such as ESDU Data Sheets and the USAF Datcom and the textbooks derived from these sources consider only fuselage cross flow and the effect of the vertical position of the wing on the fuselage and of the wing dihedral on this cross flow , all at zero angle-of-attack.

In the present analysis the different contributions to the cross-flow or sidewash at the tail mentioned above and not covered by the design manuals are discussed in detail. As the analysis is entirely based on experimental data sometimes large variations in flow characteristics are noted on configurations wit relatively small variations in geometry. Nevertheless an effort is made to present elementary guidelines for the preliminary design of vertical tail surfaces.

The data compilation in this report took place over the years 1978 – 2013. The text was finished in July 2013.

Some general guidelines for the analysis of directional stability and control of transport aircraft.

With respect to fin and rudder sizing directional stability and control requirements for transport aircraft refer primarily to steady-state conditions. The two main conditions to be considered are:

Crosswind take-offs and landings with maximum crosswind.
Maintaining directional control after an engine failure at low airspeeds.

As the information provided in the present report is primarily intended for preliminary design studies, the attention is focused on the low-speed regime.

Tail surfaces perform three functions :
1. They provide static and dynamic STABILITY. 2. They enable aircraft CONTROL. 3. They provide a STATE OF EQUILIBRIUM in each flight condition.

In general the following DESIGN REQUIREMENTS can be formulated for VERTICAL TAIL SURFACES:

1. They shall provide a sufficiently large contribution to static and dynamic directional STABILITY. This determines primarily their lift SLOPE, $dC_{L_v} / d\alpha_v x S_V$.
2. They shall provide sufficient CONTROL CAPABILITY $dC_{L_v} / d\delta_r x S_V$ without flow separation up to high sideslip and rudder deflection angles.
3. Control shall be possible with sufficiently LOW CONTROL FORCES either for manual control or to minimize control system weight.
   Control Force F = $C_h x \frac{1}{2} \rho v^2 S_c \overline{c_c}$.
   For a constant rudder area the HINGE MOMENT is MINIMISED when the factor $S_c.\overline{c_c} \approx b_c.\overline{c_c}^2$ is minimized.

   For all three requirements a MAXIMUM ASPECT RATIO and for HIGH ASPECT RATIOS MINIMUM SWEEP is favourable.
4. The vertical tail surface shall be able to cope with HIGH TAILPLANE ANGLES - OF - ATTACK both with sideslip angle and rudder deflection with equal sign and with opposite sign. In this case a LOW ASPECT RATIO and applying SWEEP is beneficial.
5. The tail surface shall be able to provide a MAXIMUM FORCE sufficiently large to BALANCE the total tail-off forces and moments so that STATIC EQUILIBRIUM is achieved in all flight conditions. This leads to specific requirements on TAIL SURFACE AREAS and on the MAXIMUM LIFT COEFFICIENT of the vertical tail with a varying degree of rudder deflection including the effect of ice roughness.

The RUDDER performs three functions :

1. It provides a means to achieve a STEADY STATE OF EQUILIBRIUM (TRIM) either at zero or at non-zero control force.
2. It allows MANOEUVRING up to maximum yaw rates.

3. It provide a means to COUNTERACT DISTURBANCES, both small and large, such as gusts, which might otherwise cause the aircraft to deviate from its intended flight path (flight path TRACKING).

In order to obtain a MAXIMUM LIFT FORCE due to rudder deflection the use of a deep rudder may be tempting. However, the resulting maximum force and moment increases far from linearly with rudder depth for the larger rudder-to-fin chord ratio's.
Within the normal range of rudder-to-fin chord ratio's (c_R / c_V = 0.20 to 0.35) the MAXIMUM SIDE FORCE DUE TO RUDDER DEFLECTION is FAIRLY INDEPENDENT OF FIN SHAPE AND RUDDER DEPTH.

The type of AERODYNAMIC BALANCE on the rudder has a LARGE EFFECT on the DEGREE OF LINEARITY of the variation of the hinge moment due to angle-of-attack and due to rudder deflection. ($C_h = C_{H_0} + \frac{\delta C_h}{\delta \alpha_V}\alpha_V + \frac{\delta C_h}{\delta \delta_R}\delta_R$ seldom applies at large angles.)
HORN BALANCES and DORSAL FINS IMPROVE LINEARITY OF HINGE MOMENTS.
LONG SPAN OVERHANG BALANCES have an ADVERSE EFFECT on this linearity.

LINEARITY of hinge moments is particularly important for RUDDERS because in sideslips the rudder may be deflected to its maximum angle both to the weather side (during V_{MC}- tests) and to the lee side (in sideslips and cross-wind take-offs and landings)

A special characteristic of vertical tail surfaces

The most stringent design requirement for vertical tail surfaces is the ability to cope with VERY LARGE SIDESLIP ANGLES up to 25 degrees. Therefore vertical tail surfaces have :
- Low aspect ratio's
- Large leading-edge sweep
- sometimes dorsal fins

As shown on page I-21 to I-24 for lifting surfaces with an aspect ratio A $\leq$ 1.5 the lift curve gradient C_{L_α} =0.0274 A. As A = b^2/ S and $L = C_{L\alpha} \times \alpha \times ½\rho V^2$ S then
$L = 0.0274\, b^2 \times \alpha \times ½ \rho V^2$ (Note $\alpha = \alpha_v = -\beta$)

Thus: The side force gradient on a fin is to a first order independent of the shape and the fin chord but only of the fin span (fin height).

Adding a dorsal fin or applying wing sweep does however often increase the maximum lift and the angle-of-attack for maximum lift and improves the linearity of the aerodynamic characteristics. Therefore a dorsal fin and fin sweep are also beneficial for low-speed aircraft.

Tail – off side force and yawing moment

On pages I-1 to I-12 the tail-off side force and yawing moment is presented of a number of aircraft models as obtained from wind tunnel tests. Page I-13 shows for one model, F-29 Model 2-5, the raw data and the sideslip derivatives as given in ref. 59. Ref.59 shows the sideslip derivatives in fig.66b which is reproduced as the lower left figure on page I-13. Reconsidering the slope of the raw data produced slightly different derivatives.(See page I-13 with data from ref.59 figs.34a,b and 35 and the lower left part of page I-12). This illustrates that inaccurate determination of derivatives may lead to confusing conclusions.

The tail-off side force and yawing moment are analyzed in the present report, although in a slightly modified form, according to the method presented in the USAF Datcom and NACA TN D-6946.

In the USAF Datcom the side force is estimated according to the formula :

$$\left(C_{y_b}\right)_{WFN} = \frac{S_{fus.cross}}{S_W} K_i \frac{2}{57.3} - 0.0001\Gamma - 0.0011\ n_{nac}$$

(The latter term is taken from ESDU Data Sheet No. 79006.)

From the data on pages I-8 to I-12 and the lower part of page I-14 it is concluded that flap deflection increases the tail-off side force and decreases the yawing moment and both are slightly affected by angle-of-attack. Although these effects show considerable variations a trend can clearly be observed. Therefore average curves for these changes in tail-off side force and yawing moment due to flap deflection $\left(\Delta C_{y_\beta}\right)_{FL}$ and $\left(\Delta C_{n_\beta}\right)_{FL}$ are proposed on the upper half of page I-14.
For the models in cruise configuration no unambiguous effect of angle-of- attack on side force or yawing moment could be determined.

The test data of Models SKV-LST-3 (page I-11) and SKV-6 (page I-12) with and without engine nacelles on the wing show on average that fitting engine nacelles on the wing produces an increase in side force $\left(\Delta C_{y_\beta}\right)_{nac}$ =-0.0035 and in yawing moment $\left(\Delta C_{n_\beta}\right)_{nac}$ = -0.0005 for two engines.

The test data of Models 8/41 (pages I-8, I-9) and SKV-LST-3 (page I-11) with and without engine nacelles on the rear fuselage show on average that two engine nacelles on the rear fuselage produce an increase in side force $\left(\Delta C_{y_\beta}\right)_{nac}$ =-0.0005 and no effect on yawing moment($\left(\Delta C_{n_\beta}\right)_{nac}$ =0) is observed.

Based on the analysis of the wind tunnel data as described above the tail-off side force formula is modified to :

$$\left(C_{y_b}\right)_{WFN} = \frac{S_{fus.cross}}{S_W} K_i \frac{2}{57.3} - 0.0001\Gamma + \left(\Delta C_{y_\beta}\right)_{FL} - 0.00175\ n_{nac} \text{ (nacelles on wing)}$$

$$- 0.00025\ n_{nac} \text{ (nacelles on fuselage)}$$

For K_i see page I-15 For $\left(\Delta C_{y_\beta}\right)_{FL}$ see page I-14 (1)

The tail-off yawing moment in the USAF Datcom is estimated via :

$(C_{n_\beta})_{WFN} = -K_N \frac{S_{B_S}}{S_W} \frac{l_B}{b_W}$ with the factor K_N read off a graph presented on page I-16.

The analysis of the wind tunnel data on pages I-8 to I-14 showed the effect of angle-of- attack and flap angle on the tail-off yawing moment and led to the modified formula:

$$(C_{n_\beta})_{WFN} = -K_N \frac{S_{B_S}}{S_W} \frac{l_B}{b_W} + (\Delta C_{n_\beta})_{FL} \quad \text{with } K_N \text{ taken from page I-16} \qquad (2)$$

On pages I-17 and I-18 a comparison is presented of the tail-off side force and yawing moment for the models in cruise configuration as estimated with the formula given above and data derived from wind tunnel tests.

The tail contribution to side force and yawing moment

Some definitions

On page I-19 some geometrical definitions concerning the vertical tail surface or fin are presented.

Note that in the definition of area and span (height) the tail surface is assumed to continue inside the fuselage up to the fuselage centre line. This is in accordance with the definition used in most NACA publications and differs from the definition used in the ESDU Data Sheet and used by several aircraft manufacturers.

Page I-20 shows some sketches explaining the flow characteristics in front of the vertical tail affecting the contribution of the tail to side force and yawing moment.

The lift curve slope of isolated lifting surfaces.

On pages I-21 to I-24 lift curve slopes for various lifting surfaces are shown. (3)

These figures clearly show that for low-aspect-ratio surfaces with $A \leq 1.5$ the actual shape (sweep, taper ratio, tip shape) has hardly any effect on the lift curve slope.

The effect of a dorsal fin on the lift curve slope and the aerodynamic centre of the vertical tailplane.

Pages I-25 to I-38 show the effect of a dorsal fin on the vertical tail characteristics.
Although the main purpose of a dorsal fin is increasing the maximum angle-of-attack of the vertical tailplane before flow separation occurs the tailplane lift gradient is slightly increased and the aerodynamic centre moves forward. These effects can also be seen when leading-edge strakes or leading-edge extensions (LEX) are considered in the wing designs of modern combat aircraft .The data presented are derived from wind tunnel tests performed during the development programmes of both the Fokker F-27 and the F-28.

Page I-35 shows the data derived from the wind tunnel test results of the F-28 Models 8/4 and 8/41.
From the tests on the F-27 tail model only cross force coefficients (= - side force coefficients) were available. (page I-37). The change in lift curve slope due to dorsal fins of different size is indicated in the lower figure on page I-38.
The lower figure on page I-36, taken from test data of a complete F-27 model, shows that for different dorsal fins the yawing moment, at least up to medium yaw angles,is not affected by fin size or shape. This means that the increase in side force due to an increase in fin size is counteracted by a forward movement of the aerodynamic centre. With this in mind this **shift in aerodynamic centre was determined with the data from page I-37. (Upper figure on page I-38)**

Note the similarity between the curves for the two data sets on pages I-35 and I-38.

On pages I-25 to I-34 a collection of available raw wind tunnel data and on page I-35 to I-38 a collection of available dorsal fin aerodynamic data is presented.
(4)

The endplate effect of the horizontal tailplane on the vertical tailplane lift curve slope.

Wind tunnel test data of the endplate effect of the horizontal tailplane K_{VH} is shown on pages I-39 to I-45.

The lower figure on page I-39 shows a graph of the endplate effect of the horizontal tailplane on the lift curve slope of the vertical tailplane as expressed by a change in effective aspect ratio A_V as presented in the USAF Datcom.
Analysis of all available test data, including wind tunnel data on later transport aircraft produced a slightly modified curve (pages I-41 and I-42), in particular for horizontal tailplanes mounted on the fuselage. (page I-45).

The derivation of the individual data points in the figures on pages I-41, I-42 and I-45 can be found in the second part of this report, pages II-1 t0 II-68.
These data are rearranged in a separate chapter on pages III-1 to III-14.

The effect of the tailplane area ratio S_H / S_V on the endplate effect is shown for a number of configurations on page I-43 together with the average curve given in the USAF DAtcom.

The endplate effect of the horizontal tailplane on the vertical tailplane can be determined with the aid of the graphs presented on page I-39 to I-45.
(5)

The endplate effect of the horizontal tailplane is not only affected by the tailplane relative vertical position and tailplane area ratio but also by the horizontal tailplane effective angle-of-attack or lift coefficient. This is illustrated on page I-44 for a number of model configurations.

It will be clear that a lifting swept horizontal tail surface shows a cross flow above and below the upper and lower surface in a sideslip just as a wing produces a cross-flow and a rolling-moment-due-to-sideslip. It is however not immediately clear what the relation is between the sign of sideslip angle,,tailplane lift coefficient and average cross flow direction at the vertical tailplane.

For the average horizontal tailplane the effect of the tail lift on the endplate effect on the vertical tailplane can be expressed as :

$$K_{VH} = (K_{VH})_{\alpha_H=0}\left[1-0.014(\alpha_H+\alpha^*)\right]$$

(6)

Some additional data on the lift curve slope of the vertical tail including the endplate effect of the stabilizer of models SKV-LST-3 and F-29-1-1 are given on pages I-57 and I-58.

Sidewash at the vertical tailplane.

1. Sidewash or cross-flow due to the presence of the fuselage.

Sidewash due to the flow around a fuselage in sideslip is illustrated on page I-20.

On page I-46 a collection of sidewash data for fuselage-tailplane combinations is shown.

The sidewash parameter is defined as the product of the actual sidewash ratio (1+ $\delta\sigma / \delta\beta$), the effective-versus-free-stream dynamic pressure ratio q_V / q (to take into account the fuselage-boundary-layer effect) and the tailplane-fuselage lift carry-over effect K_{FV}.
The parameter (1+ $\delta\sigma / \delta\beta$) q_V / q K_{FV} is presented as a function of fin-span-to-fuselage-diameter ratio b_V / d_V .(See page I-19 for the definition of b_V and d_V)

In the upper figure on page I-39 this fuselage-tailplane interference effect is expressed as a ratio between the nominal and effective vertical tailplane aspect ratio $(A_{V(B)})/(A)_V$.
For $A \leq 1.5$ the lift gradient can be written as $C_{L\alpha}$ = 0.0274 A and thus the tailplane aspect ratio given above is equivalent to the fuselage-tailplane interference factor (1+ $\delta\sigma / \delta\beta$) q_V / q K_{FV} . Therefore the curves on pages I-39 and I-46 show a high degree of similarity.

For estimating the tailplane-fuselage sidewash (1+ $\delta\sigma / \delta\beta$) q_V / q K_{FV} ------------------------------------- an average curve was drawn in the figure on page I-46. (7)

2. Sidewash due to wing-fuselage interference. (Rolling moment due to sideslip I .)

The data on pages I-47 and 48 show the effect of the wing position in height on the fuselage on the sidewash-due-to-sideslip derivative.

$$\left(\Delta \frac{d\sigma}{d\beta}\right)_{h_W} \frac{q_V}{q} K_{FV} = -0.40 \frac{h_W}{D_{f_{max}}}$$

For definition of h_W and $D_{f_{max}}$ see page I-19 (8)

3. Sidewash due to wing dihedral and sweep. (Rolling moment due to sideslip II.)

Based on a limited amount of wind tunnel test data (see page I-49) an equation (equation 9) has been found that expresses the relation between sidewash and wing dihedral. Wing dihedral has been substituted by the change in rolling-moment-due-to-sideslip derivative due to wing dihedral $(\Delta C_{l_\beta})_\Gamma$ to account for both dihedral an wing sweep .

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_\Gamma \frac{q_V}{q} K_{FV} = +\left(110 + 50\frac{h_W}{D_{f_{\max}}}\right)\left(\Delta C_{l_\beta}\right)_\Gamma \qquad (9)$$

4. Direct sidewash measurements on Model SKV-LST-3.

On model SKV-LST-3 with engine nacelles on the rear fuselage direct sidewash measurements were performed by means of a variable-incidence vertical tailplane. By comparing tail-on and tail-off side-force and yawing moment for different tailplane incidences i_{VH} , under the assumption that when tail-on and tail-off side-force and yawing moment are equal the load on the tailplane is zero and the average vertical-tailplane

angle-of-attack $\alpha_V = 0$, the average sidewash can be determined via the equation

$\alpha_{VH} = 0 = \beta + \sigma + i_{VH}$ or $\sigma = -\beta - i_{VH}$.

Note that to enable variation of the vertical tailplane incidence i_{VH} a fin root plug was installed (see page II-9b).
Therefore in the analysis two volume coefficients have been used: $\overline{V}$ = 0.1443 for the basic fin including a dorsal fin and $\overline{V}$ = 0.1554 for the fin with rootplug (but without dorsal fin). The latter configuration was not only used for the tests with variable incidence i_{VH} but also for tests with varying sideslip angle.

On pages I-57 to I-71 an analysis is presented of the vertical tailplane characteristics as determined according to the method described above
On page 57 a detailed analysis is shown for the configuration with engines on the rear-fuselage with flaps and slats retracted at α = 0.

On the left hand side of page I-57 the vertical tail lift curve slope (including the horizontal tailplane and dynamic pressure ratio and lift-carry-over effects) $C_{L_{\alpha V+H}} \frac{q_V}{q} K_{FV}$ is determined by varying the vertical tailplane incidence i_{V+H} at sideslip angle $\beta = 0$. By comparing this lift curve slope $C_{L_{\alpha V+H}} \frac{q_V}{q} K_{FV}$ =0.0290 with the theoretical value $C_{L_{\alpha V+H}}$ =0.0308 the factor $\frac{q_V}{q} K_{FV}$ =0.942 is obtained.

On the right hand side of page I-57 the sidewash is determined, both from the data on the left side for $\beta = 0$ (upper right) and by comparing the tail yawing moment contribution $\frac{dC_{n_{30VH}}}{d\beta}$ =0.0048/0.0053, as found by varying the sideslip angle β with i_{V+H} = 0, with the yawing moment contribution $\frac{dC_{n_{30VH}}}{di_{V+H}}$ =0.0045 found with $\beta = 0$. In both cases $\frac{\delta\sigma}{\delta\beta}$ = 0.13.
Page-58 shows some additional vertical tailplane characteristics.

On the upper half of page I-58 the effect of angle-of-attack and flap deflection on the tail lift curve slope (including stabilizer) $C_{L_{\alpha V+H}}$ of model SKV-LST-3 determined at $\beta = 0$ is presented. This effect is apparently due to variations in local flow direction at the vertical tail resulting in changes in the factor $\frac{q_V}{q} K_{FV}$. This is also indicated on page I-71.

The lower half of page I-58 is discussed under the heading. " The effect of engine_nacelles on the wing on sidewash".

On page I-59 two more examples are shown of the sidewash as determined from tests with different fin incidences on model SKV-LST-3.

Page I-60 shows the overall sidewash results whereas page I-61 shows the change in yawing moment due to fin incidence variation for all model configurations and angles-of-attack investigated .

On pages I-63 / I-64 and I-65 / I-66 the computed sidewash derivative (1+ $\delta\sigma / \delta\beta$) or $\delta\sigma / \delta\beta$ and the relative effective dynamic pressure ratio combined with the lift carry-over factor $\frac{q_V}{q} K_{FV}$ are presented in tabular form for both the configuration with the fin including the root plug ($\overline{V}$ = 0.1554) and with the basic fin ($\overline{V}$ = 0.1443). On pages I-67 , I-69 / I-70 and I-71 this data is presented in graphical form. Page I-68 contains the tail-off rolling-moment-due to-sideslip derivative for the wing-fuselage combination to be used in the analysis of the effect of angle-of-attack and flap deflection on sidewash.

5. <u>Sidewash analysis of other aircraft and windtunnel models.</u>

Besides model SKV-LST-3 a number of wind tunnel models and full-scale aircraft have been analysed according to the method described above :

- Fokker 100 Model 15-3
- Fokker 100 Model 15-10
- Fokker 100 Model 18-5
- Fokker 70 Model 15-24
- F-29 Model 1-2
- F-29 Model 2-5
- F-29 Model 5-3
- F-29 Model 1-1
- F-28 Mk 1000 Model 6-2-3
- F-28 Mk 1000 Model 8-3
- Airbus A320
- Airbus A340 – 300
- Douglas DC-9-30
- Airbus A300
- Boeing 737-100

The results of this analysis are shown on pages I-73 to I-87

6. <u>Sidewash due to rolling-moment-due-to-to-sideslip</u>

On pages I-69, I-70 and I-73 to I-87 the sidewash term $\frac{d\sigma}{d\beta}$ as a function of angle-of-attack α_R, is presented for all models and aircraft investigated.
The resulting curves show a large variation in shapes, even when for a given aircraft or model the curves derived from side force and yawing moment data are compared. Although some data sets, such as that for Model F-29-1-2 or F-28 Model 8-3, (page I-77 And I-83) show an opposite trend the majority of the curves clearly show a trend where the sidewash diminishes with increasing α_R. In most cases the curves show a gradual decrease in sidewash, in particular in the normal operating range of α_R's. Only at the

highest α_R's do the curves drop sharply, presumably due to the beginning of local flow disturbance. No explanation is offered for the smaller downwash at low angles-of-attack in some cases.

Overall however, it is concluded that for preliminary design purposes and lacking other data the decrease in sidewash with increasing angle-of-attack can be expressed with a straight line with a small negative slope.

This effect is attributed to the sidewash resulting from the non-uniform spanwise lift distribution in a sideslip. The upwind wing producing more lift than the downwind wing causes above the wing upper surface a cross flow towards the upward wing decreasing the overall sidewash. This is illustrated on page I-20.

In particular on swept wings the rolling-moment-due-to-sideslip increases with increasing angle-of-attack. (An increasing tendency to roll in an anti-clockwise direction with the wind coming from the right.) This is a linear relation as illustrated in the figures on pages I-89 to I-94.
As for transport aircraft the wing aspect ratio lies usually in the range A_W =7.0 – 12.0 and the wing sweep is mostly $\Lambda_W \leq$30deg the lift curve slope shows little variation as shown by the table below (complete aircraft).

Aircraft or model	Lift curve gradient	Aircraft or model	Lift curve gradient
Model SKV-LST-3 WF	0.094 / deg	A320	0.093 / deg (AI)
Model SKV-LST-3 WFN$_f$	0.095 / deg	A340-300	0.092 / deg (AI)
Model SKV-LST-3 WFN$_w$	0.093 / deg	F-29 model 1-2	0.092 / deg
F-28 model 8-3	0.087 / deg	F-29 model 2-5	0.093 / deg
F-28 model 6-2-3	0.087 / deg	Fo 100 model 15-10	0.090 / deg
		F-27	0.092 / deg

As the lifting –line theory clearly shows the rolling-moment-due-t- sideslip is directly connected to lift and consequently the slope or gradient of the rolling-moment-due-to-sideslip as a function of angle-of-attack will also show little variation with aspect ratio and wing sweep. This is clearly shown in the graphs on pages I-89 to I-94 and the lower figure on page I-108.

On pages I-95 to I-100 the tail-off rolling-moment-due- to-sideslip is presented as a function of the tail-off lift-coefficient. As for the configurations considered the lift curve has a constant gradient with little variation the curves on pages I-95 to I-100 are also straight lines with almost constant gradient.

These gradients $\left(\frac{C_{l_\beta}}{C_{L_W}}\right)$ were computed with equation (12) and compared with the measured values on page I-111. Note that apart from the data for the A340 calculated and measured data compare reasonably well.

Assuming the relation between the sidewash and the rolling-moment-due-to-sideslip discussed above and the small variation in the rolling-moment-versus- tail-off-lift-coefficient gradient the relation between sidewash and tail-off lift-coefficient is assumed to be linear with a small negative gradient.

In the figures on pages I-102 to I-107 this relation is indicated as a double straight line as an average between the curves derived from side-force and from yawing-moment data. This relation is also described as equation (10).

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{Cl\beta} = -0.50\left[\left(C_{l_\beta}\right)_{T-O} - \left(C_{l_\beta}\right)_{T-O,C_L=0}\right] \qquad (10)$$

The tail-off rolling-moment-due-to-sideslip is determined with the following equation taken from the USAF Datcom and ref.1 (after some re-writing) :

$$\left(C_{l_\beta}\right)_{T-O} = \left(\frac{C_{l_\beta}}{C_{LW}}\right)\frac{C_{LW}}{57.3} + \left(\frac{C_{l_\beta}}{\Gamma}\right)\Gamma - \left(0.042\frac{Z_W}{D_{fus_{\max}}} + 0.0005\Gamma\right)\sqrt{A_w}\left(\frac{D_{fus_{\max}}}{b_W}\right)^2 \qquad (11)$$

The coefficients which express the effect of wing dihedral and sweep on the rolling-moment-due-to-sideslip $\left(C_{l_\beta}/C_{LW}\right)$ and $\left(C_{l_\beta}/\Gamma\right)$ are given on pages I-51 and I-52.

The lift-dependent tail-off rolling-moment-due-to-sideslip $\left(C_{l_\beta}/C_{L_W}\right)$ may also be determined with the following equation :

$$\left(\frac{C_{l_\beta}}{C_{L_W}}\right) = -\frac{1}{2}\left[\frac{3}{A_W(1+\lambda)} + y^*\left(\tan\Lambda_{c/4} - \frac{6}{A_W}\frac{1-\lambda}{1+\lambda}\right)\right] + 0.05 \text{ per rad.} \qquad (12)$$

The computed rolling-moment-due-to-sideslip are shown on page I-110.

7. Sidewash due to flap deflection in the landing position

The sidewash due to flap deflection in the landing position is derived from the shift in the figures of the average linearized curves for different flap settings. This shift sometimes showed an increase in sidewash and sometimes a decrease. A similar effect was shown by the rolling-moment-due-to-sideslip. It was therefore concluded that this depended on the relative flap span. This relation is shown in the upper figure on page I-107 and also expressed by equation (13) .

For smaller flap angles a sidewash contribution due to flap deflection is assumed to be proportional to the flap angle.

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{FL,ldg} = -0.80\left(\frac{b_{FL}}{b_W} - 0.67\right) \qquad (13)$$

8. The effect of engine nacelles on the wing on sidewash

On the lower half of page I-58 some tailplane data are given for model F-29-1-1. Note that at α_R = 0 fitting the low-set wing ($h_W / D_{f_{max}}$ = - 0.26 , Γ_W = 7.0 deg) and under-wing engine nacelles onto the fuselage-tail combination increases the sidewash by $\delta\sigma / \delta\beta$ ≈0.100. Fitting the low-set wing onto the fuselage, together with the wing dihedral increases the sidewash with $\Delta \frac{\delta\sigma}{\delta\beta}$ = 0.40x0.26 – (110-50x0.260)x0.00161= = 0.104 -0.156 = 0.046. See pages I-47,I-49 I-109) and thus on this model fitting two engine nacelles onto the wings increases the sidewash with $\left(\Delta \frac{d\sigma}{d\beta} \right)_{NW}$ ≈0.145

This seems unlikely given the small increase in sidewash due to the under-wing engine nacelles on model SKV-LST-3 (page I-70) and the small decrease in rolling-moment – due-to-sideslip on models SKV-6 and SKV-6WN (page I-101). Furthermore the sidewash measured on the fuselage +tailplane combination of model1-2 (page II-14b) seems unrealistically low. The available test results on these two fuselage-tail combination are suspect. Also, the estimated sidewash data,computed without any effect of the nacelles (page I-110) and compared with measured sidewash data for the configurations with engine nacelles on the wing show relatively minor differences with either sign (+ or -) as shown in this table :

Configuration	$\left(\frac{d\sigma}{d\beta} \right)_{estimated}$	$\left(\frac{d\sigma}{d\beta} \right)_{measured}$
Model SKV-LST-3 (II) WF	0.375	0.450
Model SKV-LST-3 (II) WFN_W	0.375	0.420
A320	0.350	0.320
A340-300	0.295	0.240
F-29 model 1-2	0.280	0.270
F-29 model 2-5	0.272	0.300

It is suggested to use the following number as contribution to the sidewash due to under-wing nacelles

$\left(\Delta \frac{\delta\sigma}{\delta\beta} \right)_{NW}$ ≈0-+0.03 (page I-101 and I-103, lower figure) (14)

9. The effect of the horizontal and vertical position of rear-fuselage engine nacelles on the sidewash at the vertical tail.

On pages I-53 and I-54 wind tunnel test data are presented of the effect of engine nacelle position on the sidewash-in-sideslip at the vertical tail. The data show for these tests on F-28 Model 8/41 (ref. 22) a considerable effect of relative small variations in nacelle position. If the effect of the dorsal fin on the effective yawing moment arm is incorporated (S_{DF} / S_V = 0.071 and l_{V+DF} = l_V 0.95 see page I-35) the data on side-force and yawing moment compare very well.

Note that the longitudinal position of the nacelles is defined as the distance between the engine exhaust plane and the 0%-point of the fin root chord, positive when the engine exhaust is behind this 0%-point.

The vertical position is defined by the vertical distance between the engine nacelle centre line and the fuselage centre line, positive when the nacelle centre line is above the fuselage centre line.

With the aid of the test data shown on page I-71 the factor $\frac{q_V}{q} K_{FV}$ was estimated.

By dividing the total sidewash factor $(1+ \frac{\delta\sigma}{\delta\beta}) \frac{q_v}{q} K_{FV}$ by $\frac{q_V}{q} K_{FV}$ the true sidewash factor $\frac{\delta\sigma}{\delta\beta}$ was found. For the data on pages I-53 and I-54 $\Delta \frac{\delta\sigma}{\delta\beta}$ is given on page I-56.

> Generalized curves for estimating the effect of the position of rear-fuselage engine nacelles on sidewash-due-to-sideslip at the vertical tailplane $\left(\Delta \frac{\delta\sigma}{\delta\beta}\right)_{NF}$ are given on page 56.
> (15)

An analysis of the effective tail moment arm.

In the standard approach in analyzing the yawing moment contribution of the vertical tailplane to the aircraft's yawing moment the tailplane side-force is assumed to apply at the 25% m.a.c.-point of the exposed tailplane area. The distance between this point and the moment reference point is considered to be the yawing-moment arm . The analysis of the effect of a dorsal fin on the relation between tailplane side-force and yawing-moment justified an analysis of this relation for tailplanes without dorsal fin as found from wind tunnel tests and in the data bases of some full-scale airplanes.

On pages IV-1 to IV-36 an overview is presented of the ratio

R_{TL} = $\left(\Delta C_{n_\beta}\right)_{V+H}$ / $\left(\Delta C_{Y_\beta}\right)_{V+H}$ * $\frac{l_V}{b}$ in tabular form. On pages I- 112 to I-116 this ratio is shown in graphical form.

> Although a large variation occurs in this parameter it may in general be concluded that the ratio R_{TL} is close to one provided that :
> 1. The data are obtained at a sufficiently high Re-number
> 2. No dorsal fin is fitted
> 3. The rear fuselage is not highly tapered

Rudder Characteristics

Side- force due to rudder deflection

On pages I-117 to I-120 available data are collected on rudder characteristics of ten aircraft and wind tunnel models. In most cases the side force curves show a linear behavior up to δ_R=25 deg. In the normal range of rudder-chord-to-tailplane chord ratio

(c_R / c_V=0.20-0.35) the maximum side force is reached at $\delta_R \approx$ 35 deg. The maximum side force loss, relative to the linear $C_{L_V} - vs. - \delta_R$ relation is then $\Delta C_{L_V} = 10$ to 15 %. The maximum lift (or side force) is $C_{L_{V\,max}} \approx$ 0.8 based on exposed tailplane area or $C_{L_{V\,max}} \approx$ 0.6 based on tailplane reference area.

Note that on model SKV-LST-2 a double-hinged rudder was tested. The data on page I-117 refer to the tests with the forward part deflected with the rear part in the neutral position(c_R / c_V=0.311) and with the rear part deflected (c_R / c_V=0.156) .

In order to be able to compare the data of rudders with different relative span the data are normalized to full-span rudders by the ratio S_{V_R} / S_V (page I-19).

With the equation given below and the equation for the yawing-moment-due-to-rudder-deflection the ratio $\frac{(C_{y_{\delta_R}})_{S_V}}{C_{L_{\alpha V+H_{est}}}}$ (both terms related to the tailplane reference area) were calculated (page I-121). They are presented in graphical form on page I-122.

Note the similarity with the data for two-dimensional flow.

$$(C_y)_{\delta_R} = C_{y_{\delta_R}} x \delta_R = C_{L\alpha_V} x \frac{q_V}{q} K_{FV} x K_{VH} x \frac{c_{l\delta}}{c_{l\alpha}} x \frac{S_{V_R}}{S_W} x \delta_R \qquad (16)$$

Yawing moment due to rudder deflection

Rudder yawing moment = Rudder side-force x Rudder moment arm.

The rudder moment arm is longer than the vertical-tailplane moment arm because the centre-of-pressure of the load due to rudder deflection lies behind the $0.25\overline{c_V}$ -point.

This difference in distance is $\Delta l_R \approx 0.30\,\overline{c_V}$ for the usual range of relative rudder chords.

An example is shown on page I-123.

The yawing moment due to rudder deflection can be estimated with equation (17).

$$(C_n)_{\delta_R} = C_{n_{\delta_R}} x \delta_R = C_{L\alpha_V} x \frac{q_V}{q} K_{FV} x K_{VH} x \frac{c_{l\delta}}{c_{l\alpha}} x \frac{S_{V_R}}{S_W} x \frac{l_{V(+DF)} + 0.30\overline{c_V}}{b_V} x \delta_R$$

With maximum rudder deflection $(C_{n_{max}})_{\delta_R} = 0.90 x C_{n_{\delta_R}} x \delta_{R_{max}}$ (17)

Aircraft (Model) Geometry and Aerodynamic data

On pages II-1a to II-68a detailed geometries are given for all aircraft types and models analyzed in the present report together with the basic available wind tunnel test data

As the analysis of the material in this part of the report took place over a long period due to improved insight small differences may be found between some numbers in this part of the report and in the text which was written at a much later date. This refers in particular to some calculations concerning the endplate effect of the horizontal tailplane the conclusions on which were modified in a later stage. These differences have not affected however the overall conclusions.

Compilation of Wind Tunnel Test Data

On pages V-1 to V-35 a compilation is presented of raw wind tunnel test data together with some computed data of all the model tests discussed in this report.

Some final remarks

1. In the design of transport aircraft the emphasis is on transport capability and thus on performance aerodynamics. In the early phases of the design process the interest is therefore , apart from the fuselage interior arrangement and the loadability, primarily focused on the wing aerodynamics and the airframe-propulsion integration. The interest for the tail surfaces is usually limited to quick estimates of the required volume coefficients for horizontal and vertical tailplanes. This approach may have been adequate when centre-of gravity-ranges were limited and thrust –to-weight ratios were much lower than today but for a modern design with its large c.g.-range, high thrust-to-weight ratio and severe requirements for take-offs and landings with strong cross-winds this approach no longer suffices and a more detailed analysis is required already in an early design stage.The weight but in particular the size of tail surfaces today is such that, in combination with the ever-increasing design range and built-in development potential the role of tailplane sizing in the overall weight and drag prediction is more important than ever.

   For horizontal tail surfaces the analysis already goes further than estimating a volume coefficient. With the aid of so-called "scissor plots" the various design requirements for the horizontal tailplane are studied.
   The vertical tailplane however, notwithstanding the more complicated flow condition under which the fin has to operate because more airframe components ahead of the fin influence the local flow direction at the fin, has up to now not received the same attention. It is hoped that the present report will help to improve on this unsatisfactory situation.

2. The approach followed in the present report is mainly based on empirical data compilations. As the experience with the USAF Datcom and ESDU data sheets has shown the accuracy of predictions with the information provided in these publications sometimes leaves to be desired.
   When no wind tunnel data are available only this empirical approach provides the required sizing information. When wind tunnel data are available on a configuration with a reasonable degree of resemblance more accurate information is obtained when both configurations are analyzed with the data in this report and the difference is added to the data of the older model. Although the actual numbers in the present correlations may not always show the required accuracy the general trends seem reliable.

A summary of equations and graphs discussed in this report

Tail-off side force

$$\left(C_{y_\beta}\right)_{WFN} = \frac{S_{fus.cross}}{S_W} K_i \frac{2}{57.3} - 0.0001\Gamma + \left(\Delta C_{y_\beta}\right)_{FL} - 0.00175\, n_{nac} \text{ (nacelles on wing)}$$

$$- 0.00025\, n_{nac} \text{ (nacelles on fuselage)}$$

For K_i see page I-15 For $\left(\Delta C_{y_\beta}\right)_{FL}$ see page I-14 (1)

Tail-off yawing moment

$$(C_{n_\beta})_{WFN} = -K_N \frac{S_{B_S}}{S_W} \frac{l_B}{b_W} + \left(\Delta C_{n_\beta}\right)_{FL}$$

with K_N taken from page I-16 (2)

Lift curve slope of isolated lifting surfaces

On pages I-21 to I-24 lift curve slopes for various lifting surfaces are shown. (3)

Dorsal fins

On pages I-25 to I-34 a collection of available raw wind tunnel data and on page I-35 to I-38a collection of available dorsal fin aerodynamic data is presented. (4)

The endplate effect of the horizontal tailplane on the vertical tailplane

The endplate effect of the horizontal tailplane on the vertical tailplane can be determined with the aid of the graphs presented on page I-39 to I-45. (5)

For the average horizontal tailplane the effect of the tail lift on the endplate effect on the vertical tailplane can be expressed as :

$$K_{VH} = (K_{VH})_{\alpha_H=0}\left[1 - 0.014\left(\alpha_H + \alpha^*\right)\right]$$

(6)

Vertical - tailplane - fuselage sidewash

For estimating the tailplane-fuselage sidewash (1+ $\delta\sigma / \delta\beta$) q_V / q K_{FV} an average curve was drawn in the figure on page I-46. (7)

Sidewash due to wing-fuselage interference

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{h_W}\frac{q_V}{q}K_{FV} = -0.40\frac{h_W}{D_{f_{max}}}$$ For definition of h_W and $D_{f_{max}}$ see page I-19. (8)

Sidewash due to wing dihedral and wing sweep

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{\Gamma}\frac{q_V}{q}K_{FV} = +\left(110 + 50\frac{h_W}{D_{f_{max}}}\right)\left(\Delta C_{l_\beta}\right)_{\Gamma} \qquad (9)$$

Sidewash due to rolling moment due to sideslip

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{Cl\beta} = -0.50\left[\left(C_{l_\beta}\right)_{T-O} - \left(C_{l_\beta}\right)_{T-O,C_L=0}\right] \qquad (10)$$

Rolling moment due to sideslip

$$\left(C_{l_\beta}\right)_{T-O} = \left(\frac{C_{l_\beta}}{C_{LW}}\right)\frac{C_{LW}}{57.3} + \left(\frac{C_{l_\beta}}{\Gamma}\right)\Gamma - \left(0.042\frac{Z_W}{D_{fus_{max}}} + 0.0005\Gamma\right)\sqrt{A_w}\left(\frac{D_{fus_{max}}}{b_W}\right)^2 \qquad (11)$$

Lift dependent rolling moment due to sideslip

$$\left(\frac{C_{l_\beta}}{C_{L_W}}\right) = -\frac{1}{2}\left[\frac{3}{A_W(1+\lambda)} + y^*\left(\tan\Lambda_{c/4} - \frac{6}{A_W}\frac{1-\lambda}{1+\lambda}\right)\right] + 0.05$$ per rad (12)

Sidewash due to flap deflection to the landing position

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{FL,ldg} = -0.80\left(\frac{b_{FL}}{b_W} - 0.67\right) \qquad (13)$$

The effect of engine nacelles on the wing on sidewash

$$\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{NW} \approx 0 \text{ - - } 0.04$$ (page I-100 and I-101) (14)

The effect of rear-fuselage engine position on sidewash

Generalized curves for estimating the effect of the position of rear-fuselage engine nacelles on sidewash-due-to-sideslip at the vertical tailplane $\left(\Delta\frac{\delta\sigma}{\delta\beta}\right)_{NF}$ are given on page 56. (15)

Side force due to rudder deflection

$$(C_y)_{\delta_R} = C_{Y_{\delta_R}} x\delta_R = C_{L\alpha_V} xK_{FV} \frac{q_V}{q} xK_{VH} x\frac{c_{l\delta}}{c_{l\alpha}} x\frac{S_{V_R}}{S_W} x\delta_R$$

With maximum rudder deflection $(C_{Y_{max}})_{\delta_R} = 0.90xC_{Y_{\delta_R}} x\delta_{R_{max}}$ (16)

Yawing moment due to rudder deflection

$$(C_n)_{\delta_R} = C_{n_{\delta_R}} x\delta_R = C_{L\alpha_V} xK_{FV} \frac{q_V}{q} xK_{VH} x\frac{c_{l\delta}}{c_{l\alpha}} x\frac{S_{V_R}}{S_W} x\frac{l_{V(+DF)} + 0.30\overline{c_V}}{b_V} x\delta_R$$

With maximum rudder deflection $(C_{n_{max}})_{\delta_R} = 0.90xC_{n_{\delta_R}} x\delta_{R_{max}}$ (17)

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30. NACA WR L – 12 (NACA ARR L4E25) — Investigation of effect of sideslip on lateral stability characteristics.
I - Circular fuselage with variations in vertical – tail area and tail length with and without horizontal tail surface. --- May 1944.

31. NACA WR L – 8 (NACA ARR L5C13) — Investigation of effect of sideslip on lateral stability characteristics.
II - Rectangular midwing on circular fuselage with variations in vertical tail area and fuselage length with and without horizontal tail surface. ----- April 1945.

32. NACA WR L – 520 — Wind – tunnel investigation of effect of yaw on lateral – stability characteristics.
IV - Symmetrically tapered wing with a circular fuselage having a wedge – shaped rear and a vertical tail.

33. NACA TN 730 — Wind – tunnel investigation of effect of yaw on lateral – stability characteristics.
II - Rectangular N.A.C.A. 23012 wing with a circular fuselage and a fin.

34. NACA Report No. 705 — Wind – tunnel investigation of effect of interference on lateral – stability characteristics of four NACA 23012 wings, an elliptical and a circular fuselage and vertical fins.

35. NACA TN 804 — Wind – tunnel investigation of the effect of vertical position of the wing on the side flow in the region of the vertical tail.

36. NACA Report 1049 — Experimental investigation of the effect of vertical – tail size and length and of fuselage shape and length on the static lateral stability characteristics of a model with 45° sweptback wing and tail surfaces.

37. NACA TN 3135 — Investigation of mutual interference effects of several vertical – tail – fuselage configurations in sideslip.

38. NACA TN 3649 — Static longitudinal and lateral stability characteristics at low speed of unswept – midwing models having wings with an aspect ratio of 2, 4, or 6.

39. NACA TN 3857 — Experimental investigation at low speed of the effects of wing position on the static stability of models having fuselages of various cross sections and unswept and 45° sweptback surfaces.

40. NACA TN 2504 — Effects of wing position and horizontal tail position on the static stability characteristics of models with unswept and 45° sweptback surfaces with some reference to mutual interference.

41. NACA TN 3961 — Effects of fuselage nose length and a canopy on the static longitudinal and lateral stability characteristics of 45° sweptback airplane models having fuselages with square sections.

42. NACA TN 3551 — Experimental investigation at low speed of effects of fuselage cross section on static longitudinal and lateral stability characteristics of models having 0° and 45° sweptback surfaces.

43. NACA RM L56E29 — Investigation at high subsonic speeds of the static lateral and directional stability and tail – loads characteristics of a model having a highly tapered swept wing of aspect ratio 3 and two horizontal – tail positions.

44. NACA RM L55J25 — Wind – tunnel investigation at high subsonic speeds of some effects of fuselage cross – section shape and wing height on the static longitudinal and lateral stability characteristics of a model having a 45° swept wing

45. NACA RM L56B10 — Investigation at high subsonic speeds of the effect of horizontal – tail location on longitudinal and lateral stability characteristics of a complete model having a sweptback wing in a high location.

46. NACA RM L57I13 — Static lateral characteristics at high subsonic speeds of a complete airplane model with a highly tapered wing having the 0.80 chord line unswept and with several tail configurations.

47. NACA Report TR 1171 — Aerodynamic characteristics of an unswept tail assembly in sideslip.

48. NACA TN 3818 — Windtunnel investigation to determine the horizontal- and vertical –tail contribution to the static lateral stability characteristics of a complete-model swept-wing configurationat high subsonic speeds.

49. NACA TN 4077 — Static longitudinal and lateral stability characteristics at low speed of 45° sweptback-midwing models having wings with an aspect ratio of 2, 4, and 6.

50. NACA TN 4397 — Static longitudinal and lateral stability characteristics at low speed of 60° sweptback-midwing models having wings with an aspect ratio of 2, 4, and 6.

51. NACA RM L 53J19 — An experimental and theoretical investigation at high subsonic speeds of the effects of horizontal tail height on the aerodynamic characteristics in sideslip of an unswept. untapered tail assembly.

52. Fokker Report L–307–24 — Test results of the low-speed windtunnel model SKV – LST – 1.

53. Fokker Report L–307– 46 — Aerodynamic characteristics of the low-speed windtunnel model SKV – LST – 2 .

55. Fokker Report L–29–118 — Aerodynamic characteristics of a high-speed F-29 windtunnel model - Model 1 – 1.

56. Fokker Report L–29–135 — Aerodynamic characteristics of an H.S.T. model - Model 1 – 2.

57. Fokker Report L–29-128 — Aerodynamic characteristics of a high-speed F29 windtunnel model - Model 2-1

58. Fokker Report L–29-137 — Aerodynamic characteristics of an HST model - Model 2-2

59. Fokker Report L–29–150 — Aerodynamic characteristics of a high-speed F – 29 windtunnel model - Model 2 – 5.

60. Fokker Report L–29–181 — Aerodynamic characteristics of a high-speed F – 29 / MDF – 100 windtunnel model - Model 5 – 3.

61. NACA RM L53J19 — An experimental and theoretical investigation at high subsonic speeds of the effects of horizontal-tail height on the aerodynamic characteristics in sideslip of an unswept, tapered tail assembly.

62. NACA TN 3818 — Wind-tunnel investigation to determine the horizontal- and vertical-tail contributions to the static lateral stability characteristics of a complete-model swept-wing configuration at high subsonic speeds.

63. NACA TN 4397 — Static longitudinal and lateral stability characteristics at low speed of 60° sweptback-midwing models having wings with an aspect ratio of 2, 4, or 6.

64. Fokker Report L–307–56 — Aerodynamic characteristics of high-speed wind-tunnel model SKV - 6

65. Fokker Report L–307–70 — Aerodynamic characteristics of high-speed wind-tunnel model SKV – 6 – WN 1

66. NLR TR 68095 C — Low-speed wind tunnel tests on stretched version models of Fokker F-28 aircraft (model 8-4 and other), including a so- called “deep stall’ investigation.

67. NLR Report T.62 — Wind tunnel tests, carried out in the HST on the 1:20 scale models 1 and 2 of the Fokker F-28. Dec.1961 – May 1962

68. Fokker Report L-290-6 — Description of the wind tunnel models 1 and 2 for Fokker project 290.

69. Fokker Report L-28-322 — Aerodynamic characteristics of the P-332 related F-28 model, Model 15-3.

70. Fokker Report L-28-350 — Aerodynamic characteristics of the F-28 Mk 100 model, Model 15-10.

71. Fokker Report L-28-350 — Aerodynamic characteristics of, Model 18-5.

72. Fokker Report L-28-522 — Windtunnel test results of a F-28 Mk0070 configuration model, Model 15-24.

73. NLL Rapport A-1374 — F 27: Onderzoek van een vliegtuigmodel,schaal 1 : 15. IV. Rompweerstand; eigenschappen van verschillende horizontale en verticale staartvlakken, vliegeigenchappen in start, landing en kruisvlucht.

74. Fokker Report L-307-56 — Aerodynamic characteristics of high-speed wind-tunnel model SKV- 6.

75. Fokker Report L-307-70 — Aerodynamic characteristics of high-speed wind-tunnel model SKV- 6-WN 1.

76. Fokker Report L-28-153 — Loads on F-28 empennage as derived from pressure distribution measurements on model 6/2-1, 1965.

A New Vertical Tail Design Procedure for General Aviation and Turboprop Aircraft

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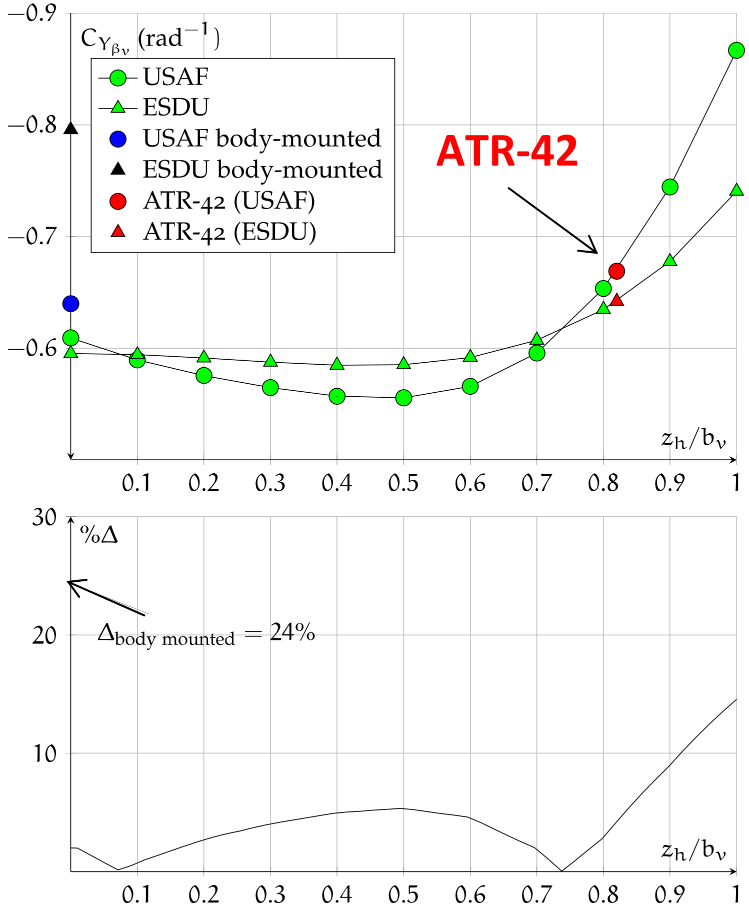
http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546414

Research motivation

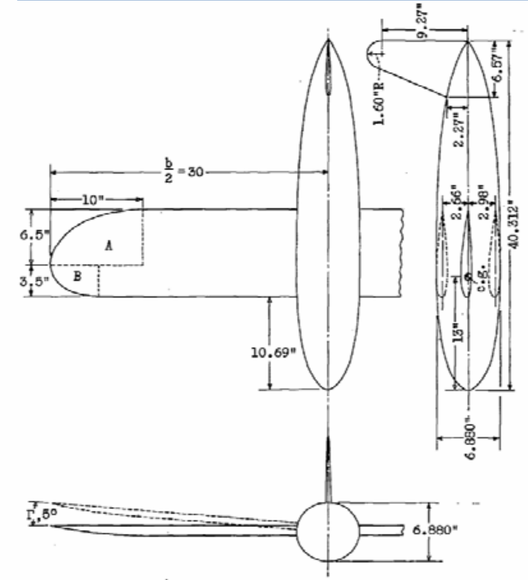
- Tail plane design needs an accurate determination of stability derivatives
- Semi-empirical methods are based on obsolete geometries (NACA '30s to '50s)
- Discrepancies between methods USAF DATCOM and ESDU
- Develop a new reliable procedure for turboprop and commuter airplanes

Effect of the horizontal stabilizer position

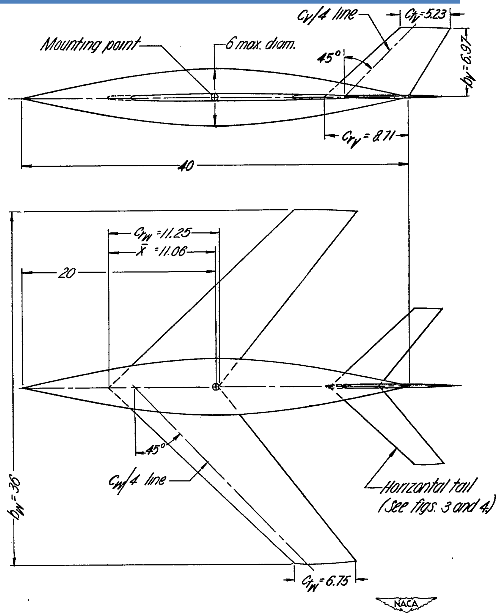


Research motivation (continued)

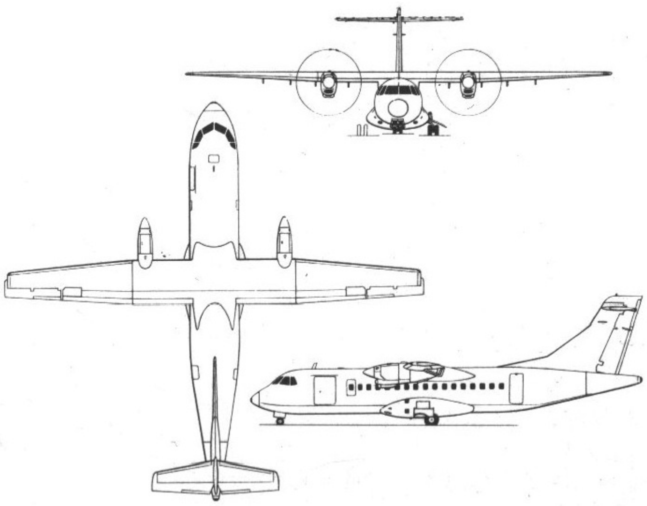
USAF DATCOM and ESDU procedures for the evaluation of directional static stability derivatives are mainly based on these geometries!



Geometry for the investigation on wing position in fuselage



Geometry for the investigation on tail-body interaction



Actual geometries ATR-42

USAF DATCOM approach

$$C_{L_\alpha} = \frac{2\pi A}{2 + \left[\frac{B^2 A^2}{\kappa^2}\left(1 + \frac{\tan^2 \Lambda_{c/2}}{B^2}\right) + 4\right]^{\frac{1}{2}}}$$

VT *effective* aspect ratio, sweep angle, Mach number

$$A_{v_{eff}} = \frac{A_{v(f)}}{A_v} A_v \left[1 + K_{vh}\left(\frac{A_{v(hf)}}{A_{v(f)}} - 1\right)\right]$$

$$C_{Y_\beta} = -k_v \, C_{L_{\alpha\, v}} \left(1 + \frac{d\sigma}{d\beta}\right) \eta_v \frac{S_v}{S}$$

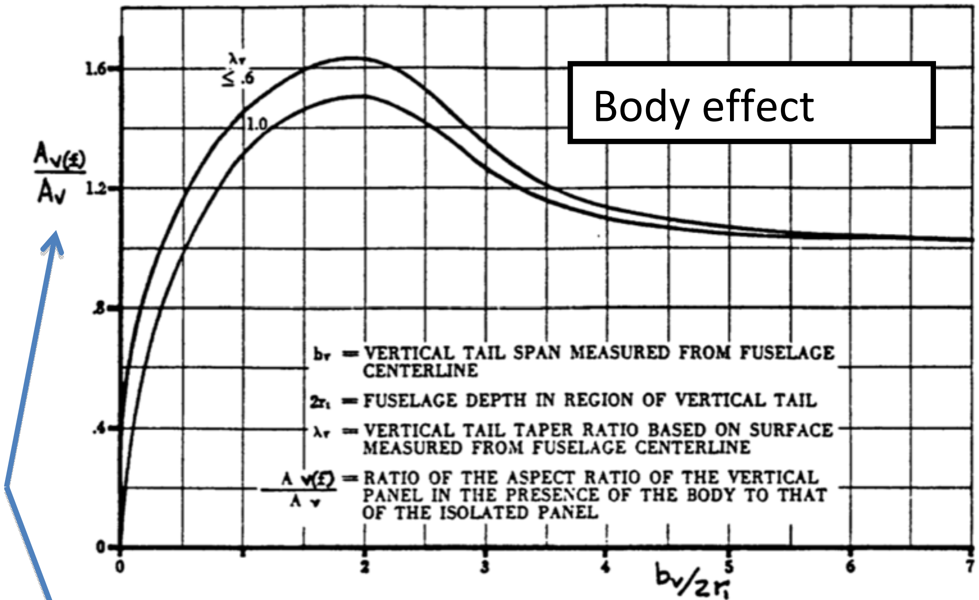
$$\left(1 + \frac{d\sigma}{d\beta}\right)\eta_v = \text{Sidewash (Wing effect)}$$

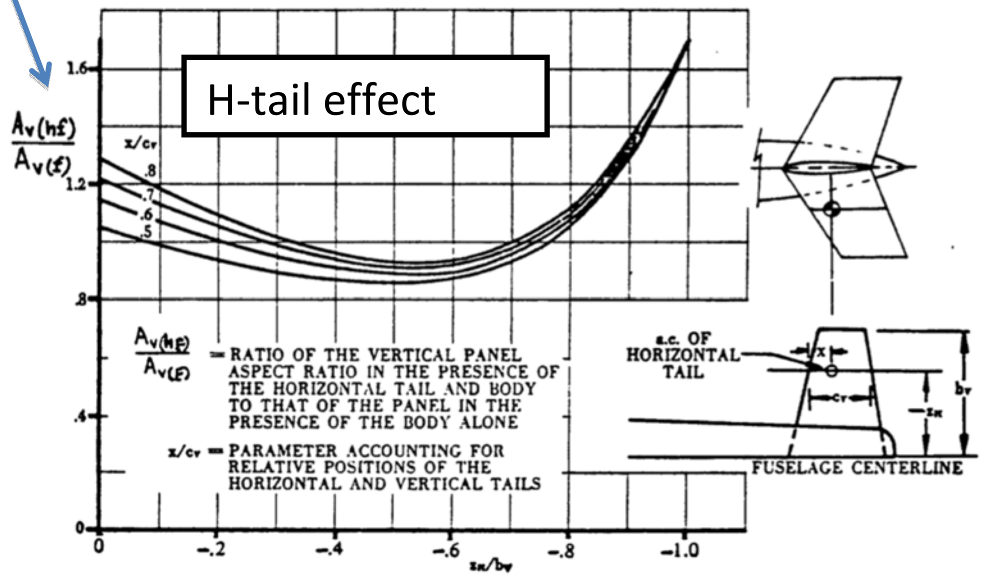
$$= 0.724 + 3.06\frac{S_v/S}{1+\cos\Lambda_{c/4}} + 0.4\frac{z_w}{z_f} + 0.009A$$

TProp values (ATR-72):
Sv/S = 0.25, A = 12

High wing = 1.04

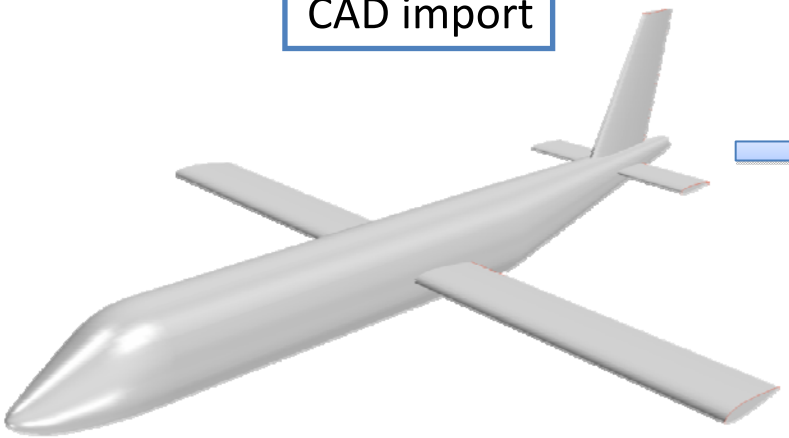
Low wing = 1.44



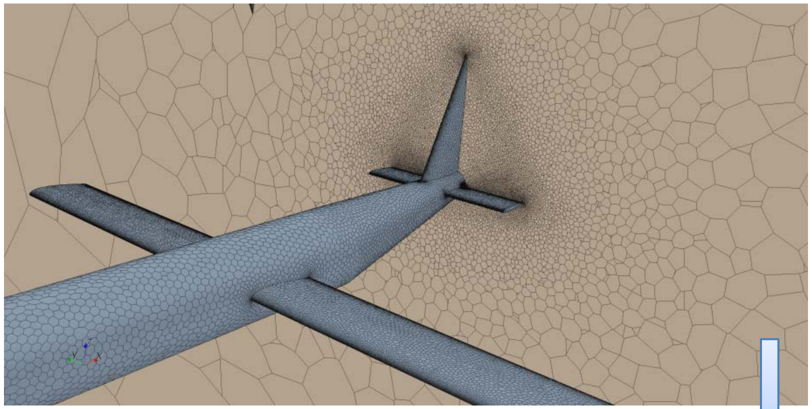


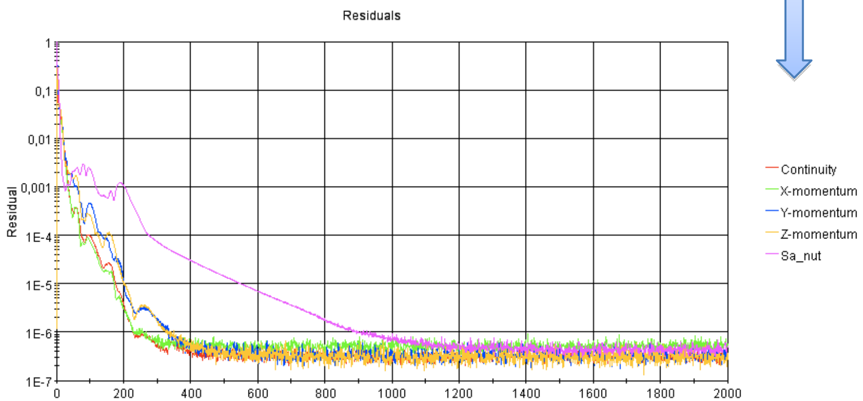
Star-CCM+

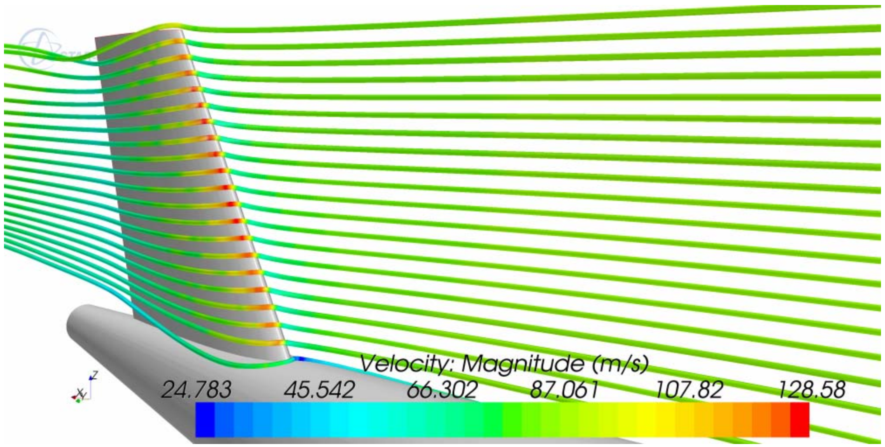
CAD import



Mesh generation



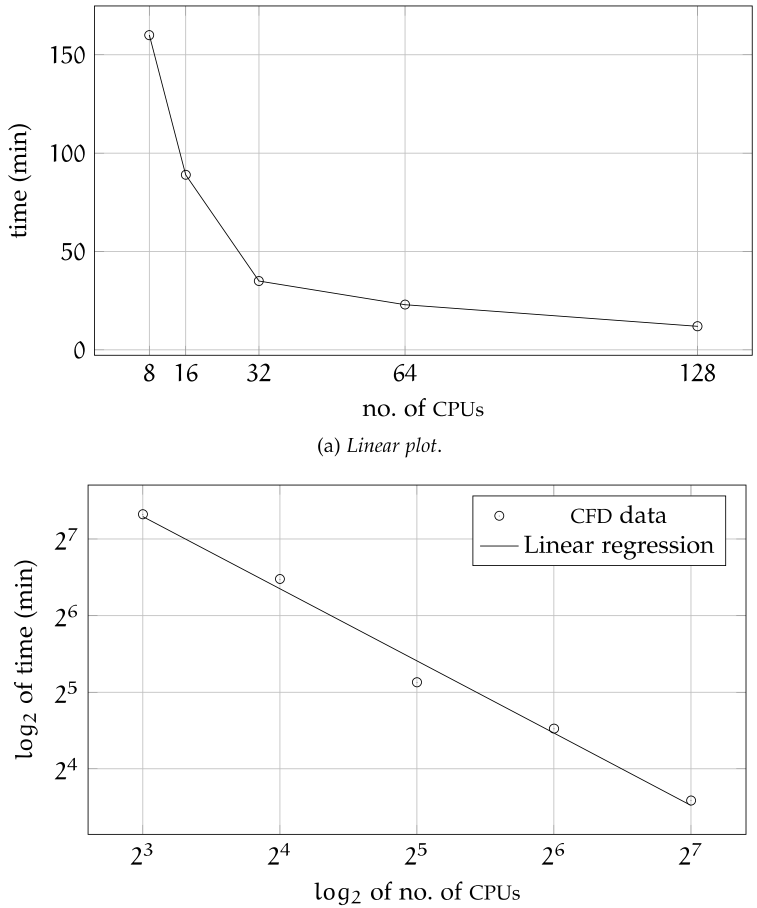




Post-process

Analysis

Computing Grid

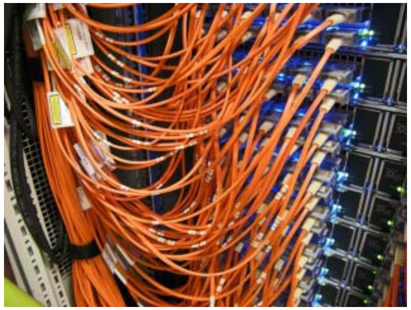


(a) *Linear plot*.

(b) *Logarithmic plot*.

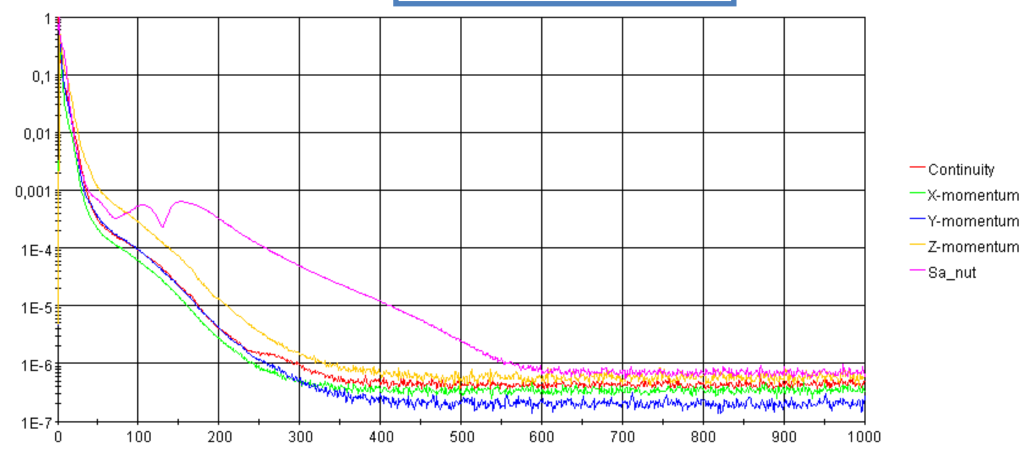
SCoPE

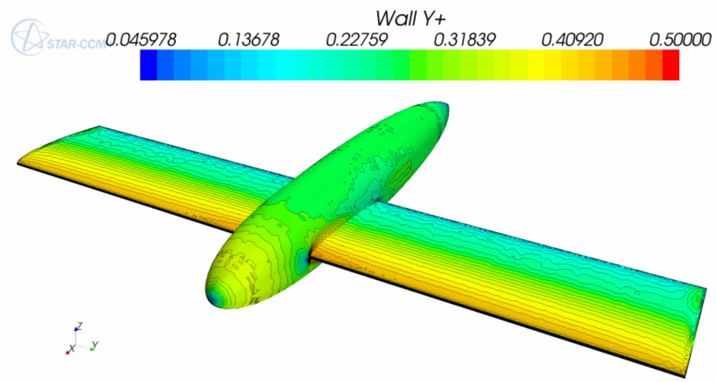
- University's cluster grid
- Up to 128 CPUs for a single run
- Advice: 1 CPU every 250000 cells
- CPU time (no mesh generation):
  - minutes for partial configurations
  - hours for complete airplane

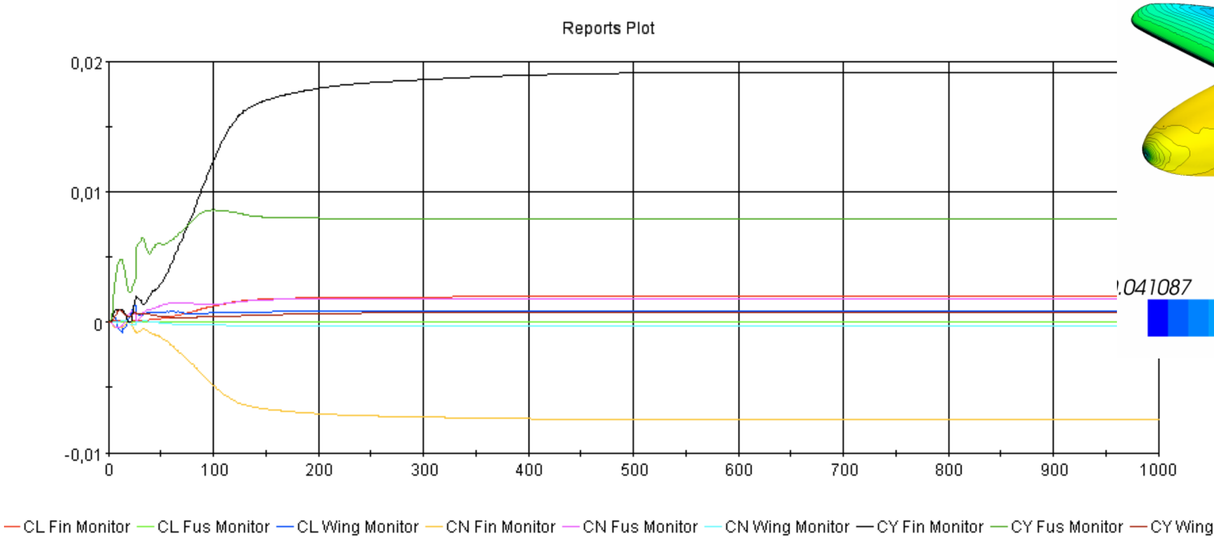


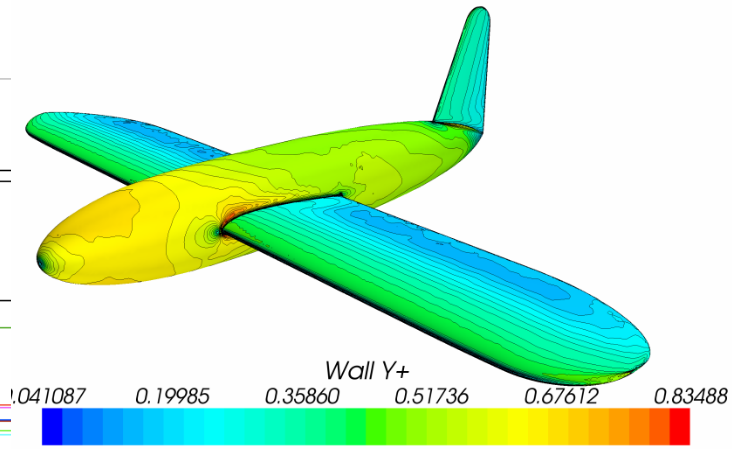
Convergence

NACA Test cases





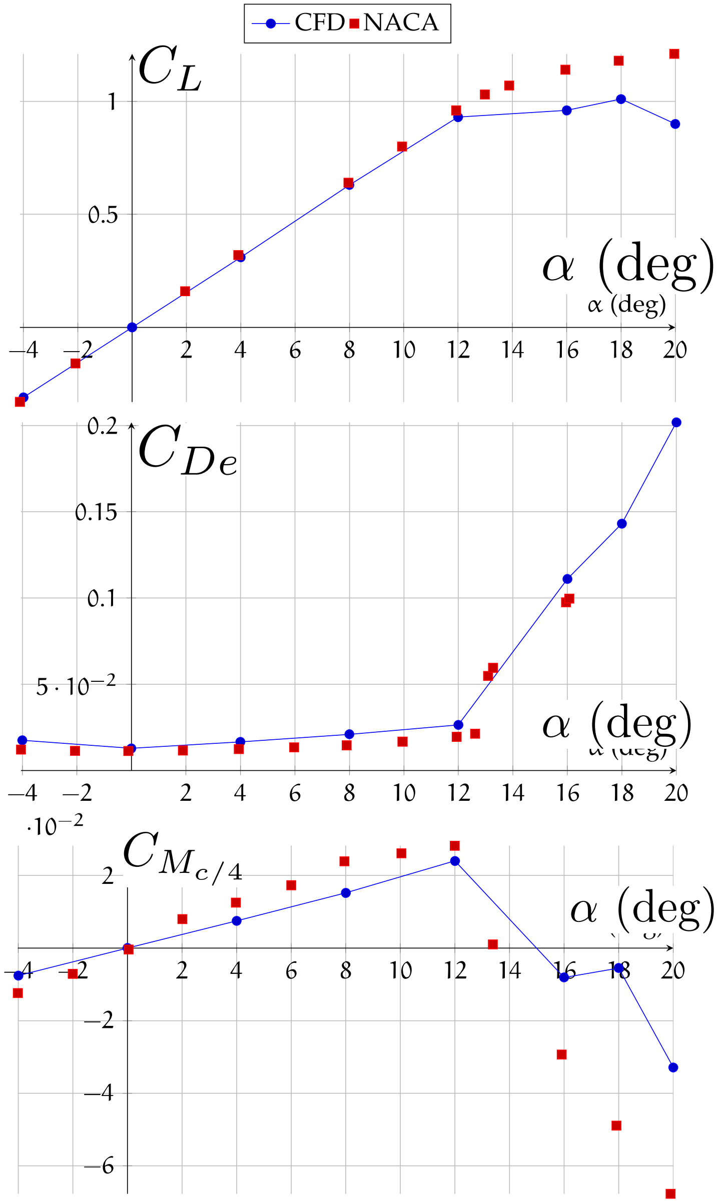


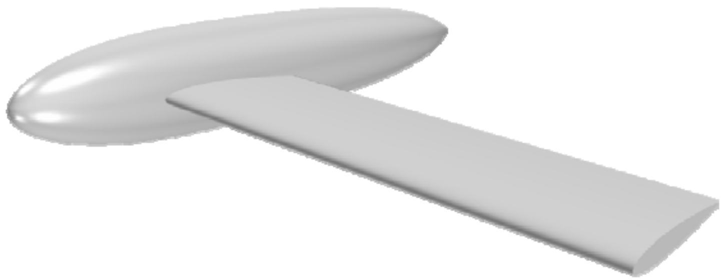


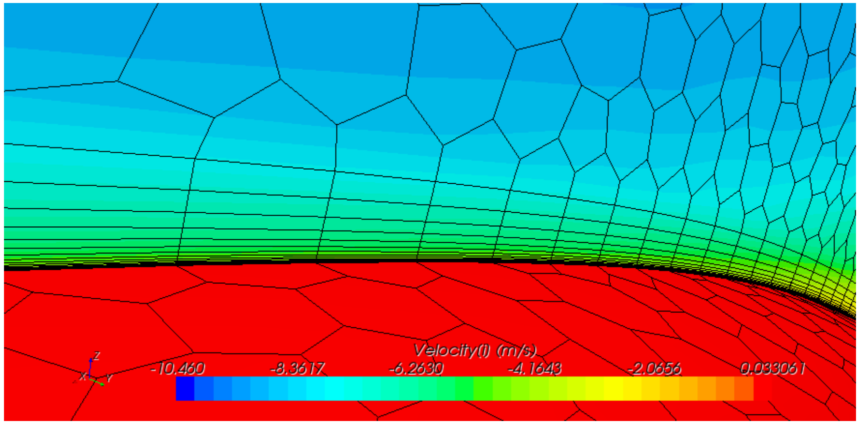
Check of convergence

1. Residuals
2. Aerodynamic coefficients
3. Wall y^+

Test cases – NACA 540





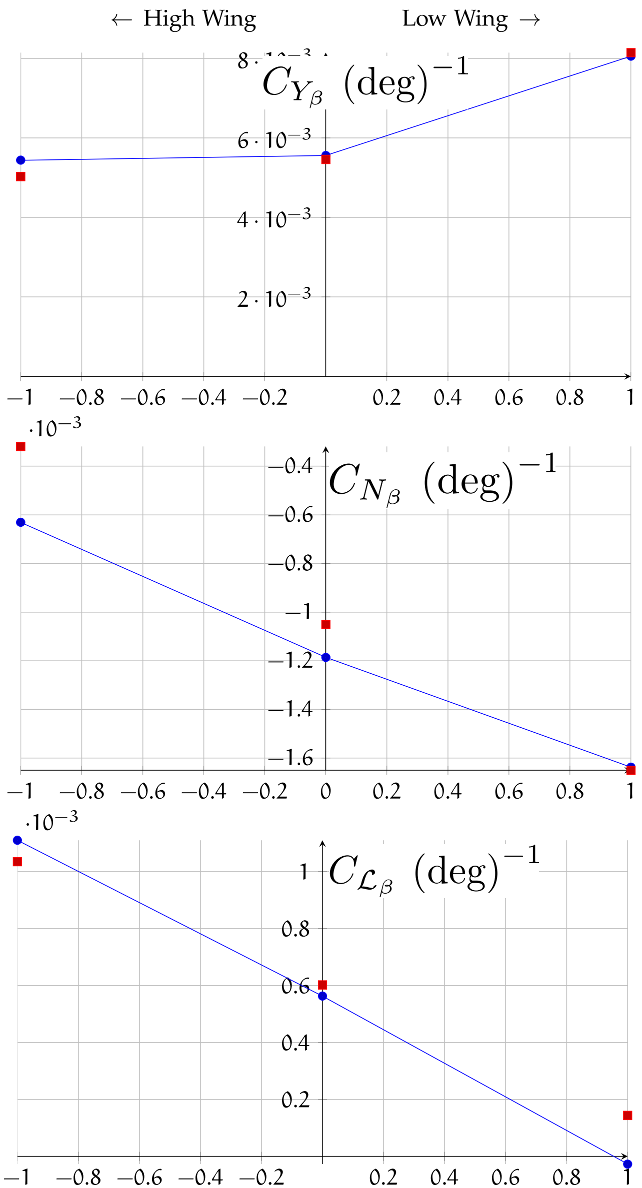


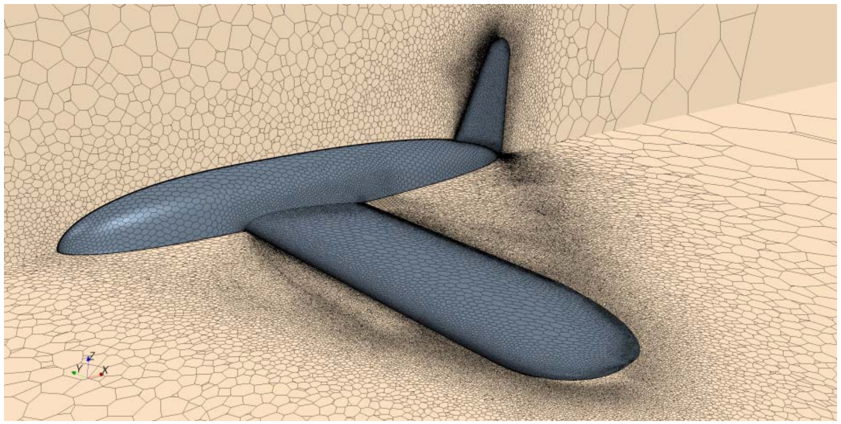
Longitudinal test case

$A = 6 \quad Re = 3\,100\,000$

no. of cells $\approx 1\,000\,000$

Test cases – NACA 730



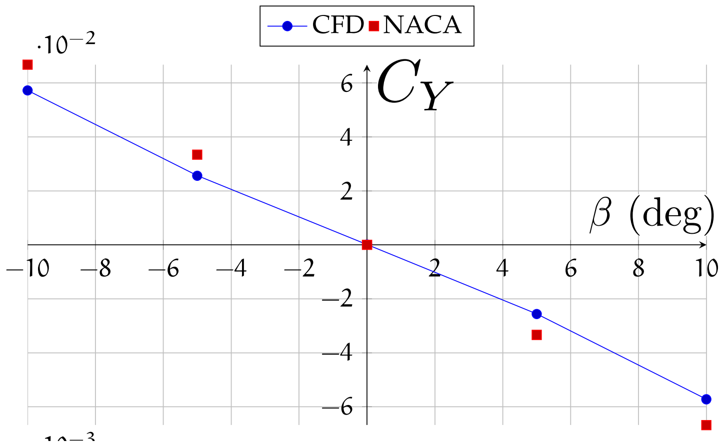


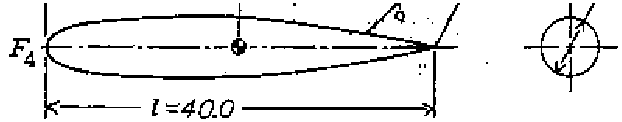
Directional test case

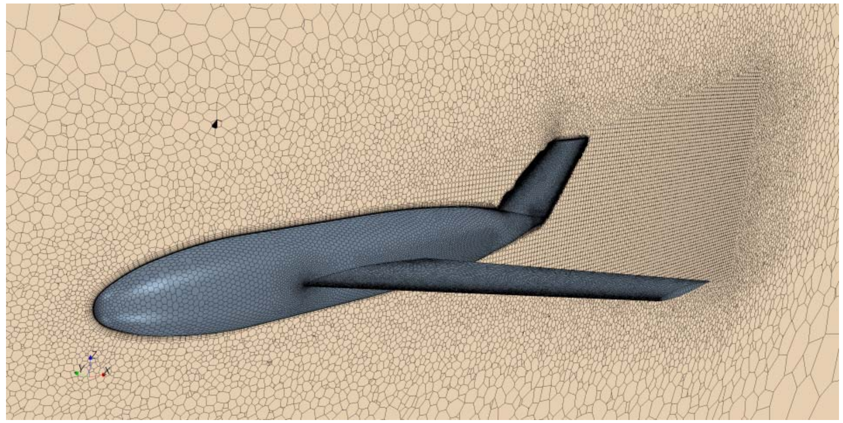
$\alpha = 0^\circ \quad \beta = 5^\circ \quad Re = 609\,000$

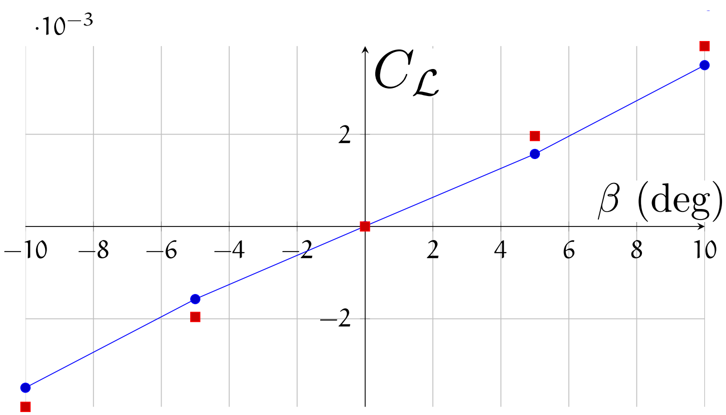
no. of cells $\approx 5\,000\,000$

Test cases – NACA 1049









Directional test case

$\alpha = 0^\circ \quad \beta = -10^\circ$ to 10°

$Re = 710\,000$

no. of cells $\approx 4\,000\,000$

Development of a new approach

Based on the aerodynamic interference effects highlighted by semi-empirical methodologies, for a typical configuration, the same effects have been investigated through a parametric CFD analysis.

Analysis of:

- Isolated vertical tail (effect of the VT aspect ratio and sweep angle)
- VT-body interference (effect of VT/body relative size)
- Wing sidewash effects (difference between high and low wing position)
- Horizontal tail effects (tailplane position, i.e. body-mounted vs. T-tail, and size)
- Separate effects estimation for control derivative

Many configurations have been investigated with a modular model, to provide a new approach to preliminary tailplane design.

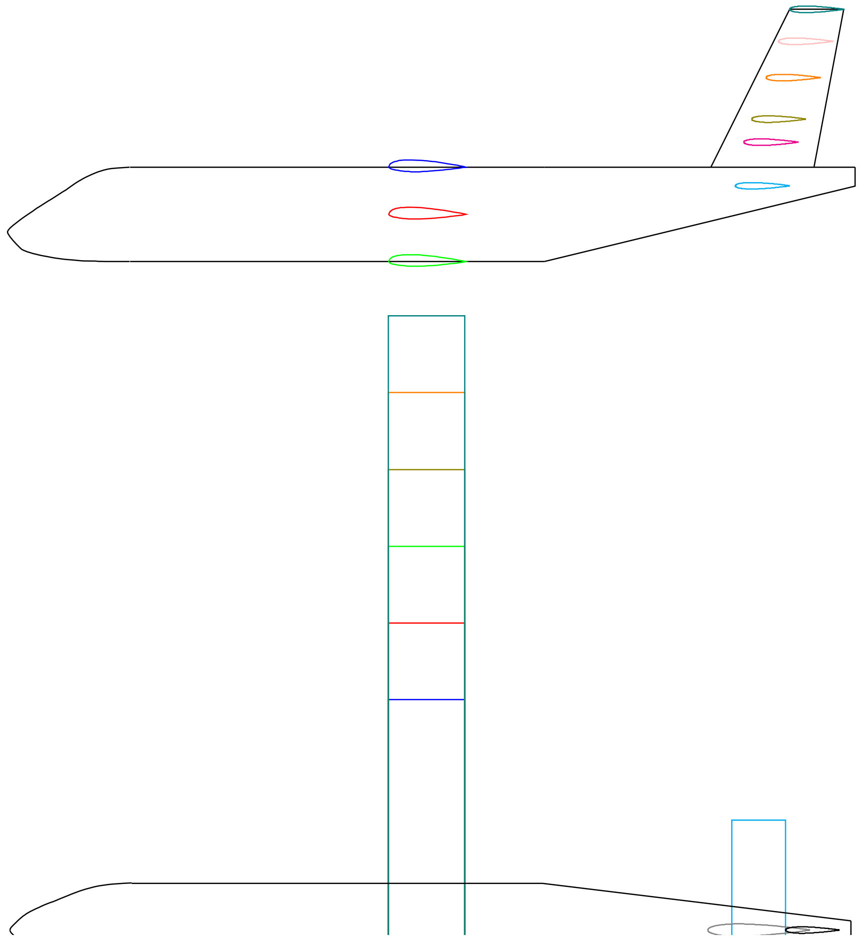


Table 8
Fuselage parameters.

	l_f/d_f	l_n/l_f	l_c/l_f	x_{wLE}/l_f
ATR-72	10.3	1.3	3.2	0.41
NGTP-5	9	1.3	3.3	0.47
CFD model	9	1.3	3.3	0.45

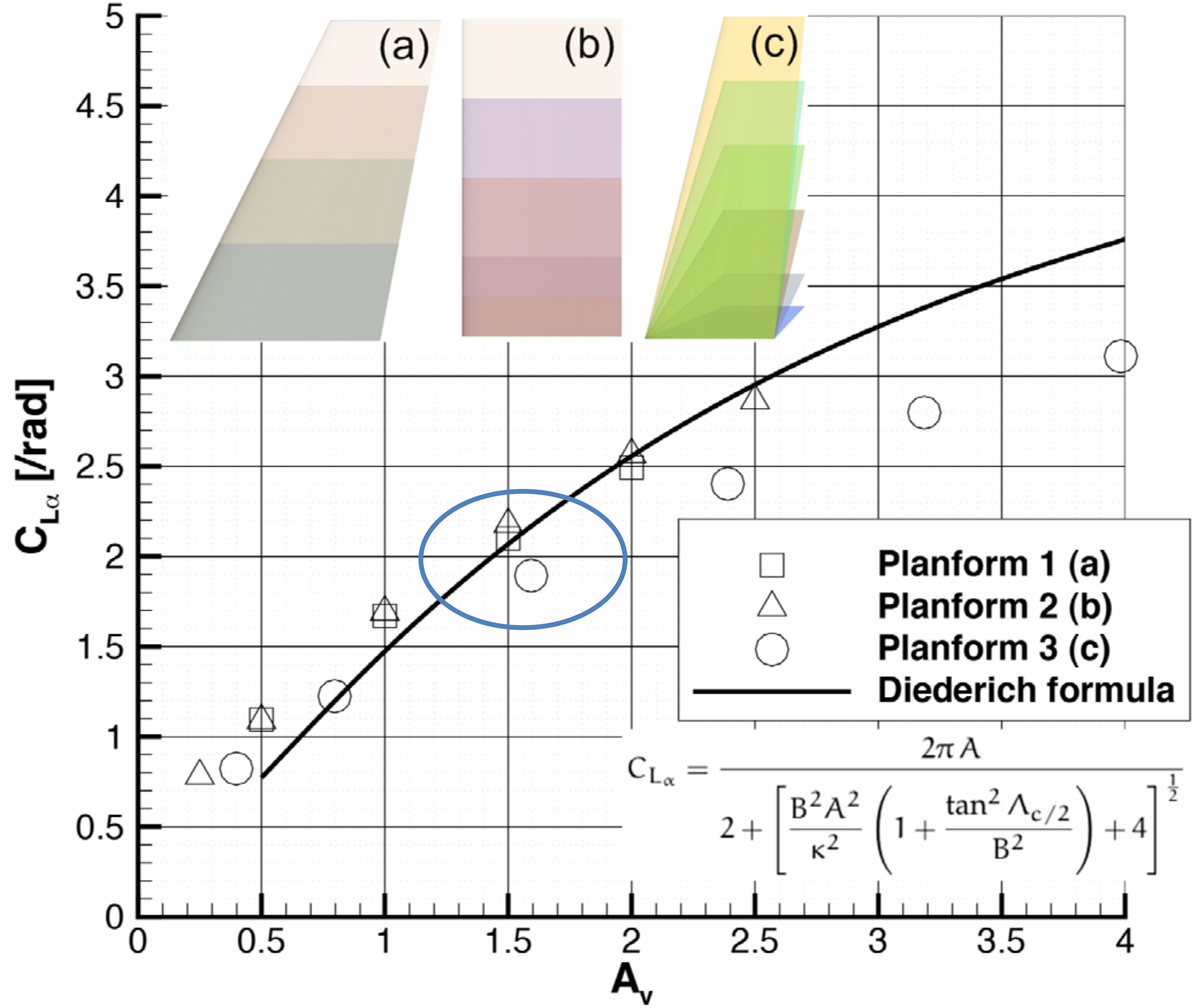
Table 9
Vertical tailplane parameters.

	A_v	λ_v	Λ_{vLE}	Λ_{vTE}	S_v/S	x_{vLE}/l_f	V_v
ATR-72	1.56	0.61	32°	17°	0.20	0.83	0.098
NGTP-5	1.43	0.63	29°	15°	0.24	0.85	0.110
CFD model	Variable	Variable	30°	15°	Variable	Variable	Variable

Table 10
Horizontal tailplane parameters.

	A_h	λ_h	Λ_{hLE}	Λ_{hTE}	S_h/S	x_{hLE}/l_f	V_h
ATR-72	4.1	n.a.	n.a.	n.a.	0.18	n.a.	0.19
NGTP-5	4.1	n.a.	n.a.	n.a.	0.25	n.a.	0.19
CFD model	4.1	0	0°	0°	Variable	Variable	Variable

Vertical tail planform effects on lift curve slope



Typical values

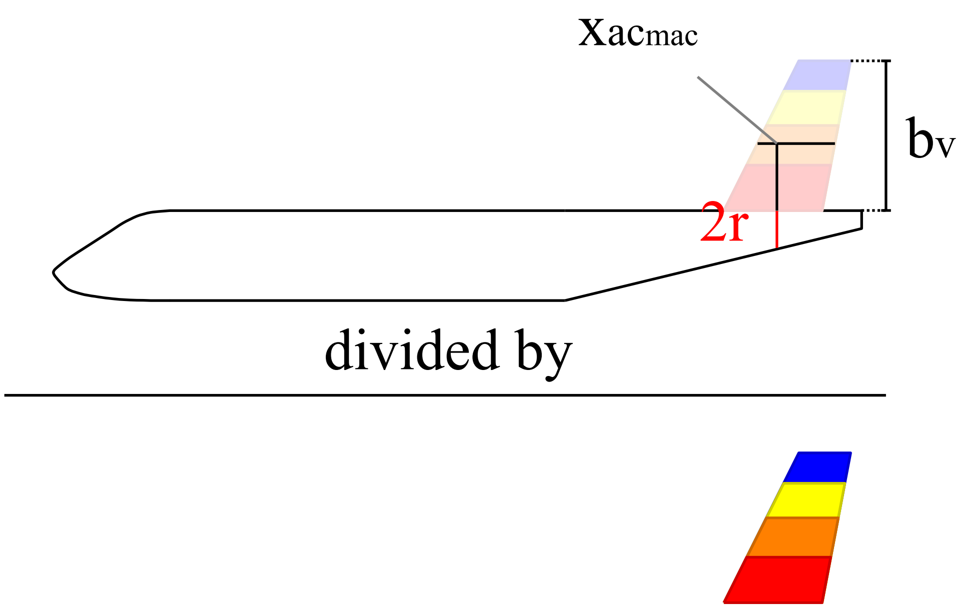
Av = 1.5

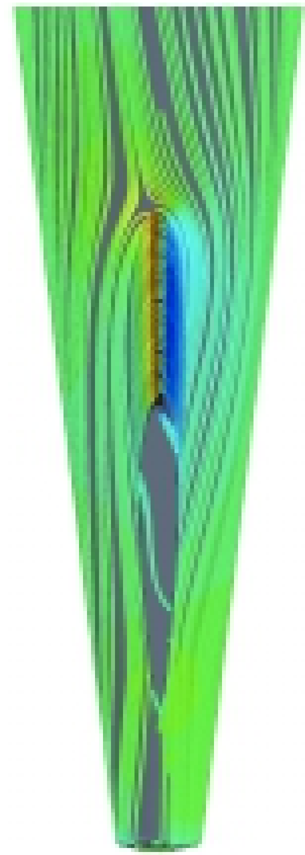
Λv = 30°

dCLα/dAv ≈ 1

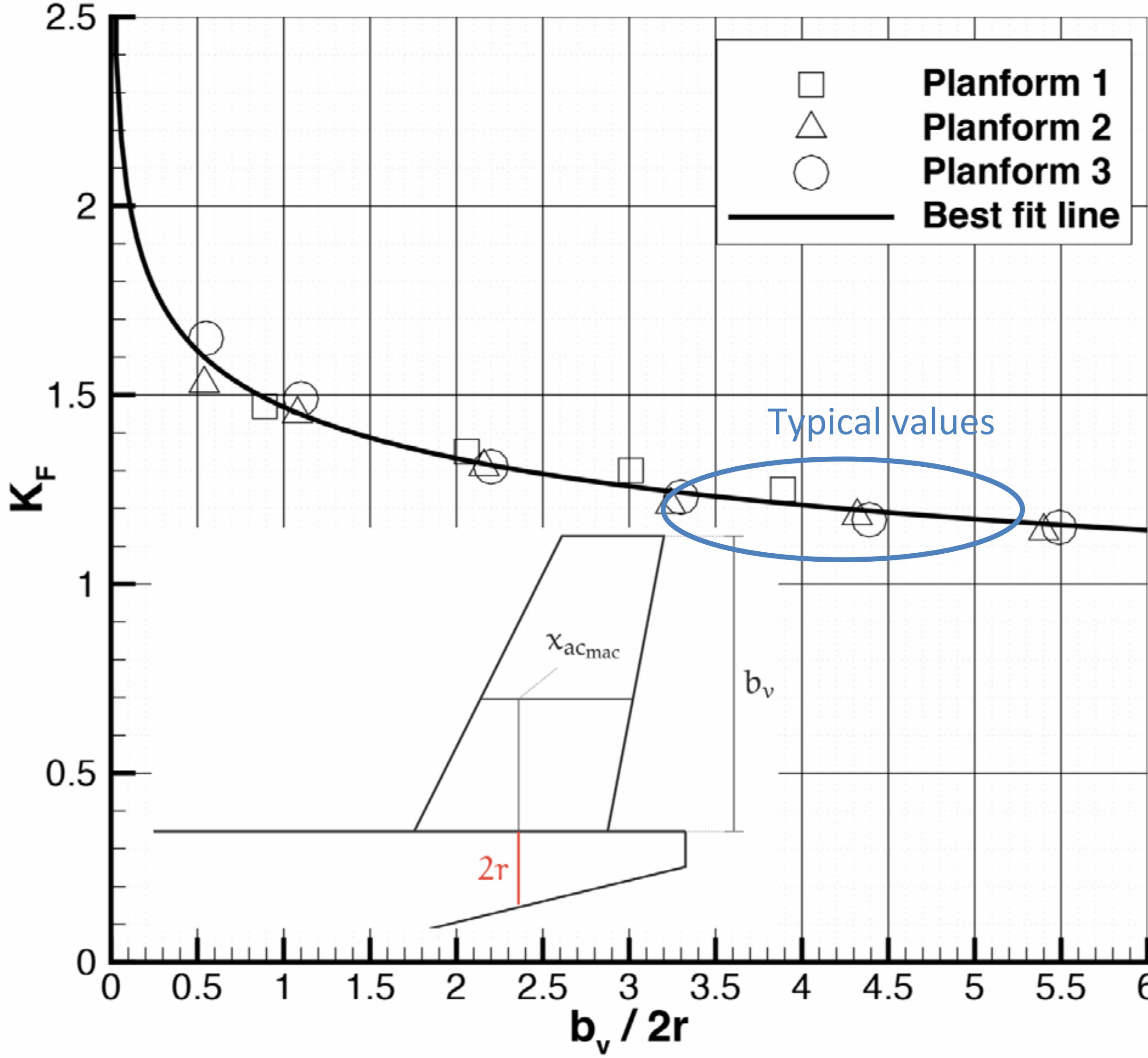
Configurations involved in the fuselage-tail investigation

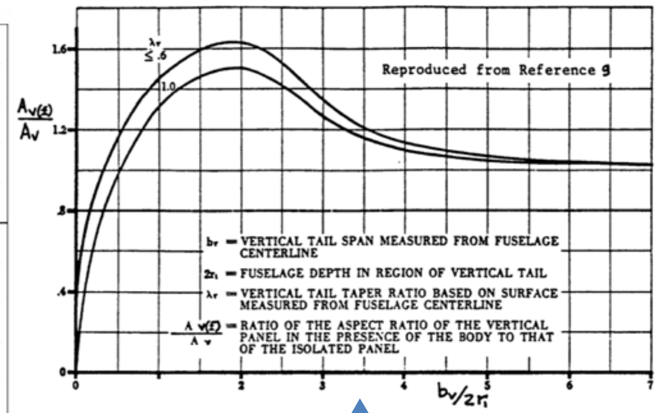
The effect of the fuselage is measured by the ratio between the vertical tail sideforce coefficients of the body-vertical configurations and those of the same vertical tail planforms previously analysed.





Fuselage effect K_F

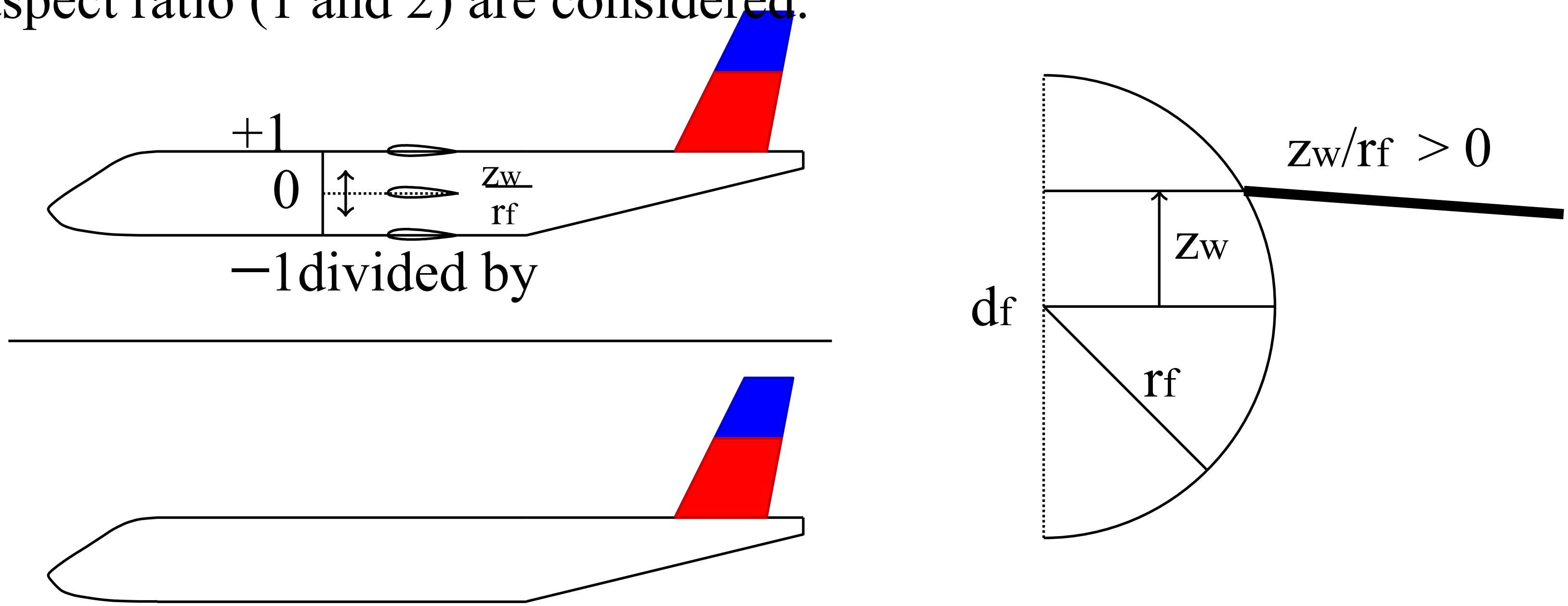




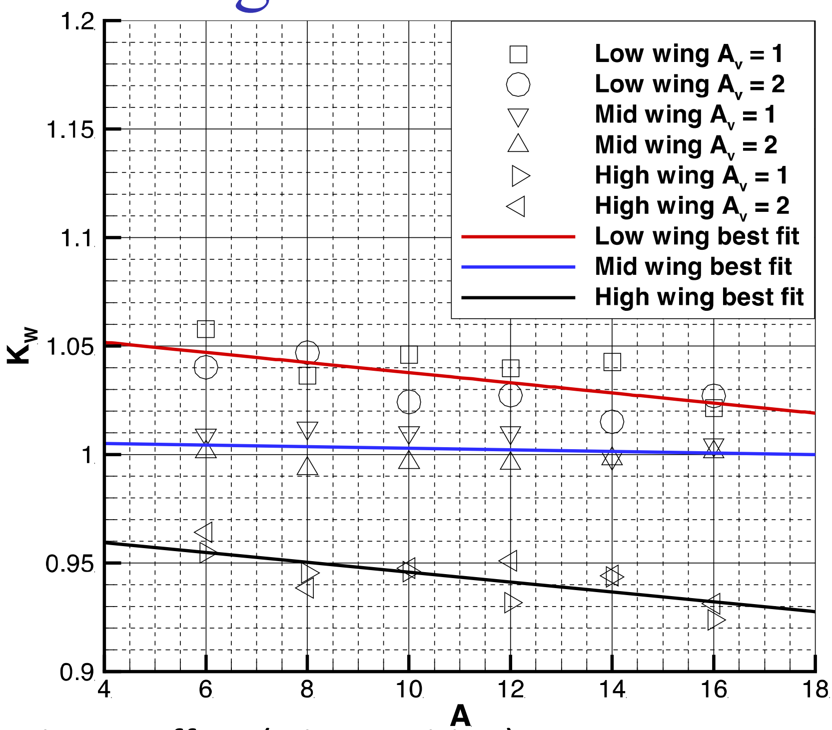
USAF DATCOM

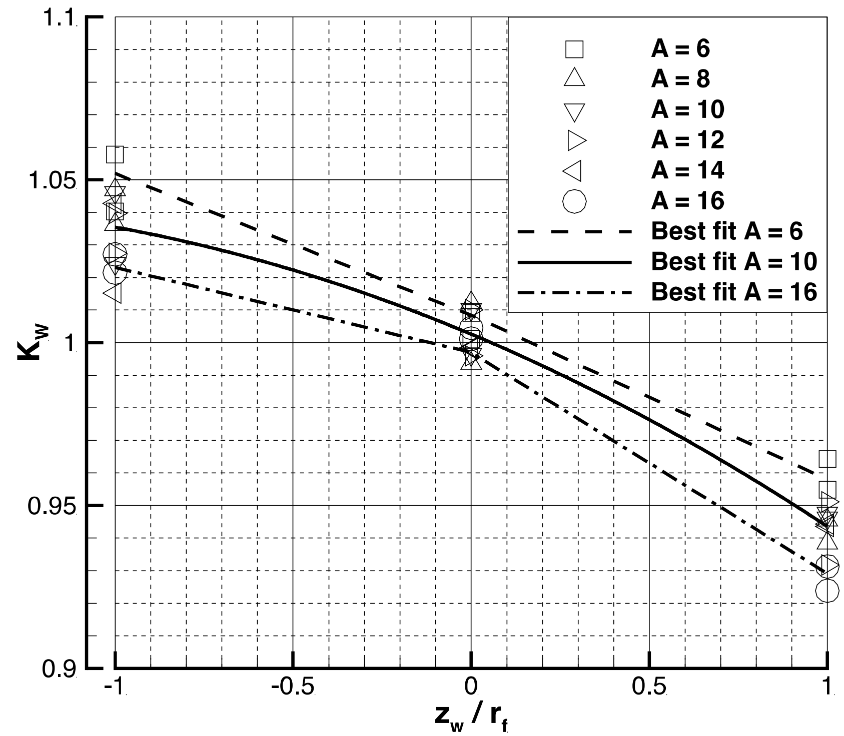
Configurations involved in the wing-body-tail investigation

Straight wings of different aspect ratio (6 to 16) in three fuselage positions (high, mid and low) have been considered. Two vertical tailplane aspect ratio (1 and 2) are considered.



Wing effect Kw

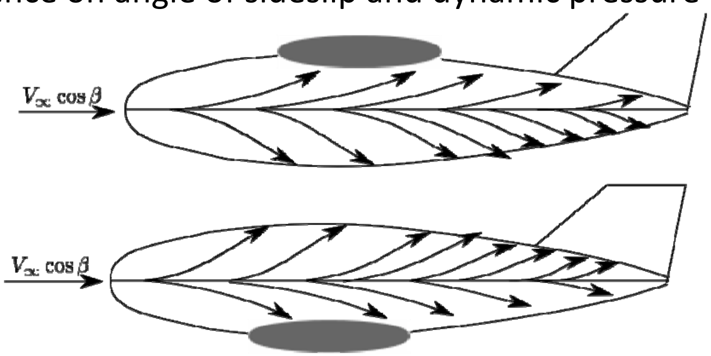


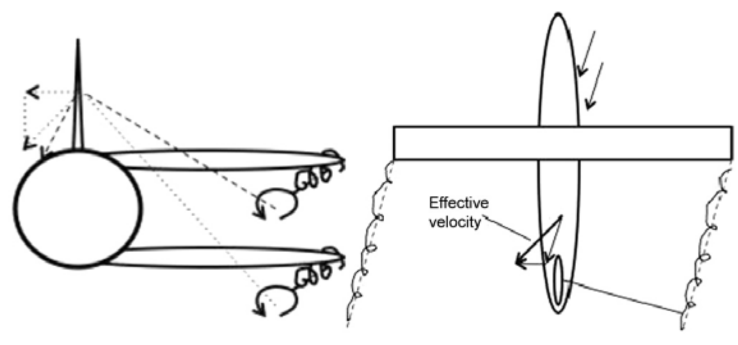


Primary effect (wing position)

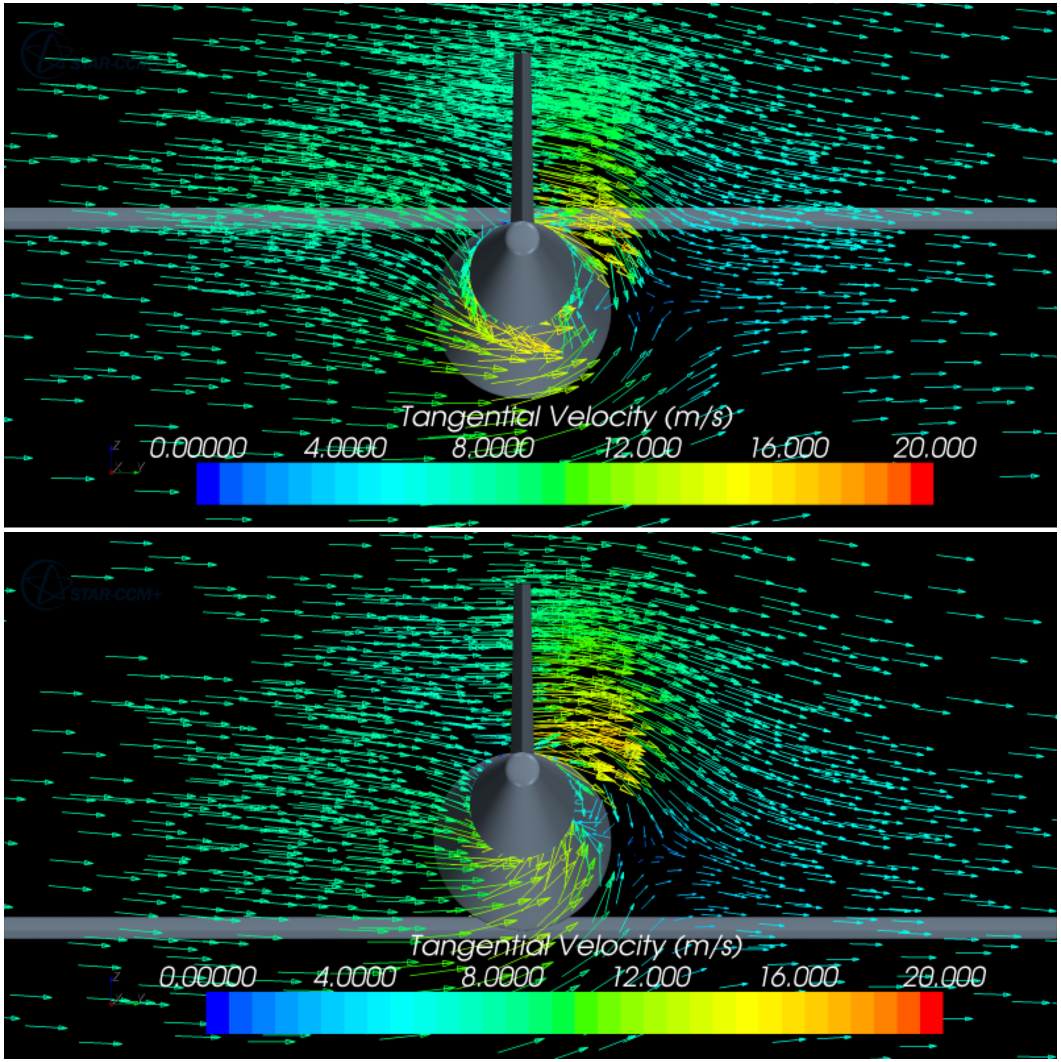
Influence on angle of sideslip and dynamic pressure at VT root

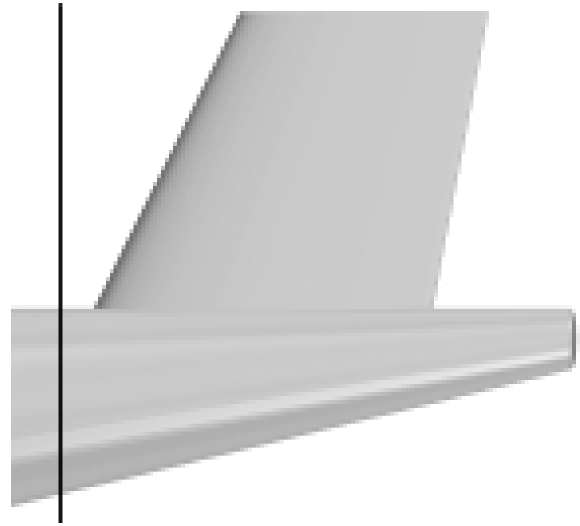
Secondary effect (wing AR)





Wing-body sidewash





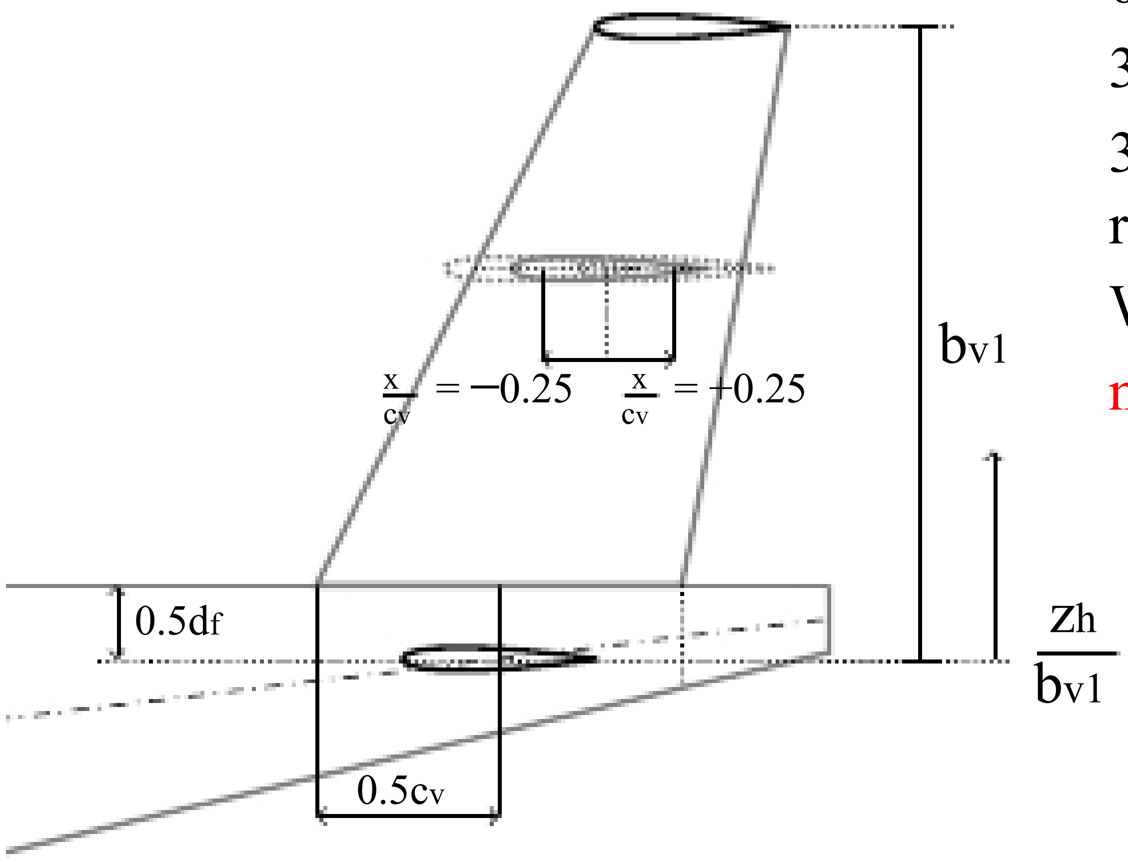
A = 10

A_v = 1

β = 5°

Cross-wind direction →

Horizontal tailplane effect



Configurations analysed

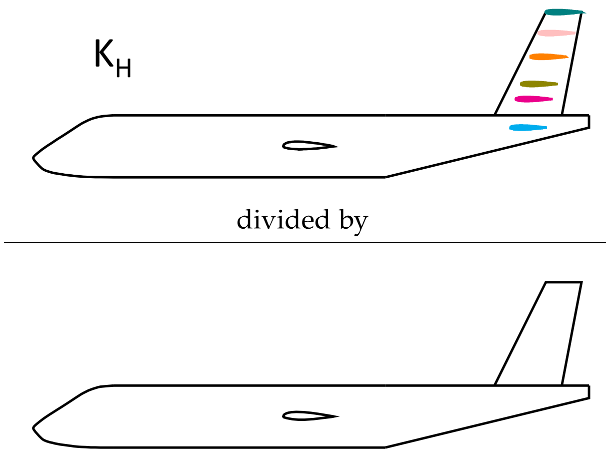
1 straight horizontal tail

6 spanwise positions

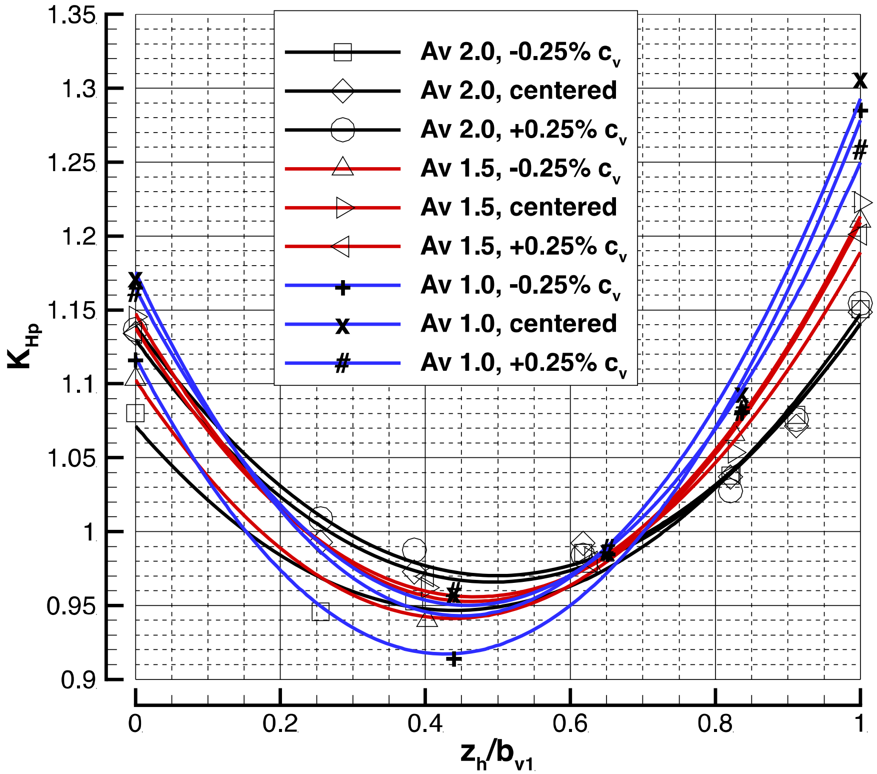
3 chordwise positions

3 vertical tail's aspect ratios

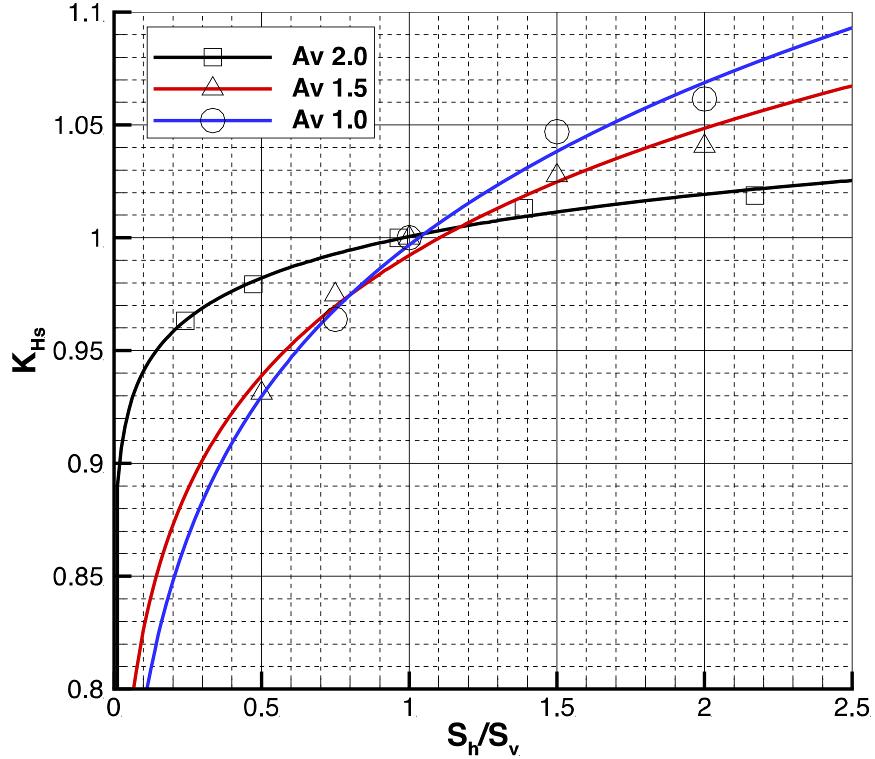
Wing position (high/low) is not important (verified)



Horizontal tailplane effect KH



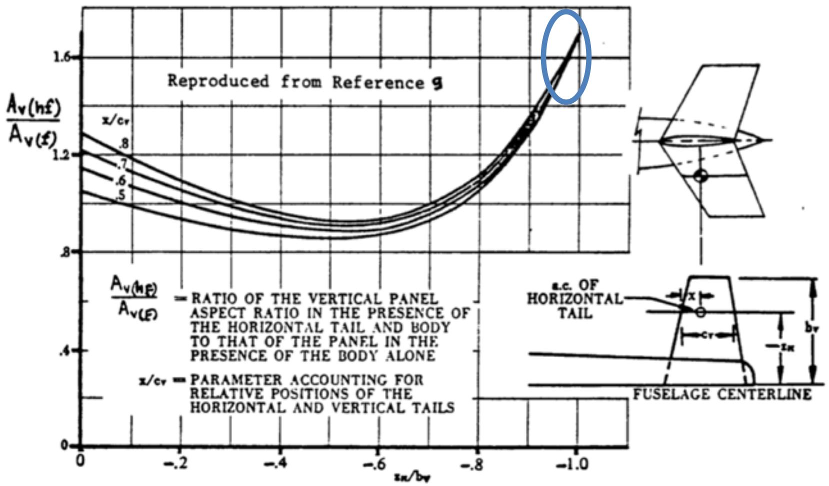
Position effect



Size effect

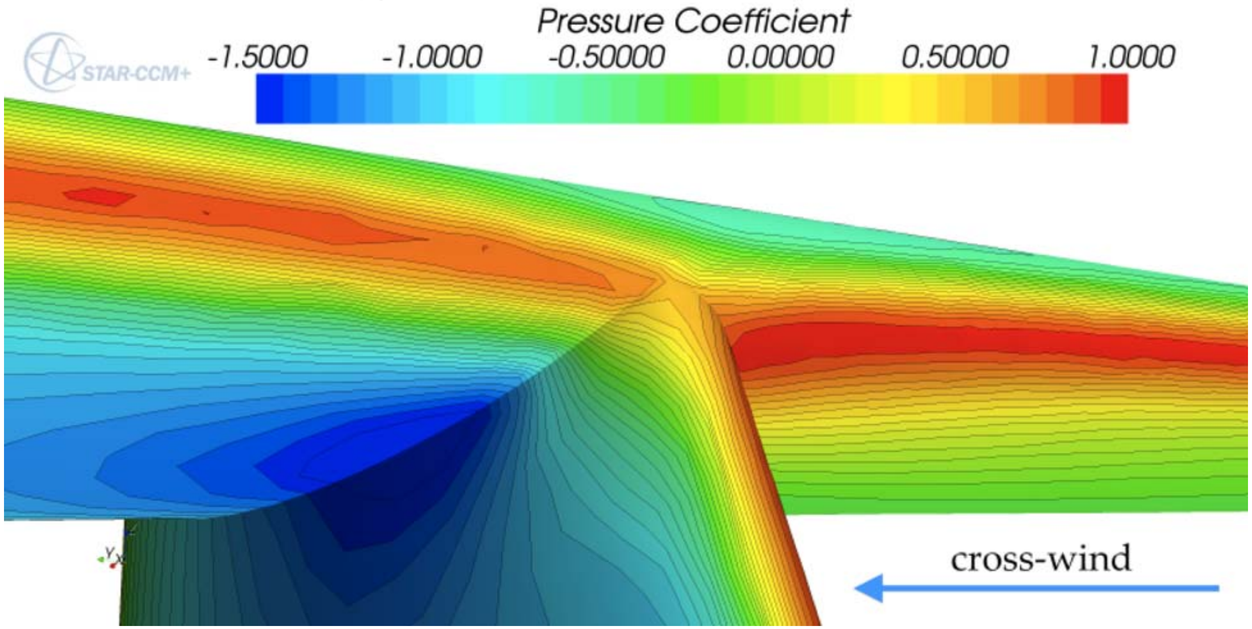
$$K_H = 1 + K_{Hs}\left(K_{Hp} - 1\right)$$

T-tail configuration



A_v	C_{Y_v}(BVH)	C_{Y_v}(BV)	ratio
1.0	0.0253	0.0194	1.30
1.5	0.0394	0.0322	1.22
2.0	0.0521	0.0451	1.15

In this approach the increase of VT effectiveness for T-tail configuration is much lower than USAF DATCOM prediction.



Directional control derivative

$$C_{Y_v} = C_{Y_{\beta_v}} \beta + C_{Y_{\delta_r}} \delta_r$$

$$C_{n_{\delta_r}} = -C_{Y_{\delta_r}} (l_v \cos\alpha + z_v \sin\alpha) / b$$

$$C_{Y_\beta} = -k_v \, C_{L_{\alpha v}} \left(1 + \frac{d\sigma}{d\beta}\right) \eta_v \frac{S_v}{S}$$

$$C_{Y_{\delta_r}} = C_{L_{\alpha_v}} (A_{veff}) \tau K_\eta \frac{S_v}{S}$$

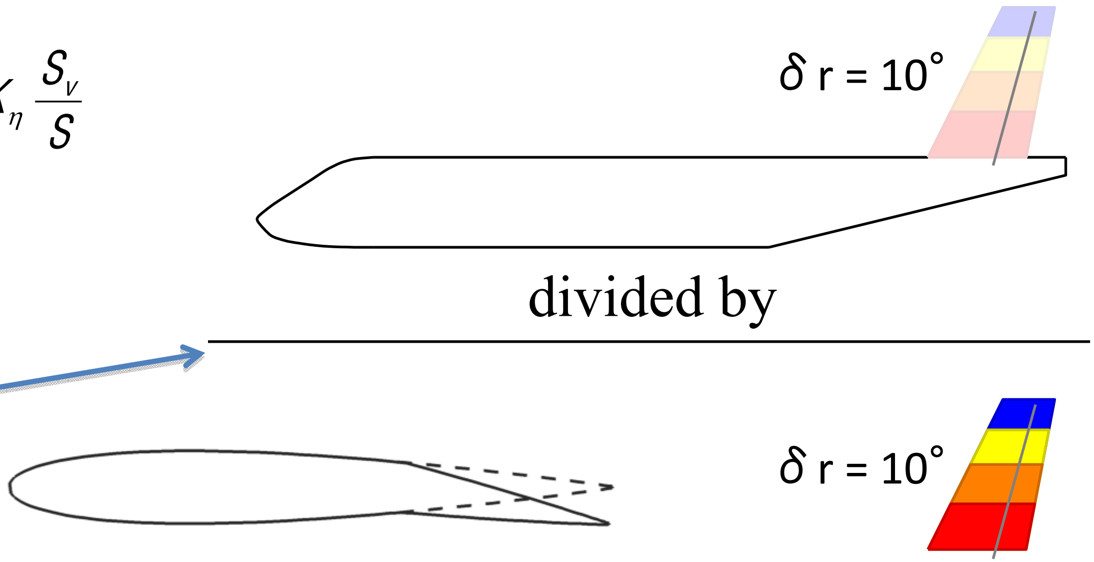
USAF DATCOM

The aerodynamic interference effects due to fuselage and horizontal tail are considered to be the same for both derivatives (stability and control).

Our approach:

$C_{Y \beta v} = f(K_F, K_W, K_H)$

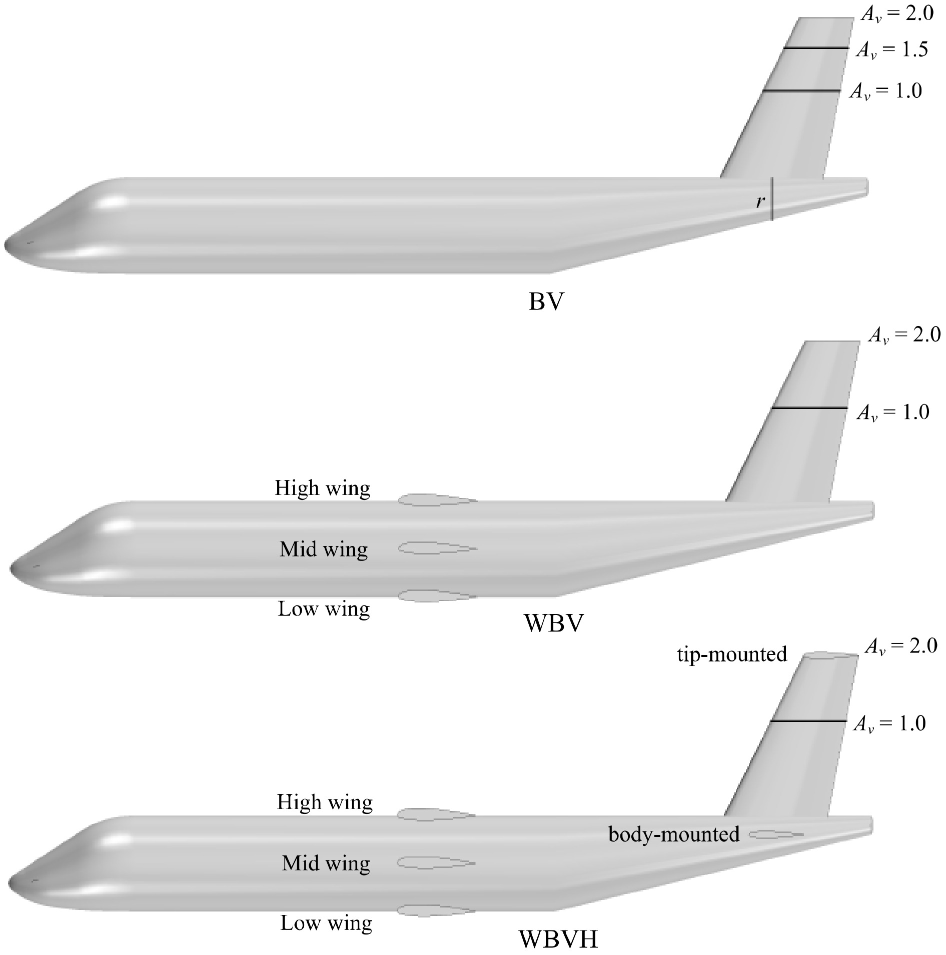
$C_{Y \delta r} = f(K_{\delta r})$

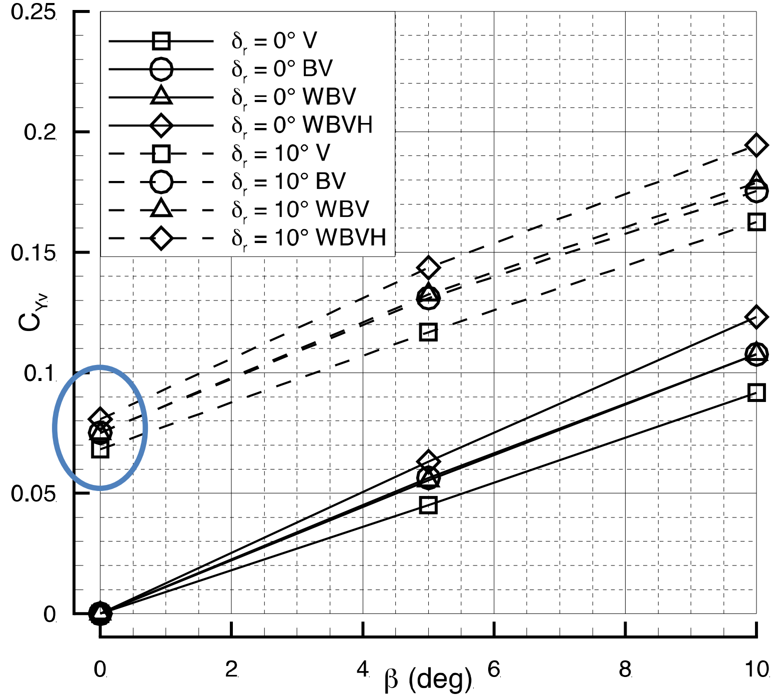


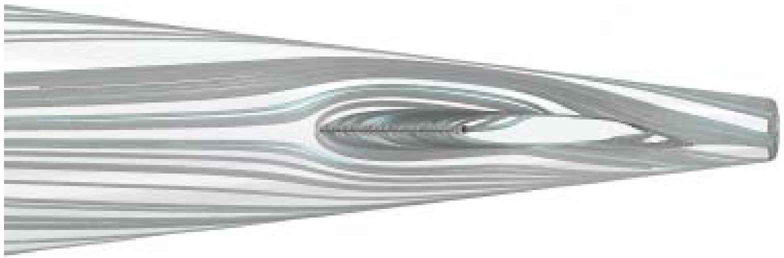
Investigation on rudder deflection's effects

A_v	$b_v/2r$	C_{Y_V}(V)	C_{Y_V}(BV)	BV/V
1.0	2.06	0.0303	0.0348	1.15
1.5	3.01	0.0505	0.0563	1.12
2.0	3.89	0.0682	0.0751	1.10

$\beta = 0°$
$\delta r = 10°$







Vertical Tail Stability and Control

Evaluation of the vertical tail contribution to aircraft directional stability and control. Developed with more than 200 CFD simulations. Valid in subsonic incompressible flow at low angles of incidence and sideslip.

$$C_{Y_v} = C_{Y_{\beta_v}} \beta + C_{Y_{\delta_r}} \delta_r$$

where

$C_{Y\beta v}$	directional stability derivative,
β	sideslip angle,
$C_{Y\delta r}$	directional control derivative,
δ_r	rudder’s deflection angle.

Directional stability

The interference effects previously evaluated are now combined.

$$C_{Y_{\beta_V}} = K_F\, K_W\, K_H\, C_{L_{\alpha_V}} \frac{S_V}{S}$$

where

K_F	fuselage effect,
K_W	wing effect,
$K_H = 1 + K_{Hs}\,(K_{Hp} - 1)$	horizontal tailplane effect,
K_{Hp}	horizontal tailplane position effect,
K_{Hs}	horizontal tailplane size effect,
$C_{L\alpha_V} = f\,(A_V, \Lambda_V, M)$	Helmbold-Diederich formula.

The new approach for directional control derivative

$$C_{Y_{\delta_r}} = K_{\delta_r}\, C_{L_{\alpha_v}}\, \alpha_\delta \,\frac{S_v}{S}$$

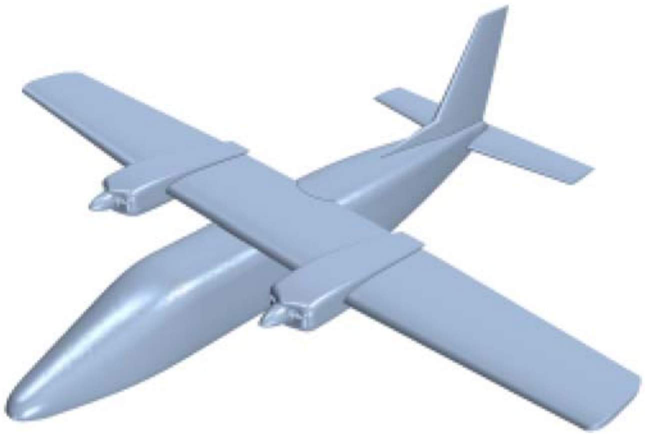
3D rudder effectiveness
(estimated on the isolated vertical tail)

$$K_{\delta_r} = \left[1 + \frac{K_F - 1}{2.2}\right] \cdot \begin{cases} 1.07, & \text{if horizontal tail is body-mounted,} \\ 1.33 - 0.9 A_v & \text{for T-tail configurations.} \end{cases}$$

Body effect is the reduced to the half of that one previously investigated in sideslip

Example of application

Tecnam P2012



Δ from CFD	
New meth	5.0 %
USAF	34.0 %
ESDU	8.8 %

$C_{L_{\alpha_V}}$		$2.160\ \text{rad}^{-1}$
K_F		1.260
K_W		0.953
K_{Hp}		1.139
K_{Hs}		1.022
K_H		1.142
$K_F K_W K_H$		1.371
$C_{Y_{\beta_V}}$	New meth	$0.358\ \text{rad}^{-1}$
$C_{Y_{\beta_V}}$	USAF	$0.249\ \text{rad}^{-1}$
$C_{Y_{\beta_V}}$	ESDU	$0.410\ \text{rad}^{-1}$
$C_{Y_{\beta_V}}$	CFD	$0.377\ \text{rad}^{-1}$

Conclusion

A new procedure to evaluate the aerodynamic interference of airplane's components on the vertical tailplane has been proposed. It has been developed by solving Navier-Stokes equations in a fully turbulent subsonic flow regime on more than 200 regional turboprop aircraft configurations, with the aim to bring CFD into aircraft preliminary design.

Features of the new procedure:

•Based on actual turboprop aircraft geometries

•Low data scatter among configurations

•Simplicity of the approach

Drawbacks:

•Extendable to commuters or jet airplanes?

•No engine, dihedral, wing sweep, flaps or propeller effects considered

•To do: wind tunnel tests

EWADE 2013

A Case Study in Aeronautical Engineering Education

Adson Agrico de Paula

University of São Paulo Brazil

EWADE, September 17th, 2013, Linköping

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546420

Summary

- Introduction
- Case study on engineering education
- A case study in aeronautical
- Results
- Conclusions

Introduction

Singular characteristics on teaching-learning process of Aeronautics:

- ❑ Initial motivation
- ❑ The childhood desire can be a potential
- ❑ Great pedagogical opportunity to awaken the ***reminiscent knowledge*** that is on natural curiosity of people.

Introduction

- Example of this approach can be seen in many aeronautical schools where professors motivate students in activities that develop ***curiosity and creativity***:

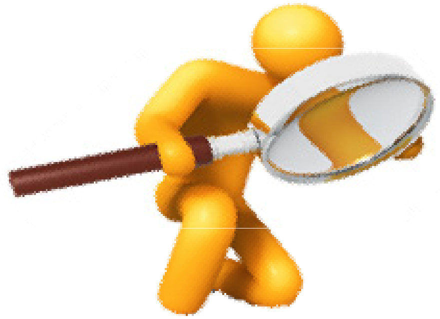
Airplane Building Competition

Tests of Experimental Aircrafts

Introduction

USP NDF

In this context of pedagogical innovation and aeronautical culture:



"A case study was applied on aircraft design classes at university of São Paulo"

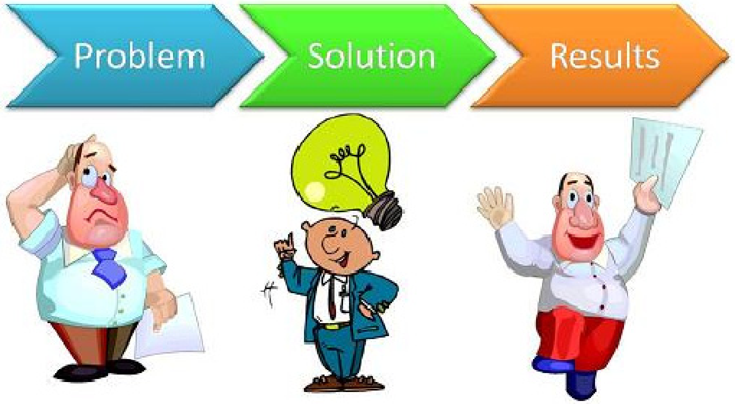
Education in engineering

Top Engineering Schools → ***Strong academic background*** *in science to solve complex problems.*

Is it enough

Engineering enviroment → *Wide engineering problem scenario requires* ***understanding and attitude*** *to deal with different engineering situations.*

Case study on engineering education



Case Study fits well with this proposal !!!

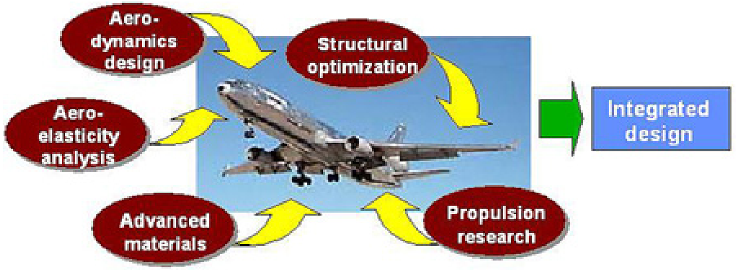
"Engineering case study as an account of an engineering activity, event, or problem containing some of the background and complexities usually encountered by an engineer" **Anwar & Ford (2001)**

"Engineering case presents a scenario that practicing engineers are likely to encounter in the workplaces" **Anwar & Ford (2001)**

Case study possibilities

Anwar (2001) **&** ***Masseto (2003)*** suggested many possibilities of case study and we can apply in aeronautical environment:

- ***Involve in real or simulated situation*** *in your profession area identifying and recognizing problems to figure out solutions.*

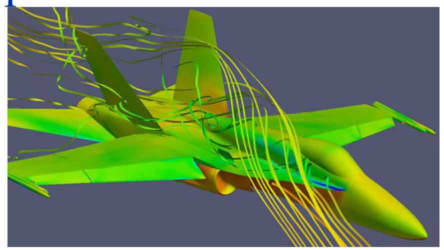


- ***Make diagnostic analyzes*** *for situation considering the* ***variables involved*** *exercising and making judgments.*

Case study possibilities

- Understanding and recognizing ***assumptions and inferences***, as opposed to concrete facts.

- Find out necessary information, ***understanding and interpreting data***, to solve problem-situation.



- Thinking ***analytically and critically***.

Case study in aeronautical engineering education

- Case study of aerodynamic design for two of the most classics aircraft in the world, ***Douglas DC-9*** and ***Boeing 737***

VS

*"**Embryonic mark of commercial aviation** and compete in the aeronautical market based on **similar engineering requirements** with different philosophies"*

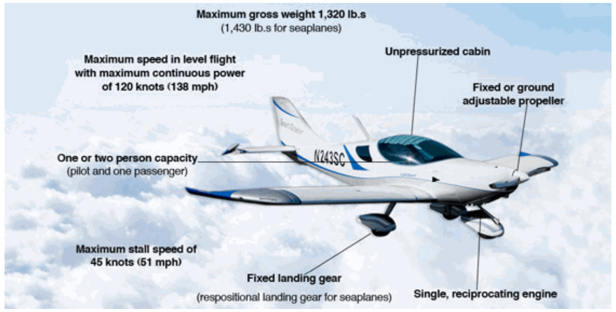
Case study in aeronautical engineering education

- The case study conducts engineering students to experiment discussions about issues related to ***historical facts, aerodynamics concepts, requirements, design philosophy, technologic and development***.

- The discussions for case study are based on scientific articles: ***"aerodynamic design philosophy of the Boeing 737"*** and ***"Aerodynamic Design Features of the Douglas DC-9"***

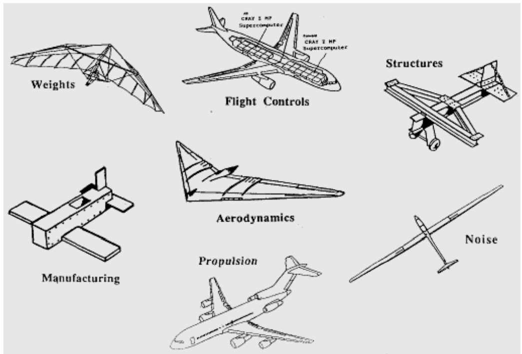
Education goals

- ❑ ***Requirements*** and their importance on design



- ❑ **Design philosophy** and airplane configuration choice

- ❑ ***Multidisciplinary*** view on design



Case study strutucure

2 Discussion groups : Douglas DC-9 and Boeing 737.

Aeronautical industry team and a Leader

Previous reading : Paper and Requirements

Discussions about educational goals

Cross-Dynamic

Requirements and their importance on design – "Perceptions"

USP NDF

Design requirements are well-defined ⇨ ***Aerodynamicists work hardly to achieve them***

Boeing 707, 727 and 737

Λ

A

λ

(t/c)

Boeing 737 ⇨ ***New step on comercial aviation***

Short range and runway

Focus on Low speed design (B737) ⇨

- ***Less wing swept***
- ***Thicker profile***
- ***Complex High-lift devices***

Requirements and their importance on design – "Perceptions"

Douglas DC-9	***Short range and runway***
Differences : DC-8 vs DC-9	***Derived from DC-8 with regional requirements***
Critical design conditions	***DC8: cruise DC9: Second segment climb***

Design philosophy and airplane configuration choice – "Perceptions"

One configuration is chosen, and some inherent engineering problems will take place, so aerodynamicists need to solve !!!!!!

- Both groups discussed about differences between ***T-tail and conventional*** configuration

- There are a mandatory criteria to chose a specific configuration

- They discussed particularly about ***"deep stall"*** phenomenon

- The nacelle configuration under-wing on B737 (problems in high speed !!!)
  Solution: Wind tunnel and CFD investigation

- T-tail configuration DC-9 (deep stall problem !!!!)
  Solution: Vortilon and greater horizontal came from exhausted analysis of wing wake and its influence on horizontal tail effectiveness.

Multidisciplinary view on design – "Perceptions"

USP NDF

Usually is hard, in aircraft design, to satisfy disciplines such as aerodynamics, aeroelasticity, performance, structure and weight at same time.

B737 | **DC-9**

Outboard Aileron

- *B737* → *Entire flight regime*
  - *Thicker profile*
  - *Less swept*
- *B707,B727* → *Low speed regime*
  - *Thinner profile*
  - *more swept*

Deep stall

- *Deep stall* → *Vortilon*
- *Vortilon* → *Increase in drag and weight*
- *Increase in drag and weight* → *Wing tip extension*

Cross-Dynamic – "Perceptions"

- Requirement of ***short range and runways***
- Boeing 737 and Douglas DC-9 have ***similar requirements***.
- ***Similar aerodynamic solutions*** to satisfy requirements (thicker profile, less swept wing, sophisticated high-lift devices)
- Distinct design philosophy (***different airplane configuration***) for similar requirements.
- There are ***characteristic problems*** for each specific configuration.

Conclusions

- The case study ***motivated strongly the engineering students***, since this activity established a relationship between theory and practice. (this is a problem in engineering education !!!! ☹)

- The education goals were achieved (***requirements, design philosophy and multidisciplinary view***)

- Teaching-learning process of Aeronautics is a ***great pedagogical opportunity***

- There are ***many possibilities*** applying case study in aeronautical education

- Case Study fits well with ***wide engineering problem scenario*** training students to deal with different engineering situations.

Thank you for Coming !!!!

http://ewade2013.AircraftDesign.org
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Aircraft Design Lectures at RWTH Aachen University, Germany

11th European Workshop on Aircraft Design Education
Linköping, 17.-19.09.2013

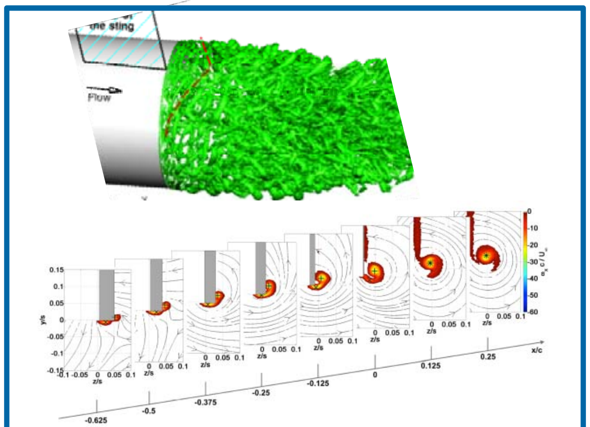
1. **Institute of Aerospace Systems at RWTH Aachen University**

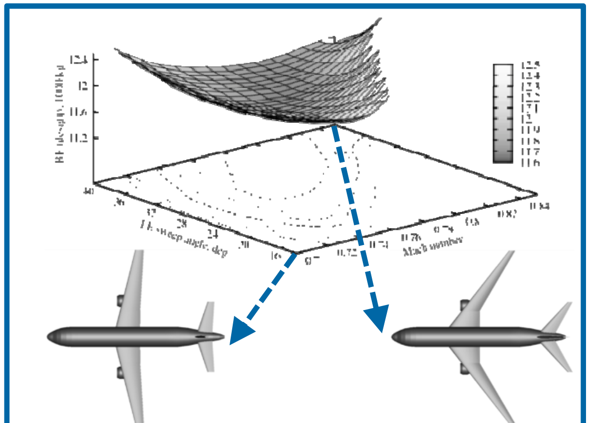
2. **ILR Fixed Wing Aircraft Course → Practical Aspects**
   - Analysing old Concepts
   - Paper & Pencil Aircraft Design

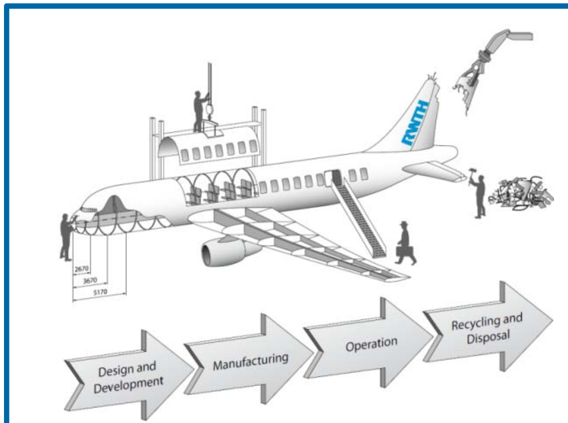
3. **Computer-Aided Aircraft Design: Familiarization with MICADO**

4. **Template for MICADO C++ Tool Development**

5. **Summary**



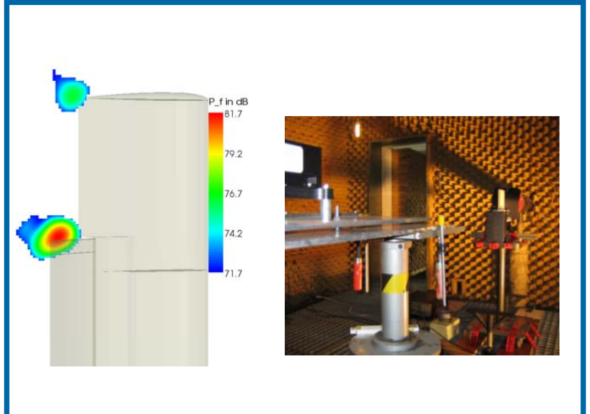


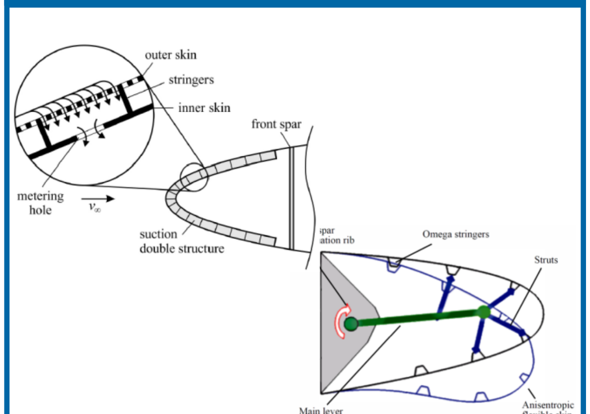


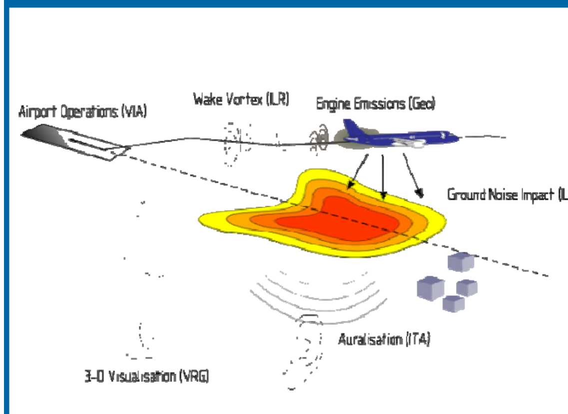
Vortex Dynamics/
Aeroacoustics

Aircraft Design/
Technology Integration
and Assessment

Air Transport System/
Life Cycle Analysis

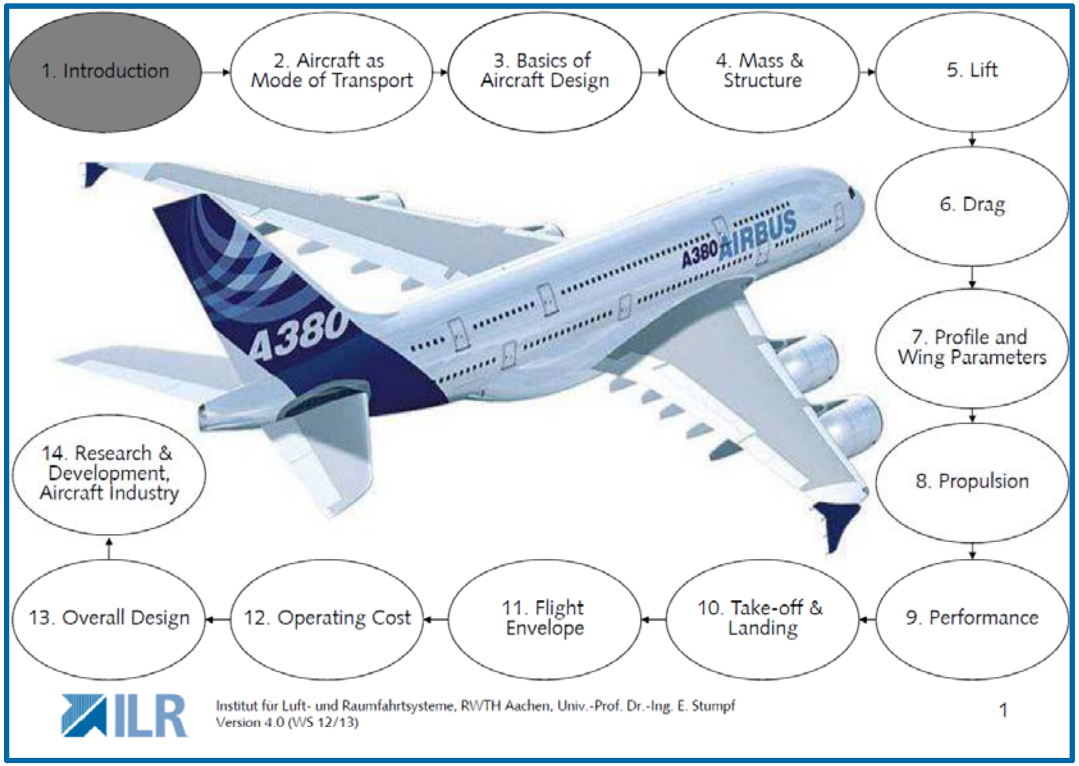






Fixed Wing Aircraft I	Fixed Wing Aircraft II	Short Course: Computer-Aided Aircraft Design
Aircraft Acoustics	Air Transportation System	Short Course: Aircraft Testing
Helicopters	Selected Current Research Topics in Aeronautics	Short Course: Windtunnel Testing
Aerospace Systems	Spacecraft I & II	Short Course: Delta Wings

- Fixed Wing Aircraft I is attended by Bachelor students with various study backgrounds → goal is to teach fundamentals , e.g.:
  - 3. Basics of A/C Design: AC decomposition, standard atmosphere, forces & moments, coefficients & dimensionless characteristic quantities
  - 9. Performance: Gliding flight, air speed stability, specific air range, climb performance
  - 13. Overall Design: Configurational decision, fuselage & empenage layout, engine installation, options for undercarriage, industrial design process
- Lecture provides basic knowledge and design-“language“ resp. design-“philosophy“ → practical aspects given in exercises

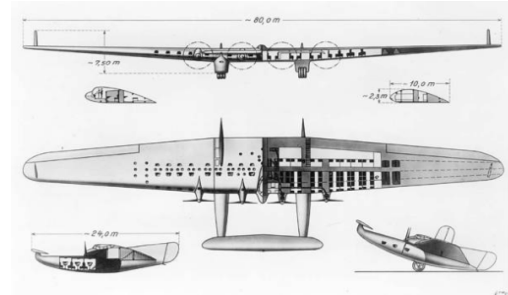


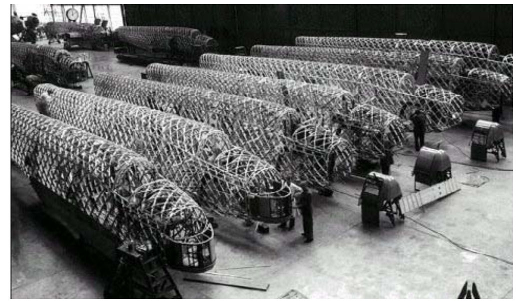
- Excercises contain calculations of separate aspects e.g.:
  - Range
  - Take-off and Landings Distances
  - DOC
- No continuous design process is run through here

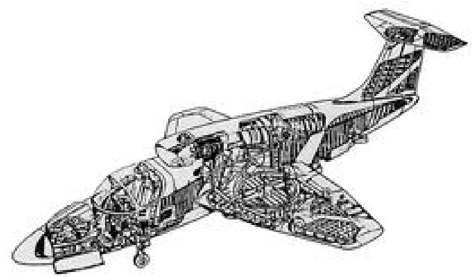
- Since this year: In order to teach the students that
  - It is needed to see the bigger picture
  - It helps to analyze and learn from the past

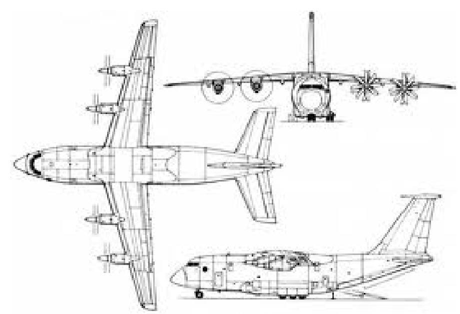
we let them investigate on past configurations

which feature currently re-visited aspects, e.g.
  - Blended Wing Body/Flying Wing → Junkers 1000
  - Isogrid Structure → Vickers Wellington
  - Fan Wing Lift Concept → Ryan 5a
  - Counter-Rotating Prop → AN70
- Work is done in groups of 5 students as homework, all on different topics → Open administrative issues

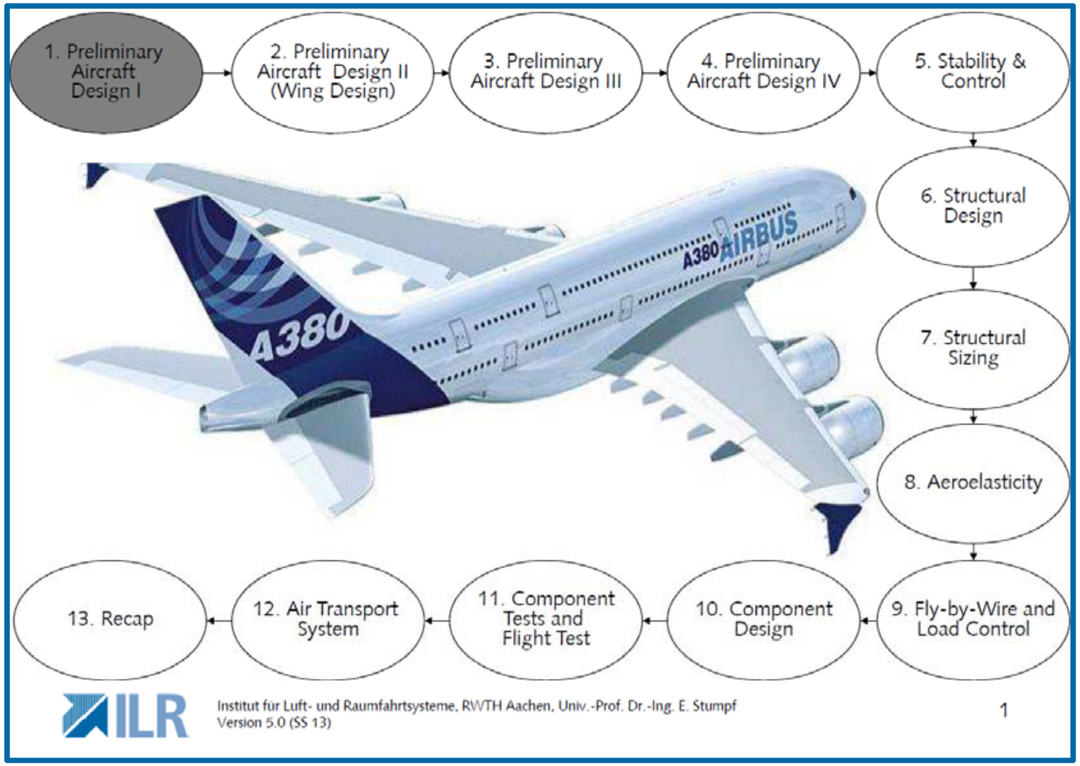






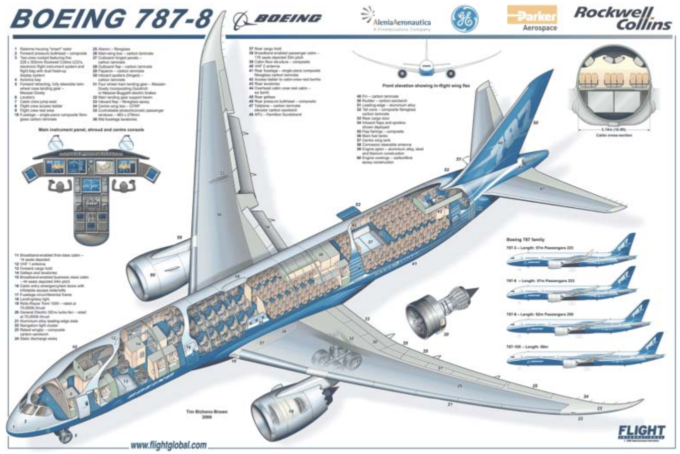


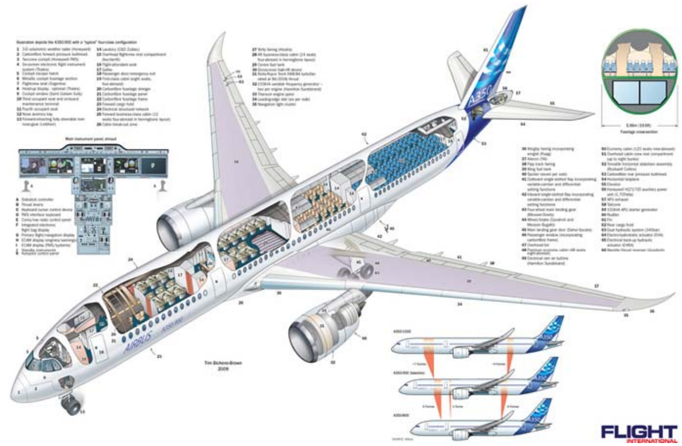
- Fixed Wing Aircraft II is attended by Master students with background knowledge → goal is to teach advanced aspects , e.g.:
  - 1. -4. Preliminary A/C Design: Top level aircraft requirements, initial sizing, layout of fuselage, cabin, wing, engine, undercarriage, empennage, mass estimation, aero estimation, performance, assessment based on general and specific criteria
  - 9. Fly-by-Wire/Load Control: FBW architecture, laws, protections, mechanical backup, load control options
- Lecture provides basic introduction into aircraft design process, but mainly advanced insight on system level → practical aspects given in exercises



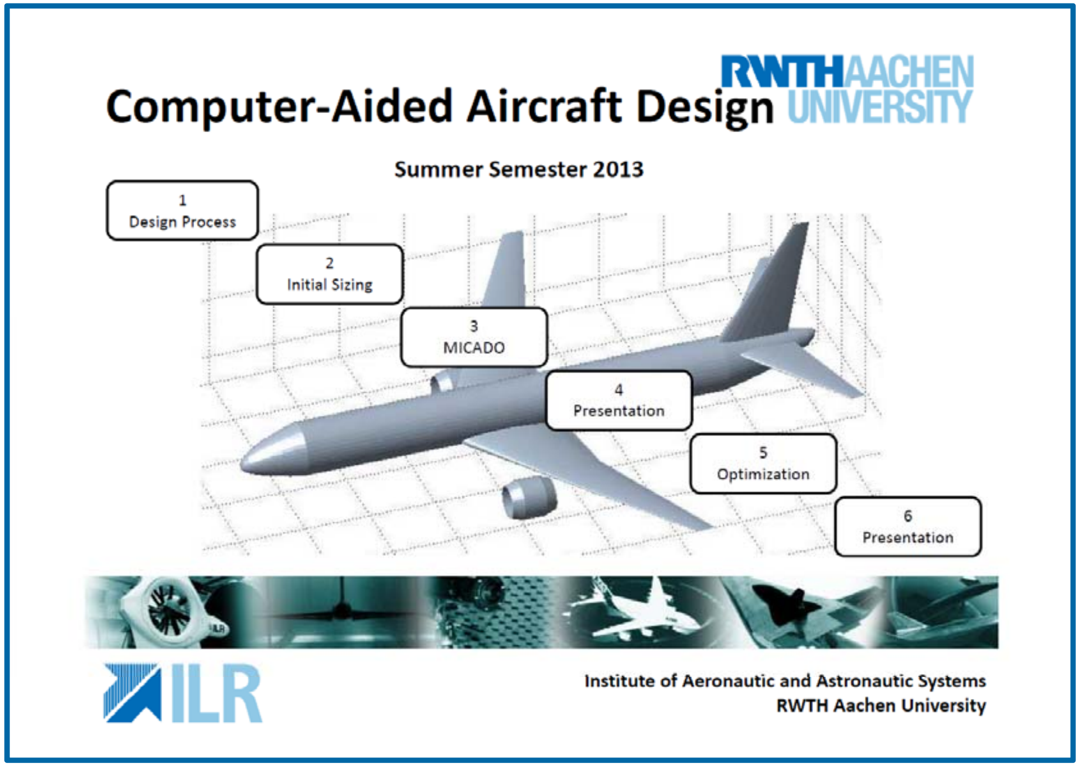
- Excercises contain calculations of separate aspects e.g.:
  - TLARs
  - Initial sizing
  - Undercarriage layout
  - Performance
- No complete design cycle is done yet
- Since this year: In order to teach the students
  - A „feeling“ for dimensions
  - A knowledge of interdependencies

  we let them re-design current aircraft configurations on paper & pencil-basis, e.g.
  - Boeing 787
  - Airbus A350
  - Sukhoi Superjet
- Work is done in groups of 5-8 students as homework, all on the same configuration, statistics and complementary infos are provided





- Computer-Aided Aircraft Design is attended by Master students with background knowledge → goal is to:
  - Teach execution of complete aircraft design cycle with advanced conceptual aircraft design tool
  - Understanding and usage of ILR design tool MICADO:
    - For preparation to use MICADO for bachelor/master thesis
    - For qualification of students as student assistants or to pursue a PhD at ILR
- Lecture provides insight into aircraft design process, but fully aligned with ILR-MICADO tool → perfect double-use option resp. win-win situation

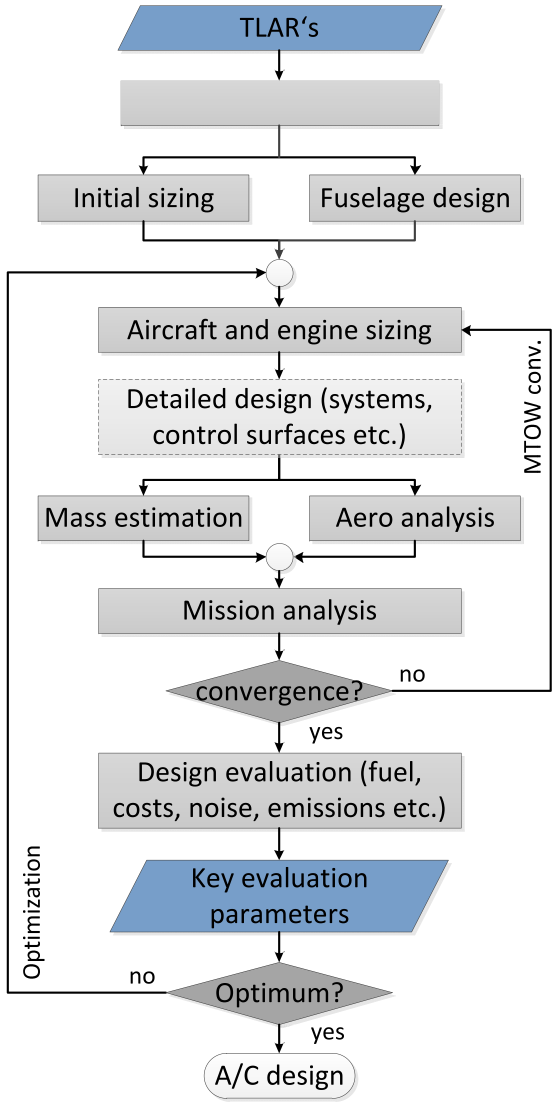


MICADO Design Methodology – Process Overview

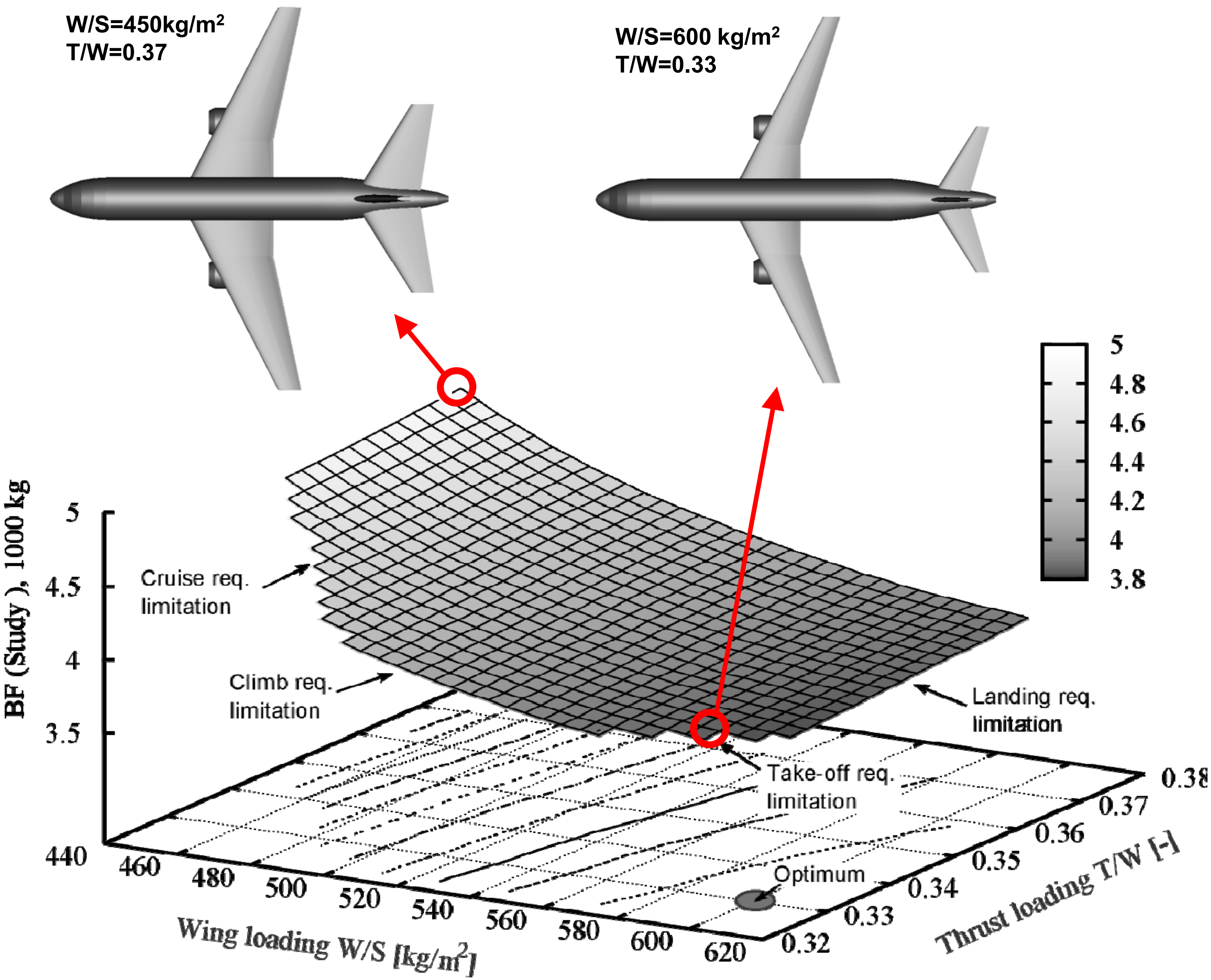
- White sheet design approach starting from a set of top-level req's (TLARs)
- Aircraft design programs size geometry components → general arrangement
- Optionally, more detailed design programs
- Design undergoes performance analysis (masses, aerodynamics, mission)
- Full a/c design iteration
- Assessment against evaluation criteria
- Evaluation parameters can be used for overall aircraft design optimizations

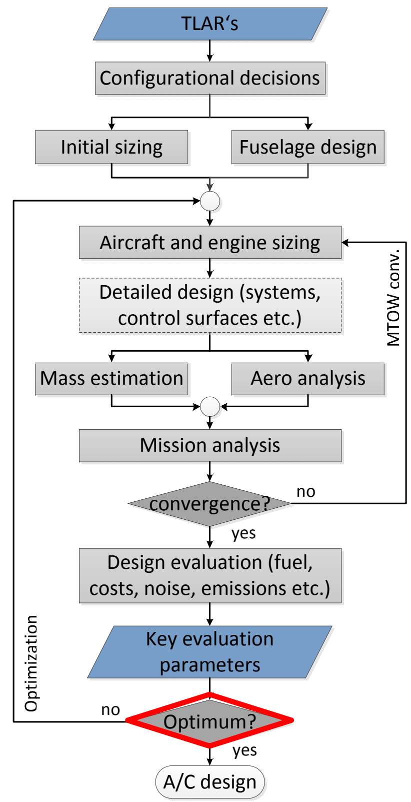
→ Capturing of particular design changes or system integration on overall aircraft level due to component resizing and snowball effects

→ A full initial design synthesis (w/o optimization) takes about 15 min. on a normal desktop PC



MICADO Short Range Design – Block Fuel Optimization





Motivation:

Contribution of Student Theses to MICADO software development

Problem:

MICADO is based on object-oriented class structure (C++)

Many Students have no or limited programming skills

Approach:

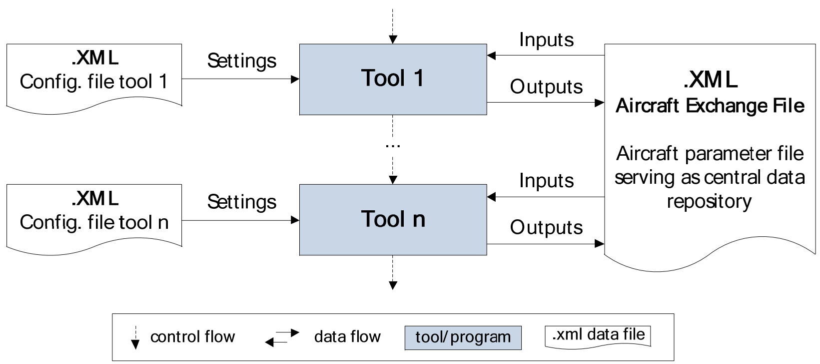
A template has been created (already at the beginning of the MICADO developent phase) that already includes all C++ software features and templates, e.g.

- Geometry classes
- XML parsers → access to Aircraft and Settings XML files
- Engines, Aerodynamic, ISA etc. libraries
- Automatic plot generation

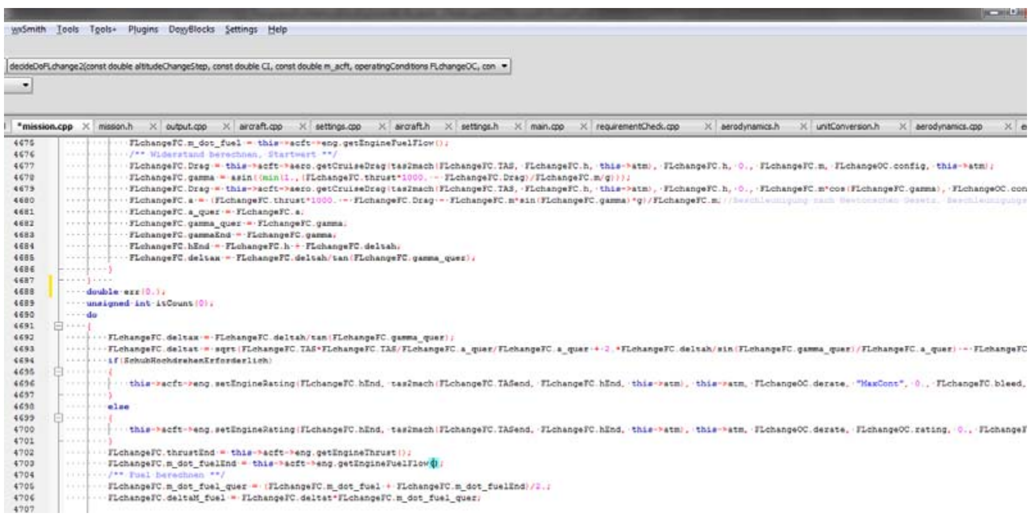
→ Completely working program package

→ Students only have to insert their methods and have a stand-alone program

MICADO control and data flow



MICADO mission classes code snippet



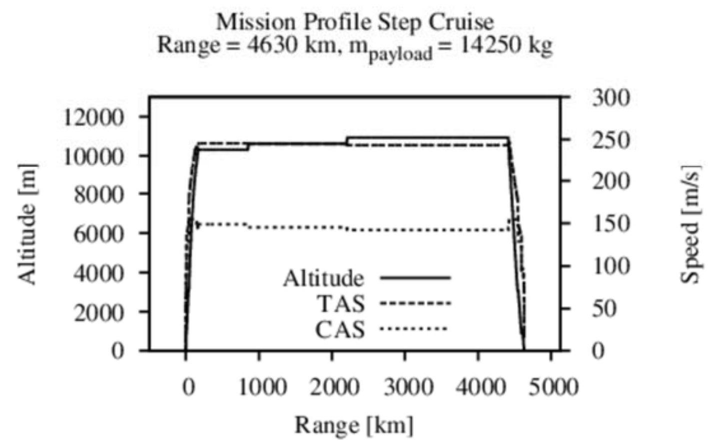
Automatic generated html report

Report Missionsanalyse Airbus-A320-200

Leermasse (OWE)	42567.6	kg	
Reichweite (gefordert)	2500	NM	
Nutzlast	14250	kg	
Passagiere	150		
Frachtmasse	645	kg	
Startmasse (TOW)	77097.4	kg	= OWE + PL + Loaded Fuel - Taxi Fuel (T/O)
Getankte Kraftstoffmenge (loaded fuel)	20520.4	kg	= Block Fuel + Reserve Fuel
Blockfuel	16234	kg	= Trip Fuel + Taxi Fuel (T/O+Ldg)
Trip Fuel	15772.8	kg	
Restkraftstoff	4266.38	kg	
Taxi-Fuel Start	240.6	kg	
Taxi-Fuel Landung	240.6	kg	
Landemasse	61324.6	kg	
Missionsstrecke (berechnet)	2501.24	NM	
Gesamte Flugzeit	5.47	h	
Blockzeit	5.81	h	

Ermitteltes optimales Cruise-Profil:

Cruise Step	Flight Level [100 ft]	Rel. Cruise Step Length [%]
1	338.7	16
2	348.7	47.9
3	358.7	100



- Aircraft design /technology integration and assessment represents main research field at ILR
- In ILR lecture Fixed Wing Aircraft I: students will work on old aircraft concepts to build up „system thinking“
- In ILR lecture Fixed Wing Aircraft II: students will execute a full design cycle to build up „system knowledge“
- In ILR lecture Computer-Aided Aircraft Design: students get familiarized with current conceptual aircraft design tool
- C++ tool templates enable to motivate students to do tool development (which otherwise would refuse)

Thank you for your attention!

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546427

The New Aircraft Design Course at the Technical University of Munich (TUM)

Sky Sartorius

Sky Sartorius, B.S., M.Sc.
Institute of Aircraft Design

Design at TUM – a broad topic

- Unique boundary conditions at TUM
- Course content/curriculum/scope
- Prescribed design methods and tools
- Course development, (short) history, past years
- Lessons learned
- Future of aircraft design education at TUM

Presentation overview

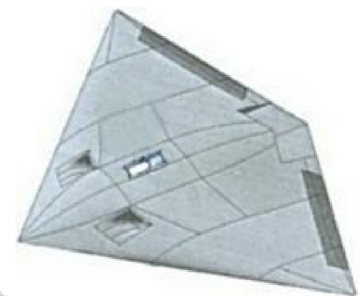
- Background
- Goals
- Course content
- Moving forward

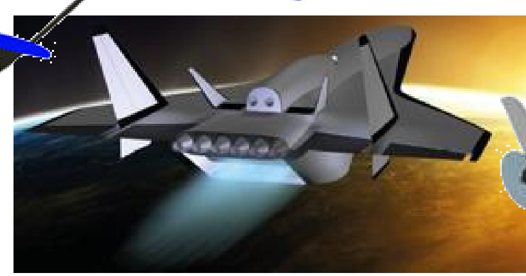
Background – student exposure to design

Credited coursework	Extracurriculars	Department projects
Aircraft design lecture	AkaFlieg	Student assistantships
	AkaModell	Student theses (bachelor, semester, & master)
	Euroavia/symposium	

New: aircraft design practical course

- Project-based (learn by doing!)
- For advance students – lecture course as prerequisite
- Not a compulsory course





Goals – overview

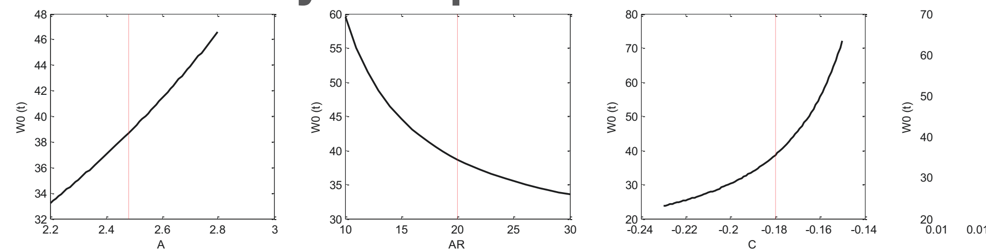
- Goals
  1. Learning value: make each student a capable conceptual designer
  2. Good result: learn by doing… right

- Boundary conditions
  - 'Customer'-oriented
    - Popular (or else no participants)
    - Appropriate workload
  - …

Goals – learning objectives

Work in multidisciplinary team

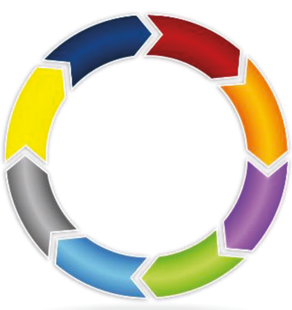
Analyze requirements



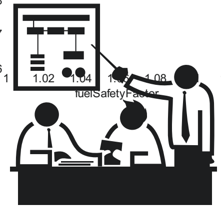
Appreciate history

Make decisions

Solve iterative/ open-ended problems



Communicate



Course content – structure

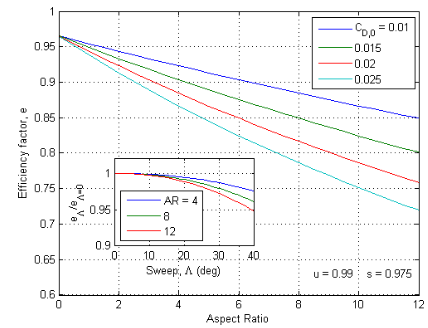
AIAA design task: HALE UAS for missile defence with directed energy laser

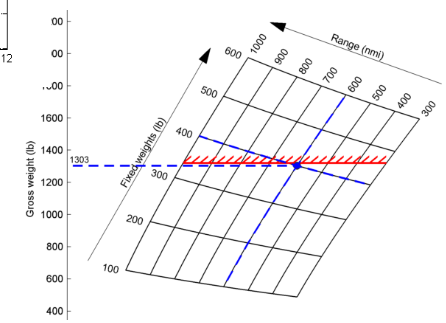
Design activity	Weeks	End milestone
Recruiting & selection	~10	Annotated concept sketches
Design basics & "first shot" design	3	Individual sizing project submission
Concept exploration Issue reports	3	Initial design review (IDR) 
Preliminary design	7	Preliminary design review (PDR)
Refinement	4	Design report submission
Revision	8	AIAA proposal submission

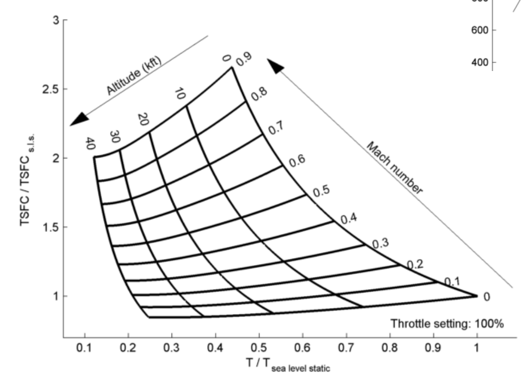
4 ECTS / 15 weeks / 3 contact hours/week

Course content – prescribed tools & methods

- **No provided tools!** (almost)
  - But many resources
- Some small exceptions:
  - Cookbook for individual project
  - Cookbook for engine modeling
  - Some basic provided software (but almost all open/free)







Course content – soft skills emphasis

Team environment

- Management
- Collaboration
- Data control
- Specialization

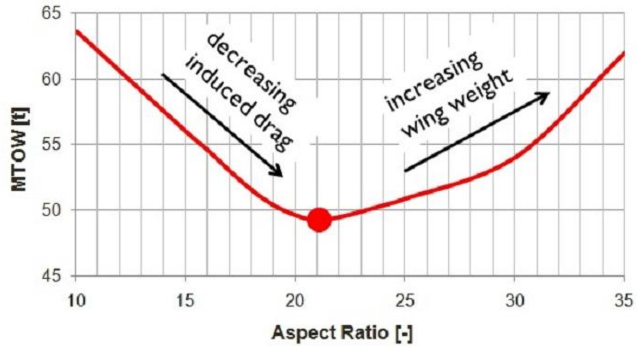
Communication

- Writing
- Technical drawing
- Audio/visual presentation
- Technical conversation

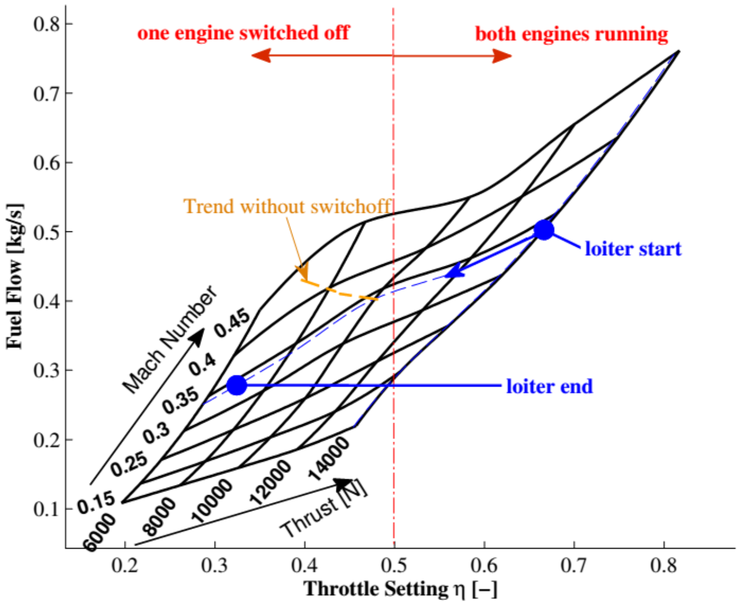
Course content – decision-making emphasis

A good trade study…

1. is well **chosen**
   – Recognize important trades to be made & where to focus efforts



2. is well **executed**
   – Appropriate tools & methods for study process and technical analysis



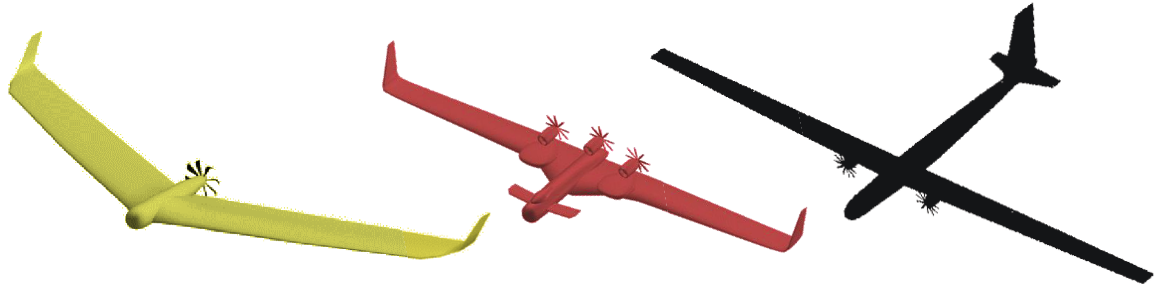
3. is well **communicated**
   – Make results clear to the decision-maker and other stakeholders

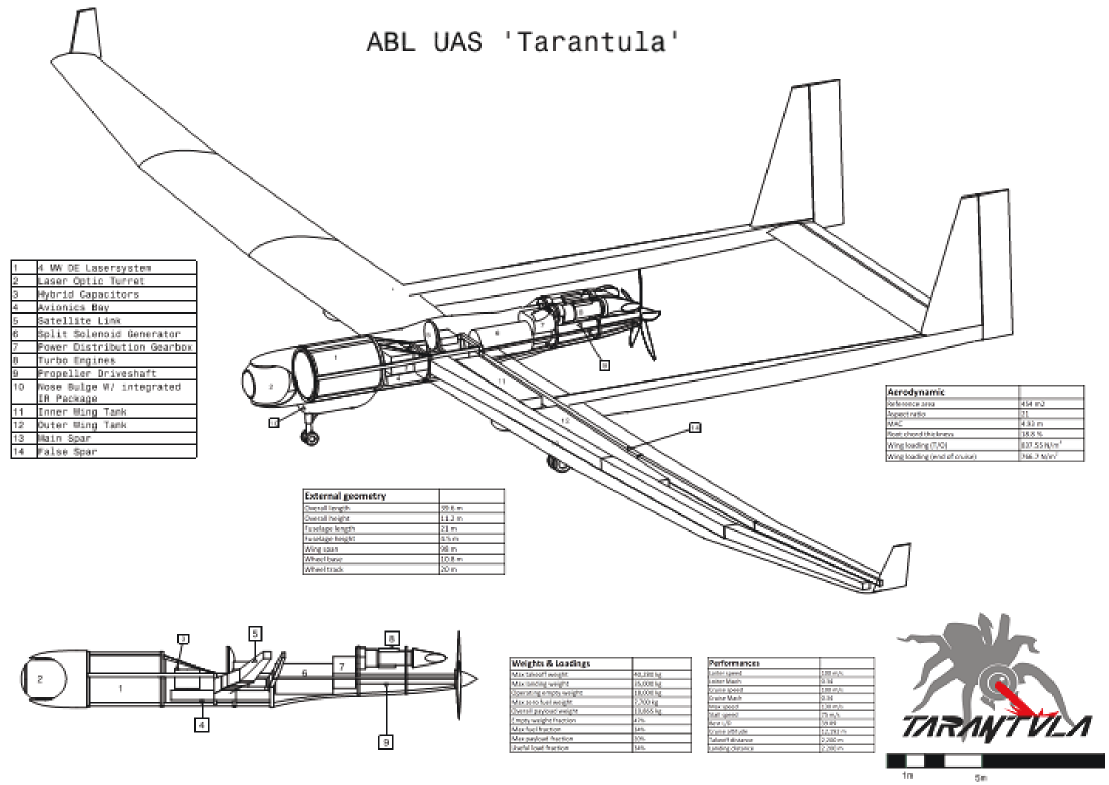
4. leads to a good engineering design **decision**

Results

Student feedback:

- “I learned a **LOT**!”
- “I’m proud of our design”
- “It’s too much work!”





AIAA Graduate Team Aircraft Design Competition 2nd Prize

Moving forward

Evolutionary approach: shrink course scope

- Simpler design task
- Easier and/or fewer deliverables
- Spread workload with largest practical team size
- No competition
- Compensate with gap-semester offering

Revolutionary approach: grow boundary conditions

- Offer thesis credit
- No structured course offering
- Add another milestone (e.g., design review, report)
- Smaller teams
- Competition-focused

Acknowledgements

- Instruction team members:
  - Sebastian Speck
  - Hannes Ross
- Design review attendees
- Design education community
- Students

UAV Research and Development in Technical University - Sofia

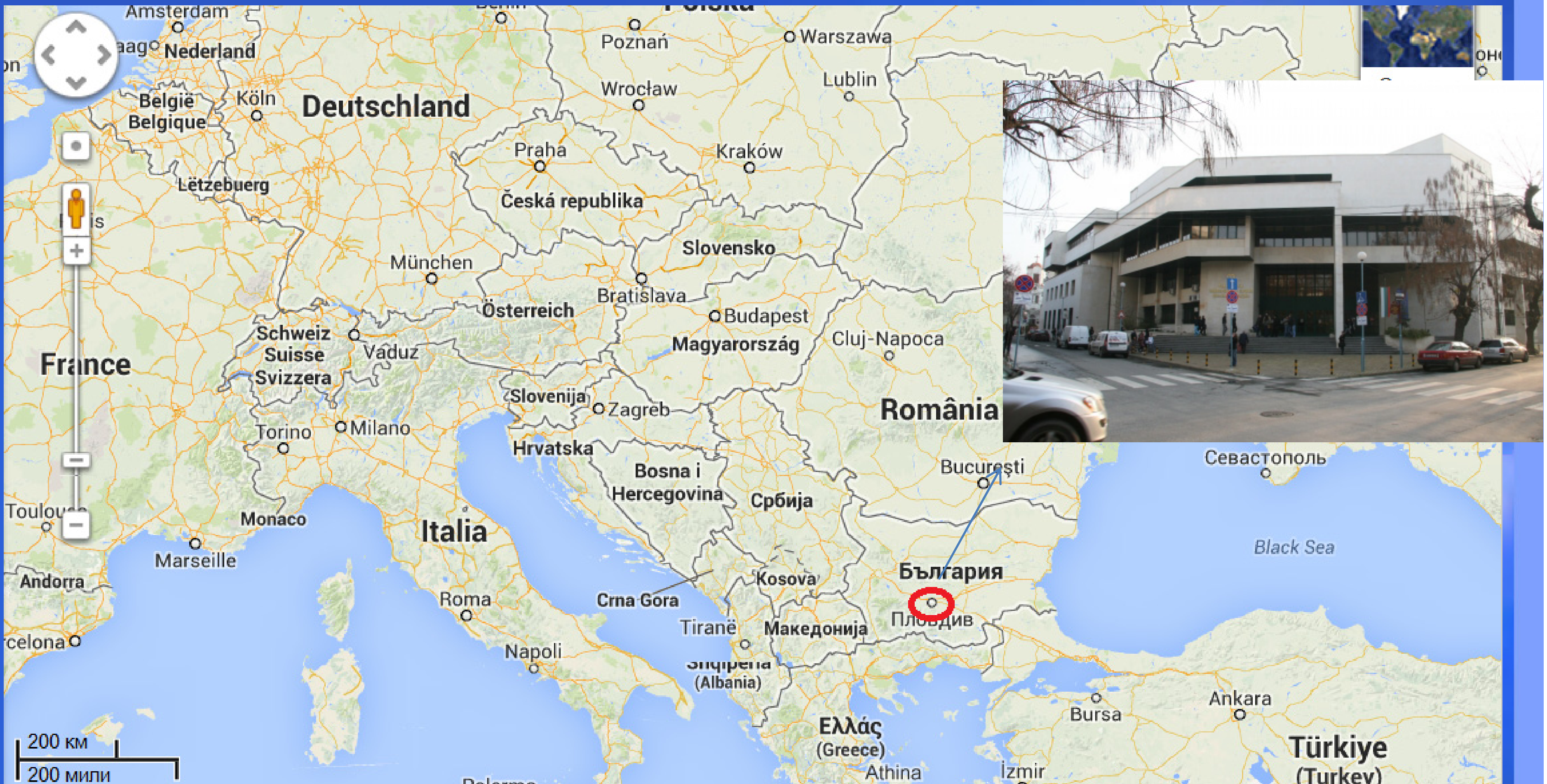
http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546431

Dimo Zafirov, Hristian Panayotov

11th EWADE, 2013

Linköping

Location

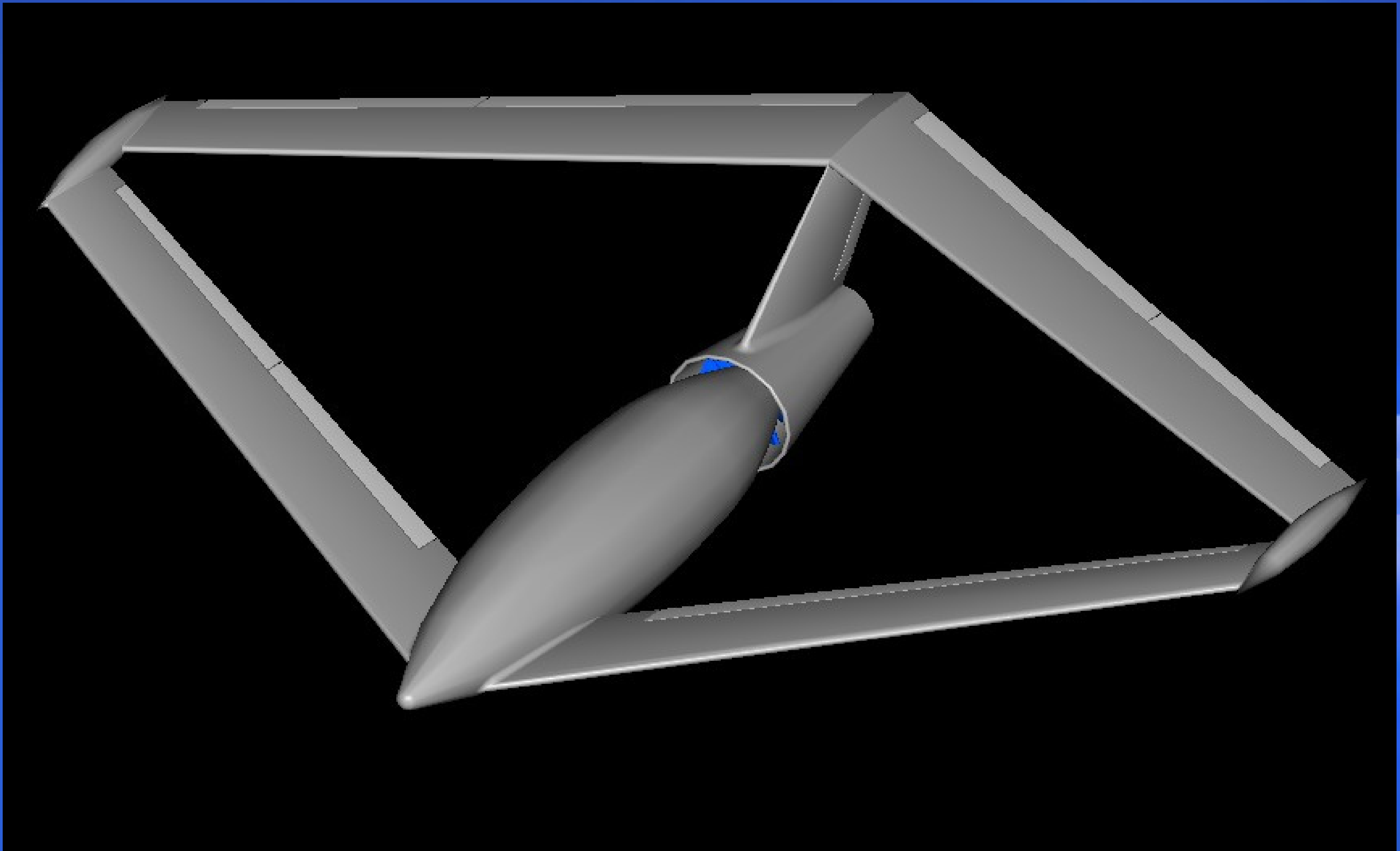

Amsterdam
Nederland
België
Belgique
Köln
Deutschland
Poznań
Warszawa
Wrocław
Lublin
Praha
Kraków
Lëtzebuerg
Česká republika
Slovensko
München
Bratislava
Österreich
Budapest
Schweiz
Suisse
Svizzera
Vaduz
Magyarország
Cluj-Napoca
France
Slovenija
Zagreb
România
Torino
Milano
Hrvatska
Bosna i
Hercegovina
București
Севастополь
Србија
Monaco
Marseille
Italia
Black Sea
Andorra
България
Kosova
Crna Gora
Roma
Tiranë
Македонија
(Albania)
Napoli
Bursa
Ankara
Ελλάς
(Greece)
Athina
İzmir
Türkiye
(Turkey)
Palermo
200 км
200 мили

Plovdiv, Bulgaria

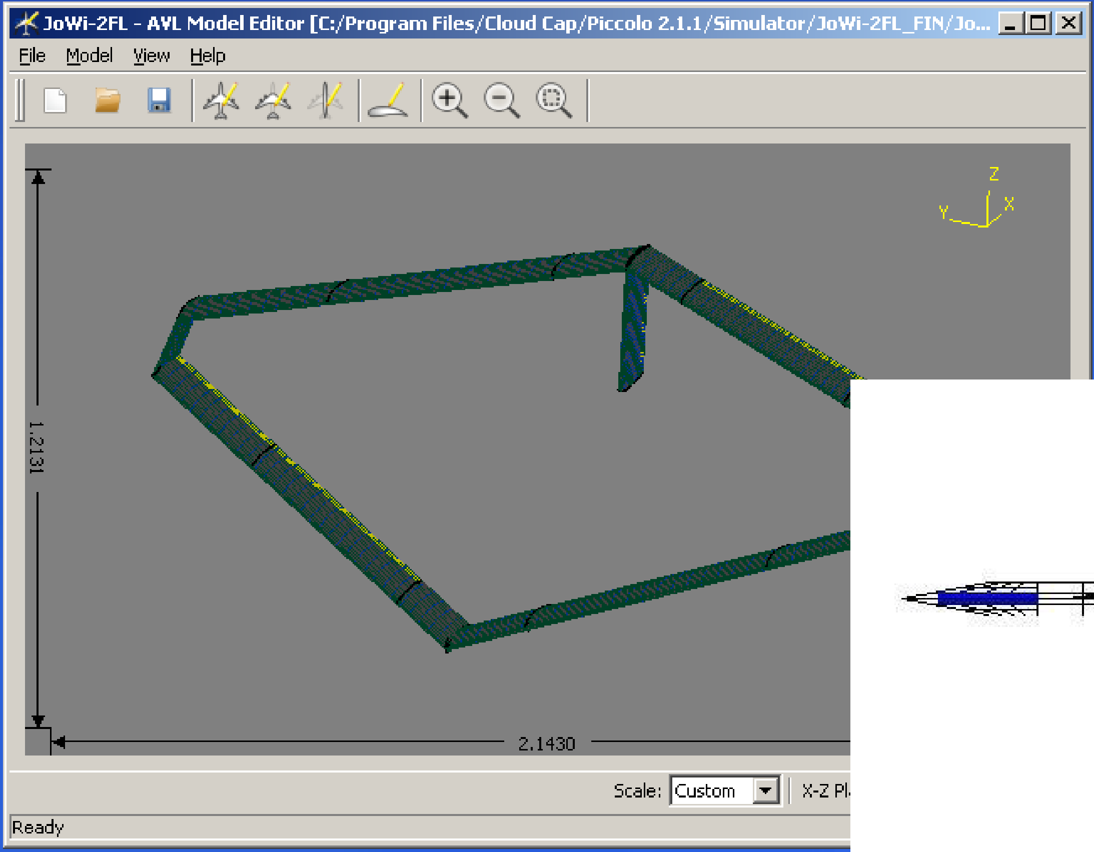
UAV Activities in TU-Sofia Branch Plovdiv

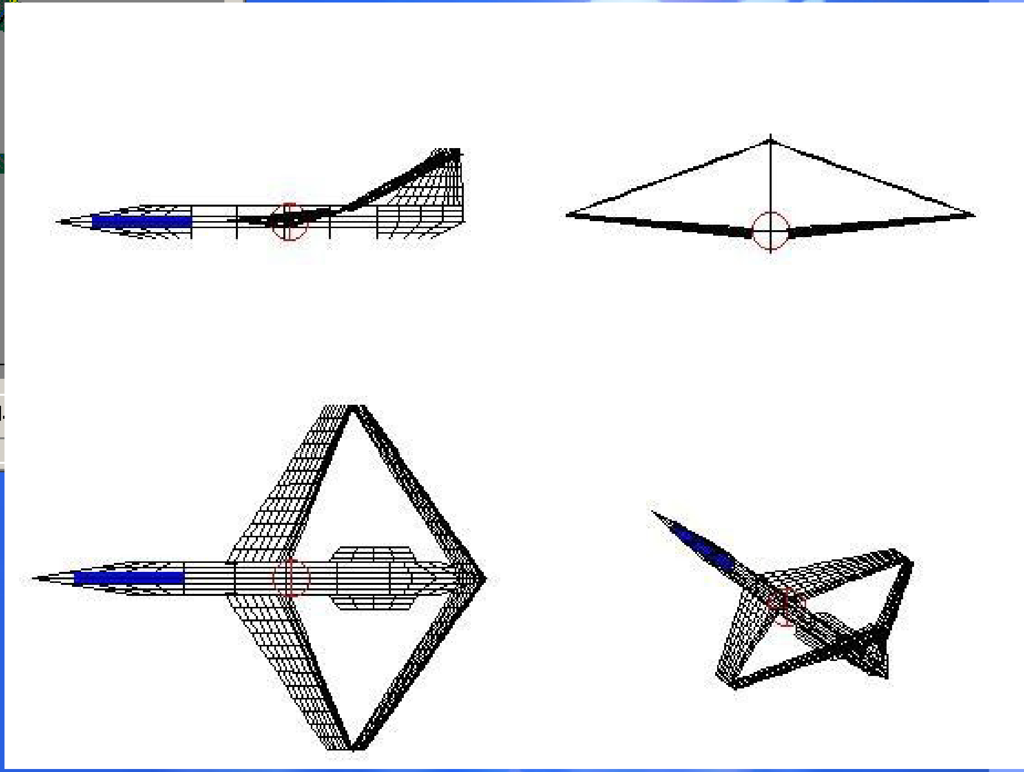
- Joined wing investigations;
- UAVs;
- Ducted fans;
- Autonomous flights;
- Vertical takeoff and landing aircraft.

Joined Wing

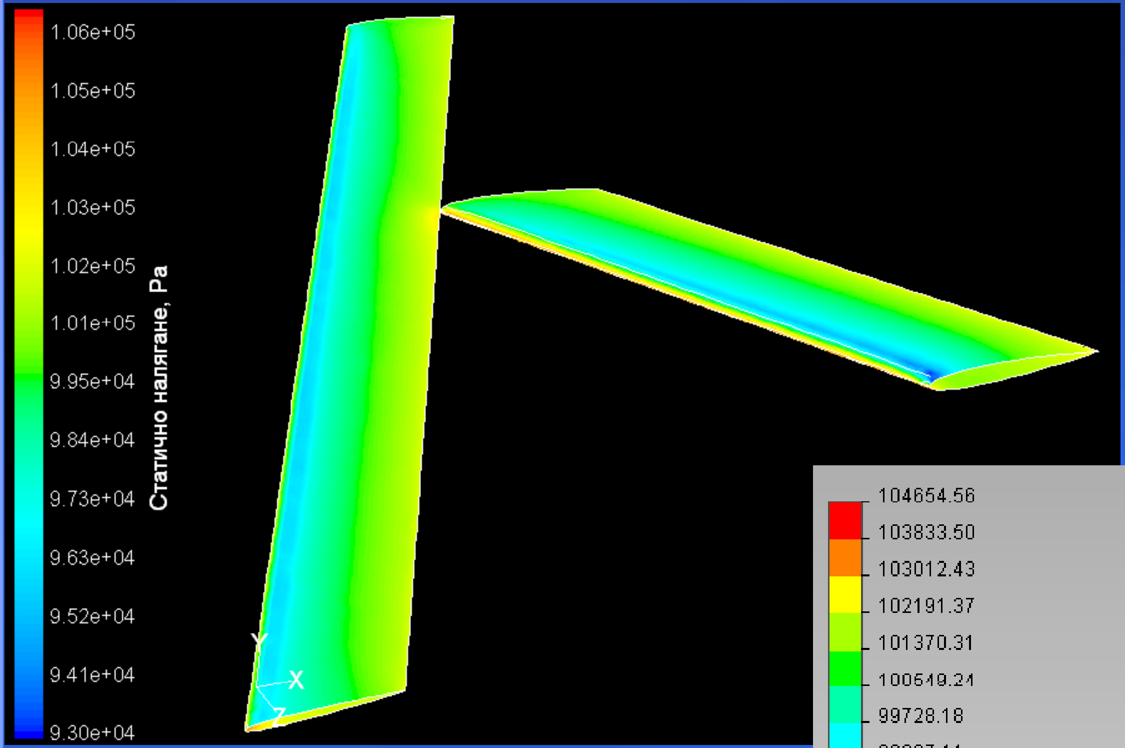


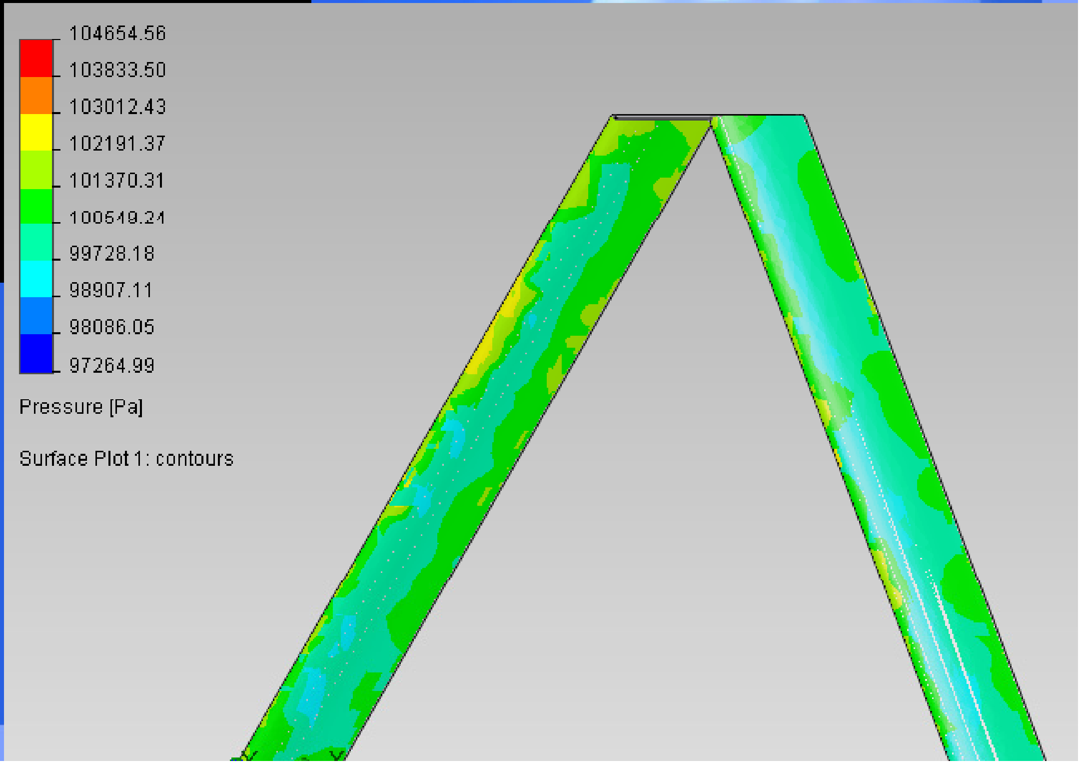
Aerodynamics. AVL & Tornado



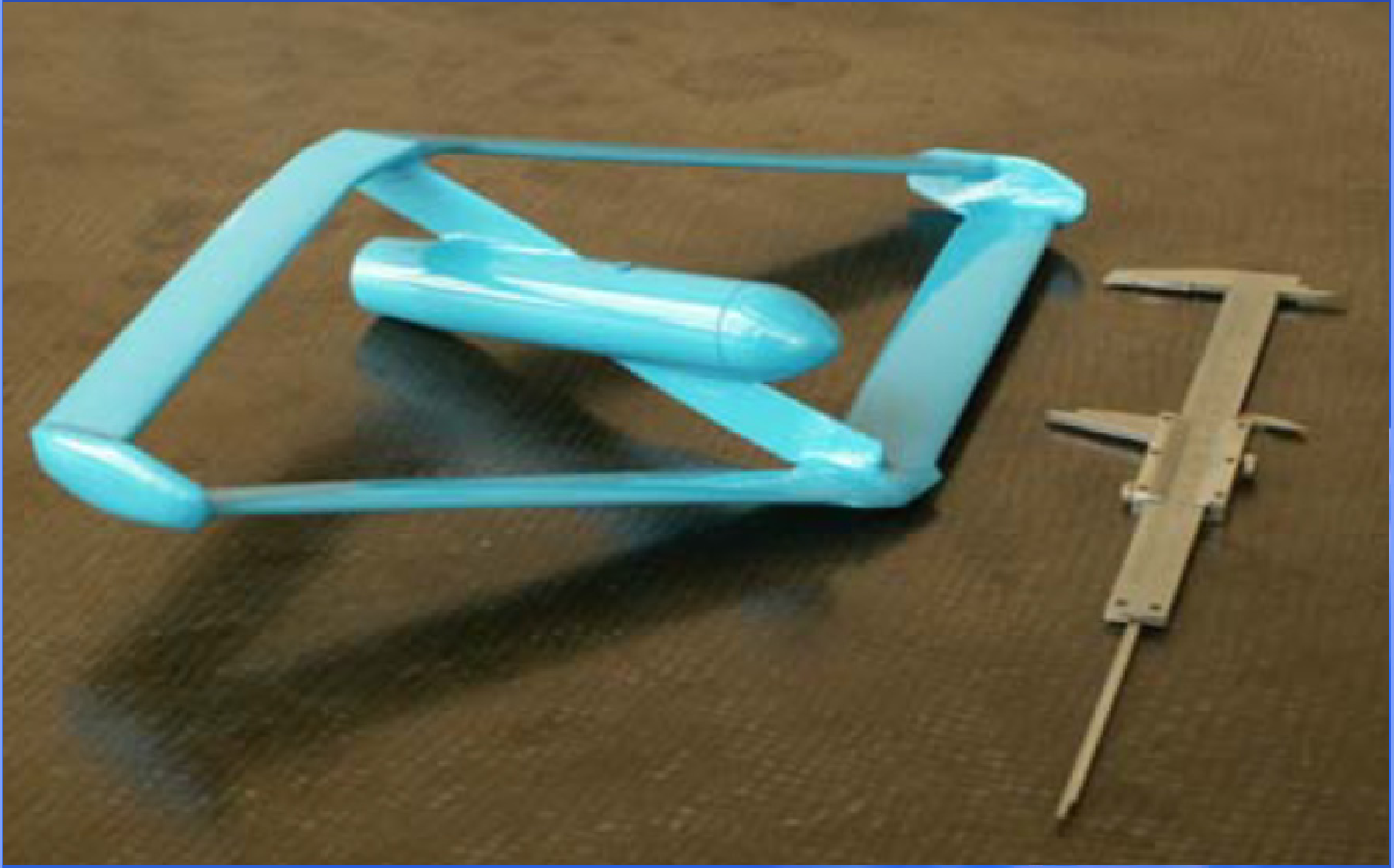


Aerodynamics. CFD



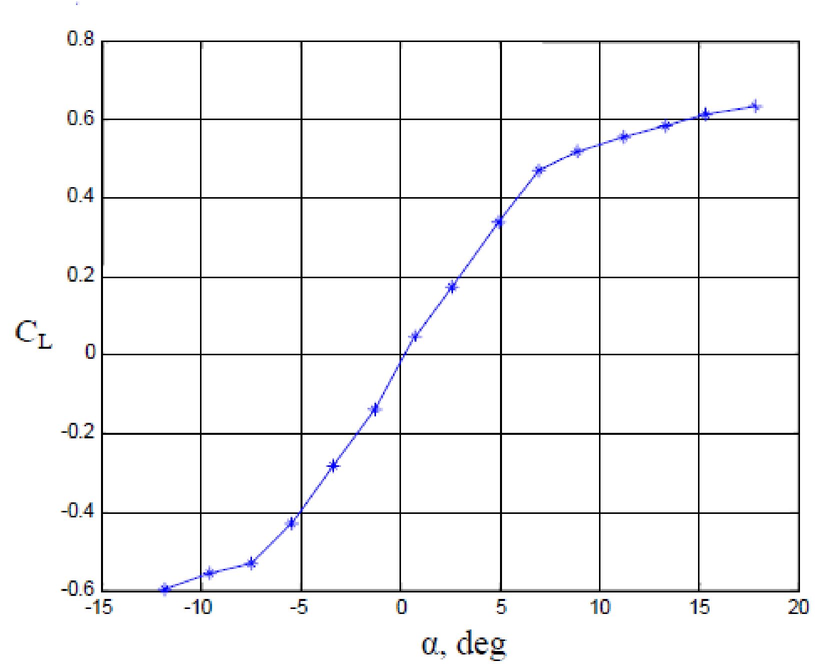


Tests in a wind tunnel

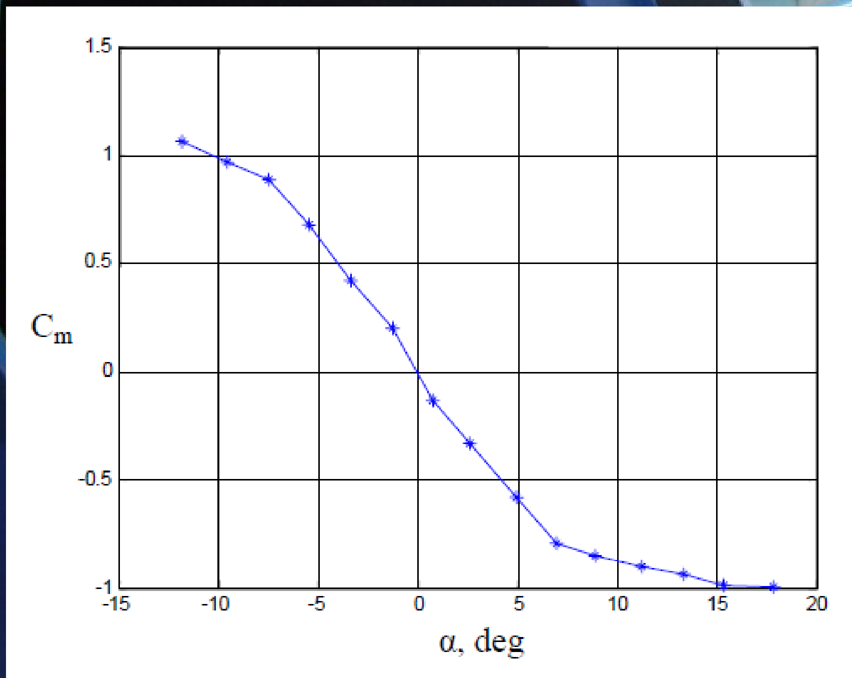


Tests in a wind tunnel

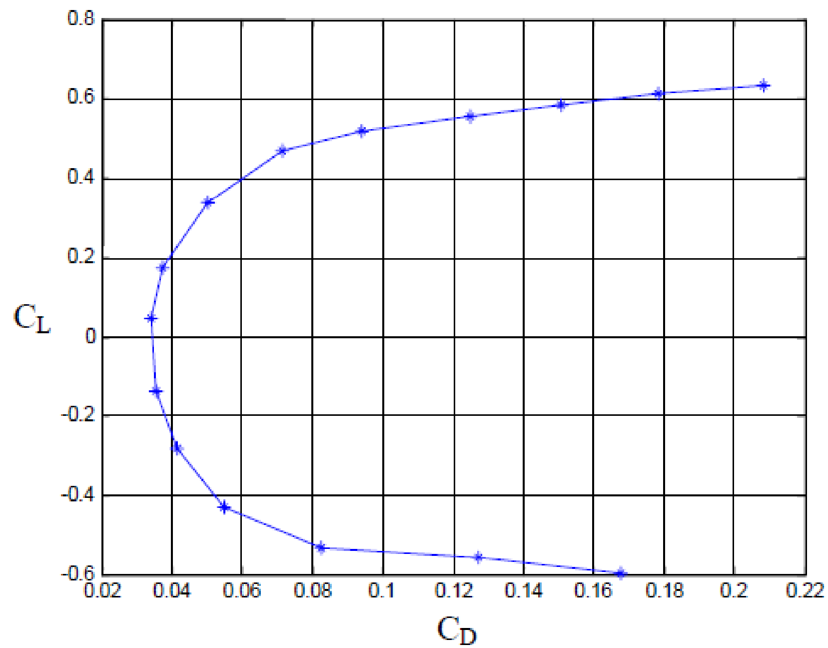
Tests in a wi



0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
C_L
-15
-10
-5
0
5
10
15
20
α, deg



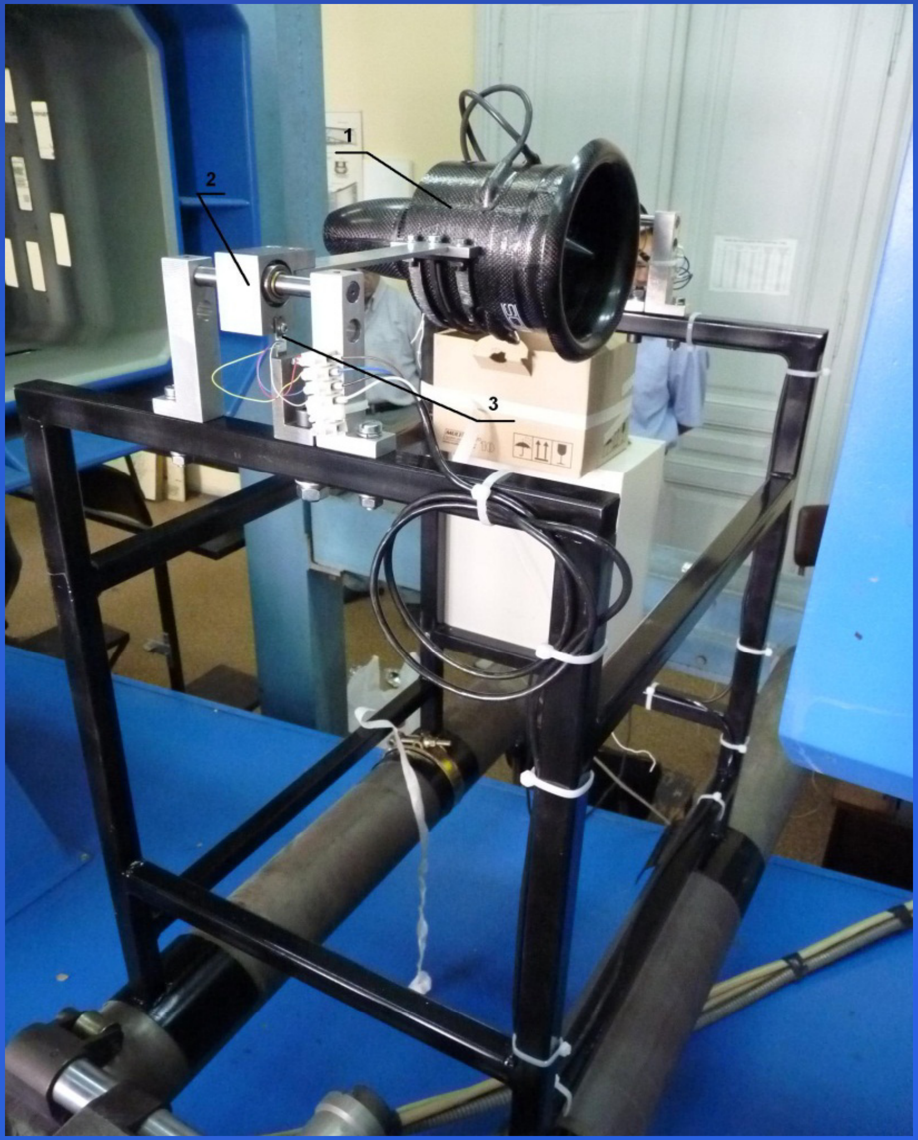
1.5
1
0.5
0
-0.5
-1
C_m
-15
-10
-5
0
5
10
15
20
α, deg

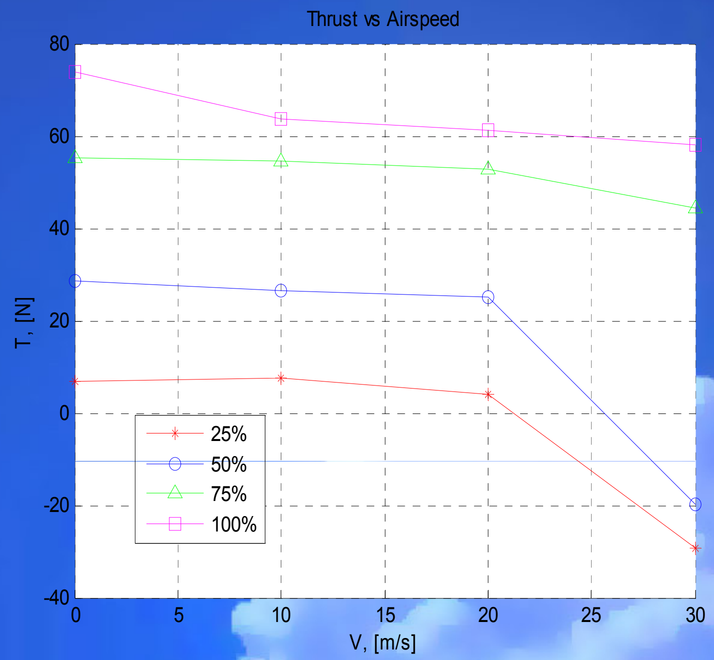


0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
C_L
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
C_D

Main Propulsion

Tests with Ducted Fans





Joined Wing (JoWi) 1

Joined Wing JoWi 2

Flight Test of JoWi 2

Flight test with Joined Wing UAV

Why VTOL

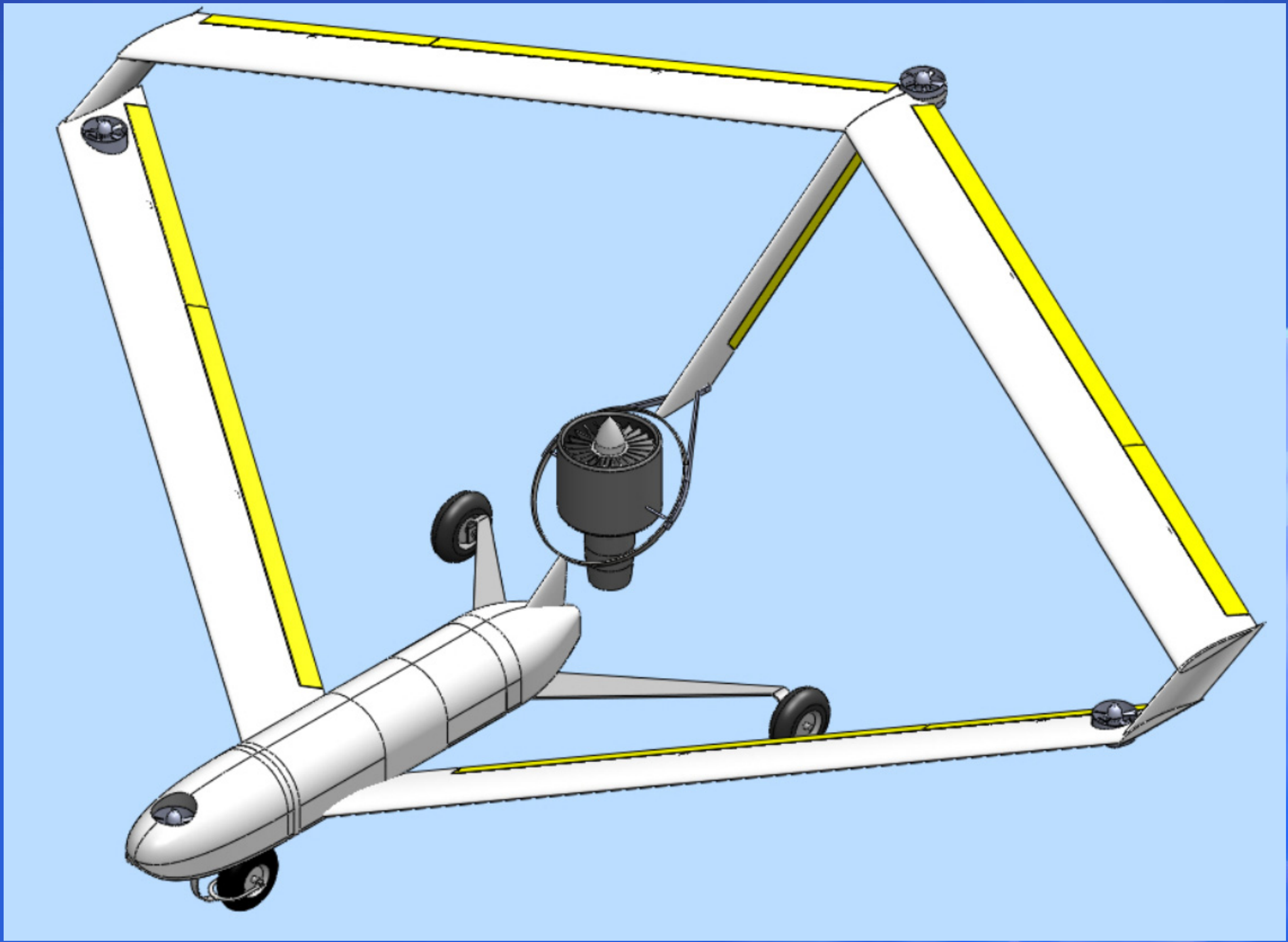
- PAV-NASA;
- Pplane-EU, 7 Framework Program;
- DARPA X-Plane;
- DARPA TERN Program;
- DARPA underwater launch vessel

Auxiliary Propulsion

Tests with ducted fans frame

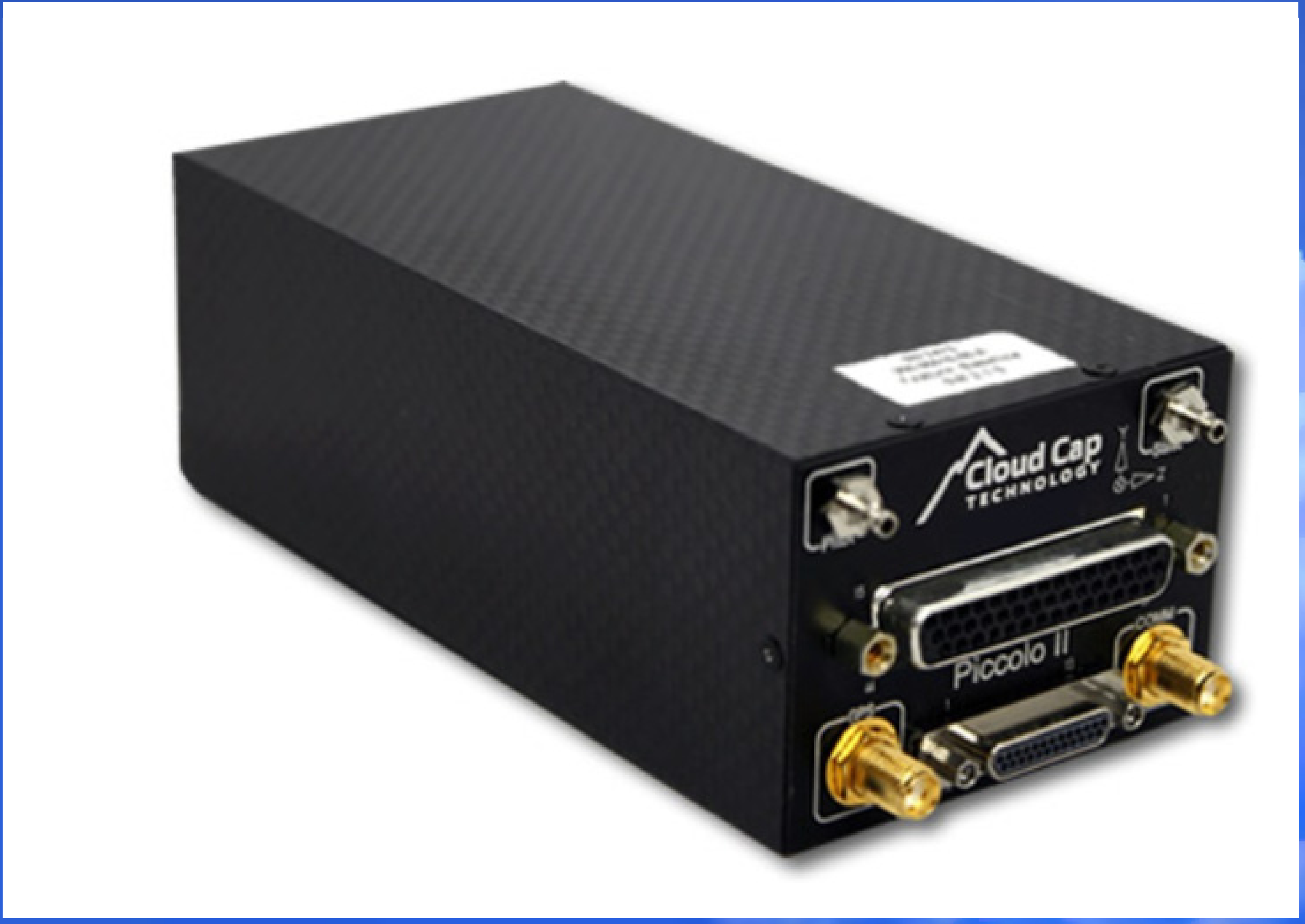
VTOL Flight Test

VTOL Joined Wing UAV



Autopilot ArduPilot Mega

Autopilot Piccolo II

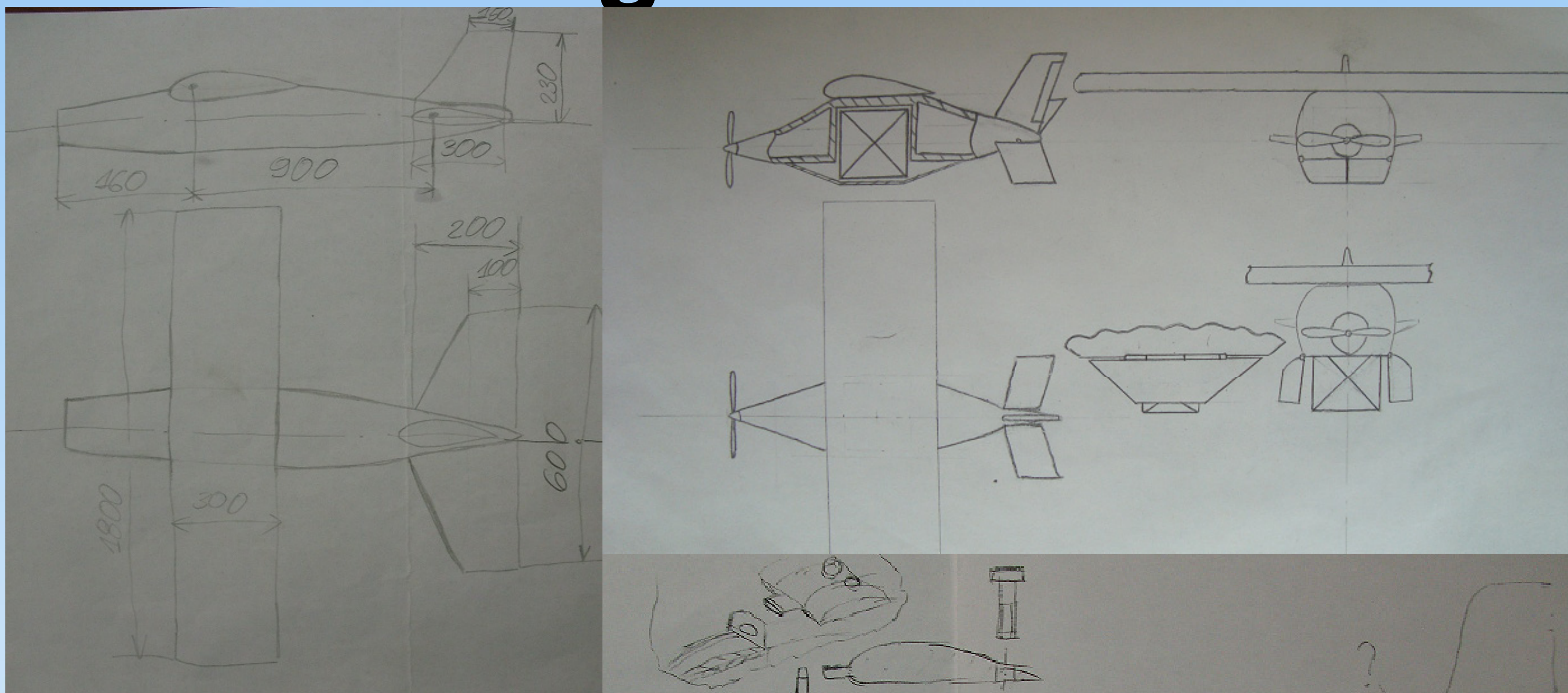


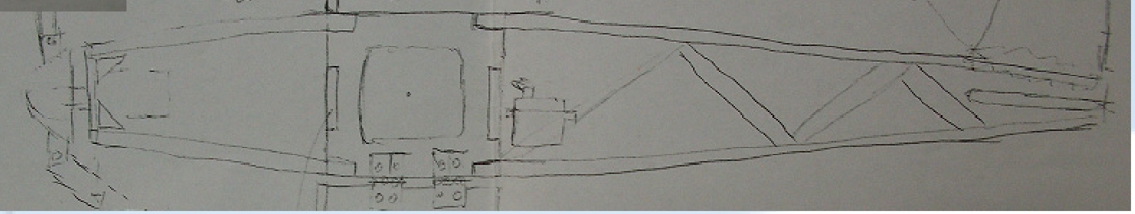
JoWi VTOL Lab Test

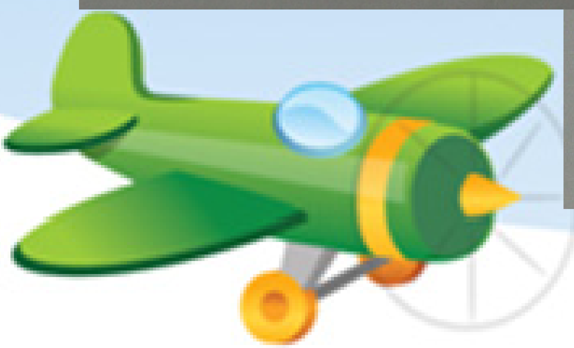
An exotic VTOL variant

Student's UAV contest

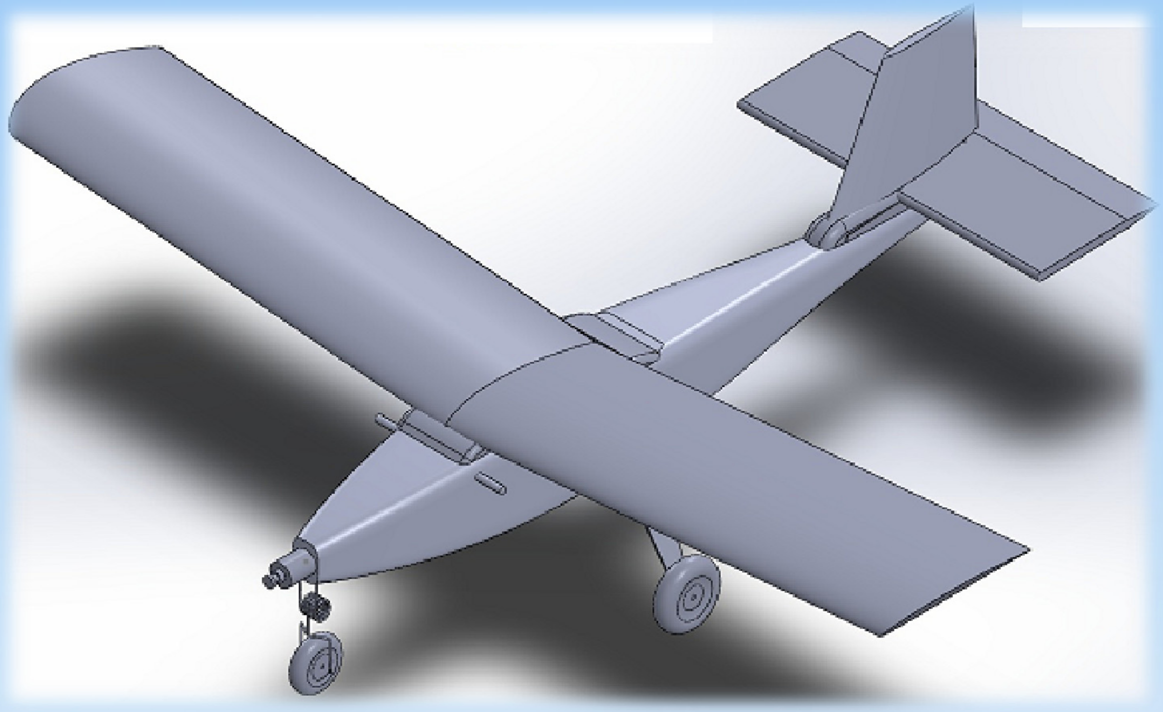
Sketching & Generation of design variants







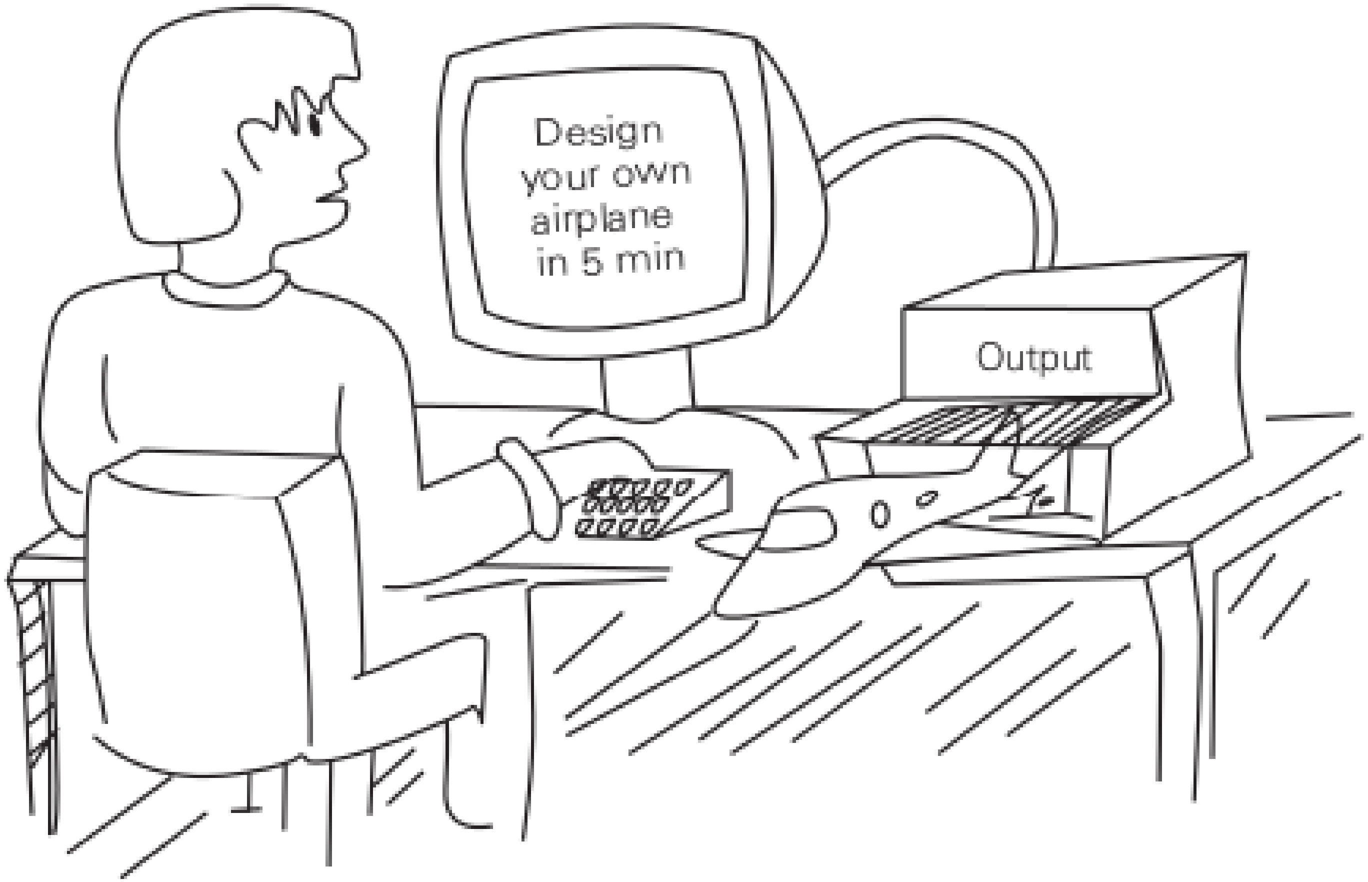
Basic design



“The winner takes it all”

Student's UAV contest

The lesson learned



The lesson learned

Cooperation

Cooperation

Cooperation

Cooperation

Thank you
for your attention

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

Open Access Publishing in Aerospace – Opportunities and Pitfalls

Dieter Scholz Hamburg University of Applied Sciences

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.18921

CEAS European Air & Space Conference 2013

Linköping, Sweden

16 to 19 September 2013

Contents

- Business Models
- Definitions: Open Access, Self-Archiving
- Open Access Spectrum
- Current Debate
- Criteria for OA Publishers and Journals
- Open Access Aerospace Journals
- Personal Conclusions

Contents

Business Models of traditional journals:

- **subscription-based** (paid by libraries, eventual by the government)
- **pay per view** (paid by readers for download of a single paper)
- **Hybrid OA** (paid by author for the benefit that readers do not need to pay for his/her paper)
- **advertisement** in journal.

Business Models of Open Access (OA) journals:

- **subsidized** (paid by: academic institution or learned society; eventual: by the government)
- **authors charged** (paid by: authors or their **funding agencies**; eventual: by the government)
- **institutional membership** (institutions pay a flat rate for publications of their members)
- **advertisement** on website

Open Access Directory: "OA journal business models"

Author payment models:

- **Free OA** (no payments by authors)
- **Gold OA** (moderate payments by authors;
  normally around 1000 €, but vary from 500 € to 2500 €.)
- **Hybrid OA** (often expensive payments by authors;
  around 3000 $)
- **Delayed OA** (embargo period, often no payments by authors)

Contents

Definition:

Open Access (OA) means “to provide the public with **unrestricted, free access to scholarly research** – much of which is publicly funded. Making the research publicly available to everyone – free of charge and without most copy-right and licensing restrictions”.

Budapest Open Access Initiative, 2001

The Budapest Open Access Initiative recommends establishing the “goal of achieving **Open Access** as **the default method** for distributing new peer-reviewed research”.

open access

Introduction

Definition:

Self-archiving is a possibility to **make research results public on the Internet** independent of a publisher. Self-archiving is sometimes also called **Green OA** and means "to deposit a digital document in a publicly accessible website".

eprints: "Self-Archiving FAQ"

Self-archiving is done for the purpose of maximizing the paper's accessibility and citation impact. The paper can be uploaded

- to the website of the researcher,
- to the website of an organization, or better
- **to a repository** (a systematic online collection of digital documents).

only 20% of traditional papers

Self-archiving is done **in parallel to traditional academic publishing**.

- A publisher with established **reputation** used for **peer review process**.
- The paper is made public in a **print journal** (with limited visibility).

Contents

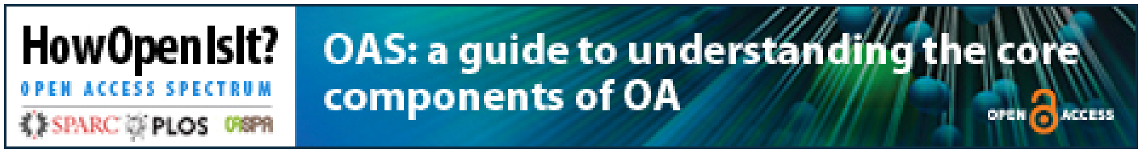
Open Access Spectrum

The Open Access Spectrum embraces **six core components**
with their *most open characteristics* they are:

1. **Reader Rights**: Free readership rights to all articles immediately upon publication.
2. **Reuse Rights**: Creative Commons License CC BY (by attribution).
3. **Copyrights**: Author holds copyright with no restrictions.
4. **Author Posting Rights**: Author may post any version to any repository or website.
5. **Automatic Posting**: Journals make articles automatically available in trusted third-party repositories (e.g. PubMed Central) immediate upon publication.
6. **Machine Readability**: Article full text, metadata, citations & data, including supplementary data, provided in community machine readable standard formats through a community standard API or protocol.

Open Access Spectrum

Access	Reader Rights	Reuse Rights	Copyrights	Author Posting Rights	Automatic Posting	Machine Readability	Access
OPEN ACCESS	Free readership rights to all articles immediately upon publication	Generous reuse & remixing rights (e.g., CC BY license)	Author holds copyright with no restrictions	Author may post any version to any repository or website	Journals make copies of articles automatically available in trusted third-party repositories (e.g., PubMed Central) immediately upon publication	Article full text, metadata, citations, & data, including supplementary data, provided in community machine-readable standard formats through a community standard API or protocol	OPEN ACCESS
	Free readership rights to all articles after an embargo of no more than 6 months	Reuse, remixing, & further building upon the work subject to certain restrictions & conditions (e.g., CC BY-NC & CC BY-SA licenses)	Author holds copyright, with some restrictions on author reuse of published version	Author may post final version of the peer-reviewed manuscript ("postprint") to any repository or website	Journals make copies of articles automatically available in trusted third-party repositories (e.g., PubMed Central) within 6 months	Article full text, metadata, citations, & data, including supplementary data, may be crawled or accessed through a community standard API or protocol	
	Free readership rights to all articles after an embargo greater than 6 months	Reuse (no remixing or further building upon the work) subject to certain restrictions and conditions (e.g., CC BY-ND license)	Publisher holds copyright, with some allowances for author and reader reuse of published version	Author may post final version of the peer-reviewed manuscript ("postprint") to certain repositories or websites	Journals make copies of articles automatically available in trusted third-party repositories (e.g., PubMed Central) within 12 months	Article full text, metadata, & citations may be crawled or accessed without special permission or registration	
	Free and immediate readership rights to some, but not all, articles (including "hybrid" models)	———	Publisher holds copyright, with some allowances for author reuse of published version	Author may post submitted version/draft of final work ("preprint") to certain repositories or websites	———	Article full text, metadata, & citations may be crawled or accessed with permission	
CLOSED ACCESS	Subscription, membership, pay-per-view, or other fees required to read all articles	No reuse rights beyond fair use/ limitations & exceptions to copyright (all rights reserved copyright) to read	Publisher holds copyright, with no author reuse of published version beyond fair use	Author may not deposit any versions to repositories or websites	No automatic posting in third-party repositories	Article full text & metadata not available in machine-readable format	CLOSED ACCESS



Contents

- Business Models
- Definitions: Open Access, Self-Archiving
- Open Access Spectrum
- **Current Debate**
- Criteria for OA Publishers and Journals
- Open Access Aerospace Journals
- Personal Conclusions

Current Debate

A **paradigm shift in the business model of academic publishing** got started.

Not all of the traditional publishers may survive, if they can not quickly enough adapt.

The “gold rush” in **starting new OA journals has not always brought quality**.

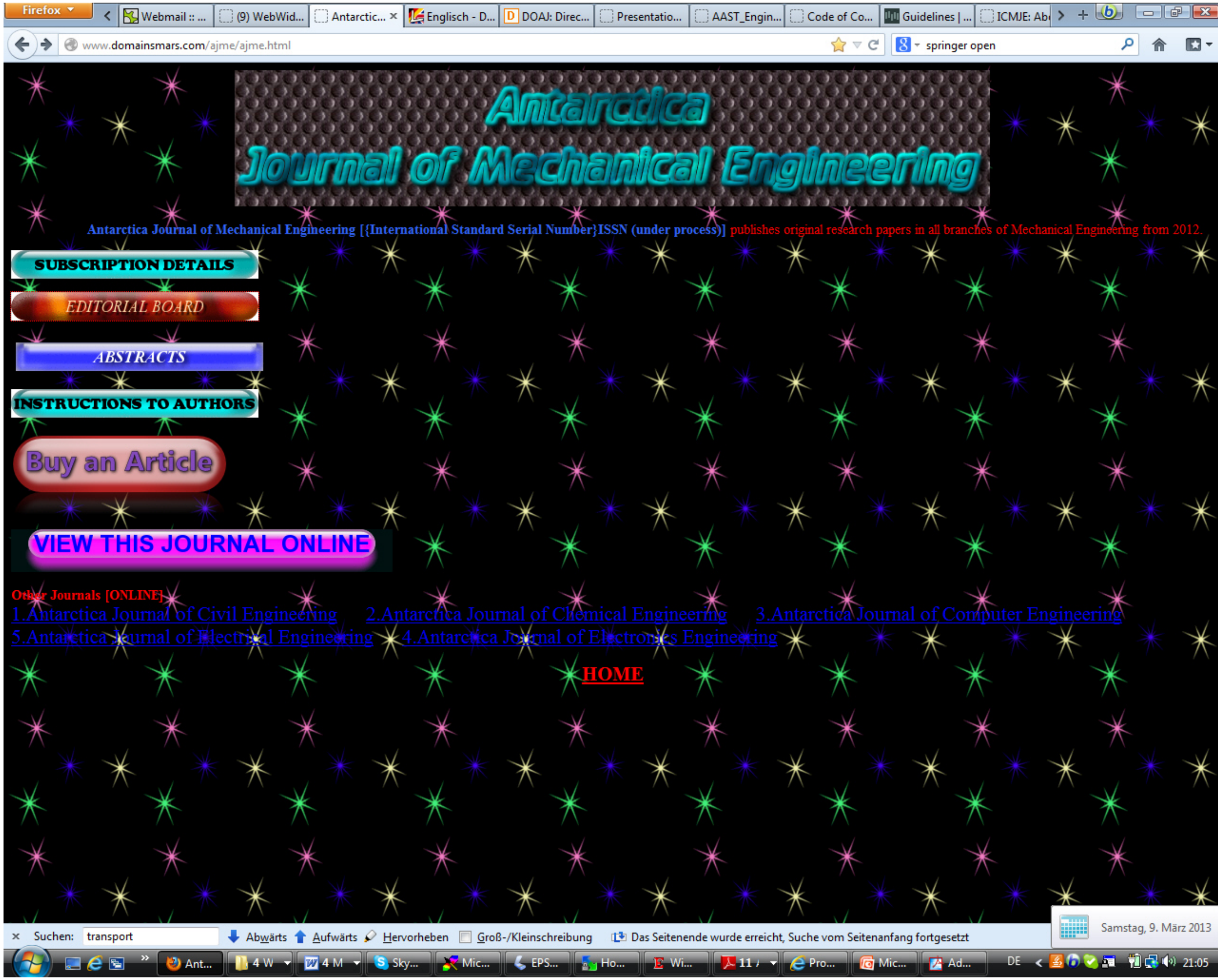
Sound and **established processes have yet to be found by the newcomers**.

At the heart of the debate is the **fear of traditional publishers to loose market share and profit**.

At the heart of the debate is the **fear to loose all quality in academic publishing**.

Current Debate

Example of a "newcomer":



Current Debate

Open access newcomers are under heavy observation. Two possibilities exist:

To black-list journals and publishers who do not perform up to established standards.
"**Beall's List of Predatory Publishers 2013**" is the current prominent blacklist with
- 242 OA publishers and
- 126 OA journals listed.

To white-list journals and publishers who have undergone a minimum check
by a respected organization and are listed with this organization:
- The **Directory of Open Access Journals** (DOAJ) it is a first good sign.
  DOAJ lists currently almost 10000 OA journals.
- The **Open Access Scholarly Publishers Association** (OASPA) doing a detailed check.
  OASPA lists currently (only) about 40 OA professional publishing organizations.

Contents

Criteria of the Open Access Scholarly Publishers Association (OASPA)

- Open Access without delay (e.g. no embargo period).
- Provide all necessary information:
    - journal's aims and scope,
    - presentation of the editorial board,
    - author guidelines,
    - description of the quality control system.
- Full contact information is visible on the website and includes a business address.
- Clear and detailed instructions for authors are present and easily located.
- All articles shall be subjected to some form of peer-based review process.
- Journals shall have editorial boards - members are recognized experts.
- Any fees for publishing in the journal are clearly displayed.
- If there are no charges to authors this should also be highlighted.

Criteria for OA Publishers and Journals

Criteria of the Open Access Scholarly Publishers Association (OASPA)

- Published articles should clearly show the licensing policy of the journal.
- Ideally, the policy should be equivalent to CC BY (also CC BY-NC is acceptable).
- Any direct marketing activities shall be appropriate and unobtrusive.
- OASPA will request information about the legal status of the publishing organization:
    - privately-owned,
    - public company,
    - not-for-profit organization or a charity.
- OASPA will request company registration information.
- Demonstration of the following is also desirable:
    - abstracting and indexing services for the journal(s),
    - availability of Document Identifier - DOIs for published content,
    - Committee on Publication Ethics (COPE) membership,
    - archiving policy.

Contents

International Journal of Aerospace Engineering

Hindawi Publishing Corporation

http://www.hindawi.com/journals/ijae

Origin: Egypt

Started: 2008

Fees: **600 USD**

Publisher and journal white-listed: DOAJ (SPARC Europe Seal) (**405**/**73000**/**79**), OASPA

Publisher black-listed: none

ISSN, eISSN, DOI, PDF, HTML, CC BY, copyright retained

Articles: 84 (14 per year)

Indexed in databases/resources: 28

Editor-in-Chief: **none**

Members on Editorial Board: **75**

Reviewers acknowledged: 340

Web page appearance: good

405: number of journals by publisher in DOAJ

73000: number of articles by publisher in DOAJ

79: number of aerospace articles by publisher in DOAJ

Open Aerospace Engineering Journal

Bentham open
http://www.benthamscience.com/open/toaej
Origin: USA / United Arab Emirates, ... / hidden
Started: 2010
Fees: 250 USD
White-listed: DOAJ (106/139/0)
Black-listed: Beall (no comments given), Linköpings Universitet
ISSN, PDF, CC BY-NC, copyright retained
Articles: 20 (7 per year)
Editor-in-Chief: Dan Mateescu, Canada
Members on Editorial Board: **84**
Web page appearance: “less convincing”

Journal of Aeronautics & Aerospace Engineering

OMICS Group
http://www.omicsgroup.org/journals/jaaehome.php
Origin: USA / India
Started: 2012
Fees: 919 USD
White-listed: DOAJ (1/207/0)
Black-listed: Beall (no comments given), Linköpings Universitet
ISSN, HTML, PDF, Audio, CC BY, copyright retained
Articles: 21 (10 per year)
Indexed in databases/resources: 4
Editor-in-Chief: Prof. Raffaele Savino, Italy
Members on Editorial Board: 47
Web page appearance: “less convincing”

Frontiers in Aerospace Engineering (FAE)

Science and Engineering Publishing Company
Journal: http://www.fae-journal.org; Publisher: http://www.seipub.org
USA / China
Started: 2012
Fees: 0 USD (in 2013)
Publisher white-listed: none
Publisher black-listed: Beall (comments outdated)
ISSN, eISSN, PDF, CC BY-NC-ND, copyright ret.
Articles: 22 (22 per year)
Indexed in databases/resources: 15
Editor-in-Chief: Prof. Pizhong Qiao
Members on Editorial Board: 10
Web page appearance: good

Advances in Aerospace Science and Technology (AAST)

Scientific Research Publishing

http://www.scirp.org/journal/aast

USA (registration) / China (offices)

Started: 2013, Fees: 300 USD

Publisher white-listed: DOAJ (**127**/**19000**/**0**), application: OASPA

Publisher black-listed: Beall (no comments given)

CC BY or CC BY-NC, copyright retained

Editor-in-Chief: Prof. Dieter Scholz, Germany

Members on Editorial Board: 10

STARTUP!

INCAS Bulletin

National Institute for Aerospace Research (INCAS)
http://bulletin.incas.ro
Origin: Romania
Started: 2009
Fees: 0 USD (according to DOAJ), no information given on web page, response to email: no fee, **international authors welcome**
Publisher white-listed: DOAJ (1/277)

European Transport Research Review

Springer
http://www.springer.com/engineering/civil+engineering/journal/12544
for the
European Conference of Transport Research Institutes (ECTRI)
http://www.ectri.org
Origin: Germany
Started: 2009
Articles: 110 (28 per year)
Fees: 0 USD (according to – information delivered to – DOAJ), no information given on web page, **response to email: 1250 EUR** (if not sponsored by ECTRI)
Publisher and journal white-listed: DOAJ (**105**/**13000**/**0**), **OASPA member**

Contents

- Business Models
- Definitions: Open Access, Self-Archiving
- Open Access Spectrum
- Current Debate
- Criteria for OA Publishers and Journals
- Open Access Aerospace Journals
- **Personal Conclusions**

Personal Conclusions

- **OA is <u>the</u> way for the future.**

- **Green OA and self-archiving is possible. This however is not a final solution.**

- **Commercial OA Journals obviously need to charge publication fees in some form.**

- **Two different approaches:**

1.) Funded organizations (universities, research establishments, societies) could handle smaller OA aerospace journals (**like** the **INCAS Bulletin**) based on PDF articles and basic and simple HTML web pages or based on the Open Journal Systems (OJS). OA publishing would be **free of charge**.

2.) In the same way as companies like **e.g.** Airbus are **cooperating with China**, editors-in-chief can get active and can build quality into existing or startup journals from such countries offering **low cost** OA publishing.

Personal Conclusions

Let every nation bring in their strength.

Let's not destroy,

but rather let's work together in this world,

share our knowledge and

let's live in peace!

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546442

Conceptual design of passenger aircraft for in-flight refueling operations

G. La Rocca
P. van der Linden
M. Li

EWADE 2013

11th European Workshop on Aircraft Design Education
Linköping, Sweden

September 2013

TU Delft Delft University of Technology

Challenge the future

Introduction

- One of the biggest challenges for future aviation is represented by the increasing **cost and scarcity of fossil fuel**.

- The demand of air transportation is steadly increasing, while the constraints on the allowed environmental impact by authorities are getting more stringent

- New designs and operational concepts are required to meet the ambitious challenges devised by ACARE

+60 years

The RECREATE project

- In the RECREATE (**RE**search on a **CR**uiser **E**nabled **A**ir **T**ransport **E**nvironment) project, European research institutes, universities and small businesses work together to investigate a future air transportation system based on the **cruiser-feeder** concept

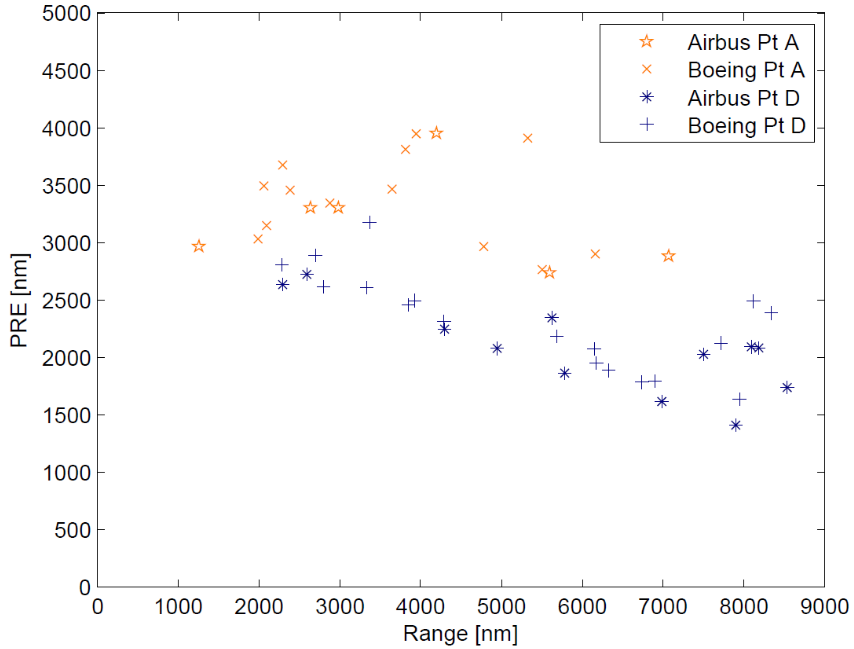
- **In Flight Refueling (IFR) operations** for passenger aircraft is actually one of the two main concepts addressed by RECREATE.

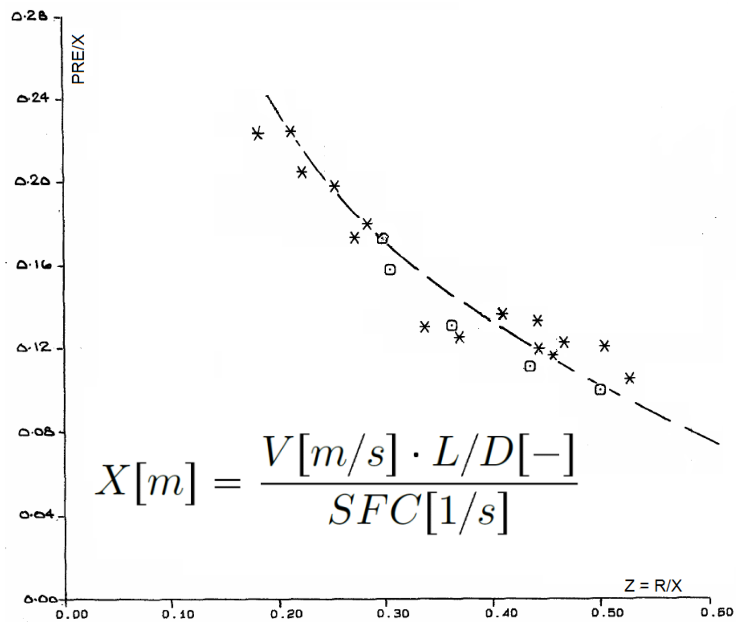
Dr. R. K. Nangia
Nangia Aero Research Associates

SEVENTH FRAMEWORK PROGRAMME

Payload range efficiency versus range

- The success of staged and IFR flight revolves on the assumption that, flying a mission divided in multiple smaller submissions, yields fuel savings
- Fuel efficiency between aircraft is compared by the **Payload Range Efficiency**: $PRE[m] = \frac{WP[kg] \cdot R[m]}{WFB[kg]}$





Objectives of this work

Although IFR is a time proven concept in military operations, is it possible and convenient to apply as such to passenger air transportation?

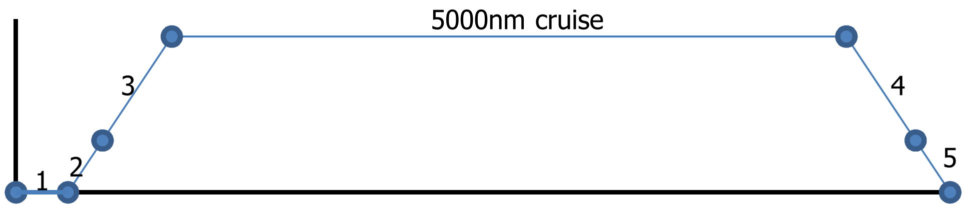
Main goal of this research*

Develop the conceptual design of a passenger aircraft (the cruiser) for IFR operations and compare its fuel consumption to direct and staged flight operation.

*sub-goal of RECREATE

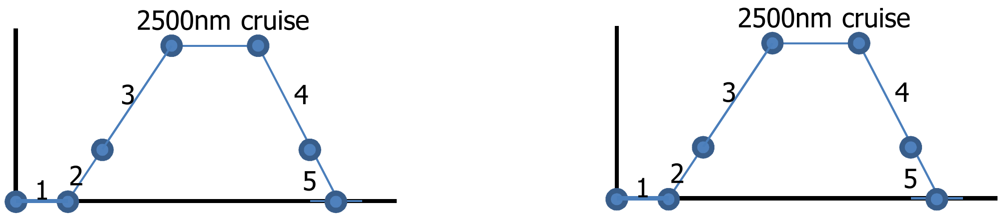
Operation concepts and mission profiles

Direct flight



1 Start & Taxi
2 Take-off
3 Climb
4 Descent
5 Landing

Staged flight



IFR operation

- Rendezvous with tanker
- Change between flight phases

Cruiser Top level requirements

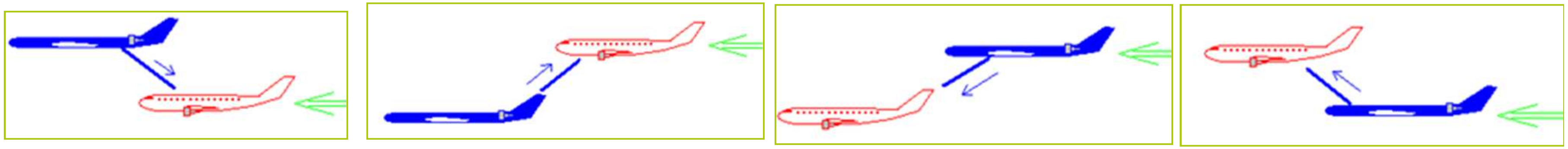
- Use a conventional configuration
- Single stage **range of 2500nm**
- **250 passengers**, single class, twin aisle, LD-3 container capability
- Take-off field length < 2000 m
- Landing field length < 2600 m
- Cruise mach number of 0.82 @ 10500 m
- Specific fuel consumption of 0.525 lb/(lbf·h)

Cruiser-tanker IFR configurations

Is this good if there are passengers here?

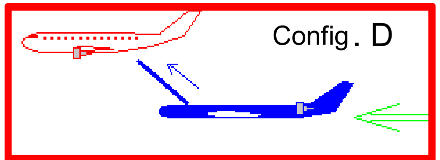
A trade-off is performed to assess possible alternatives and finally to select the most convenient procedure for civil refueling operations

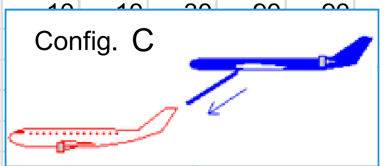
Cruiser-tanker IFR configurations

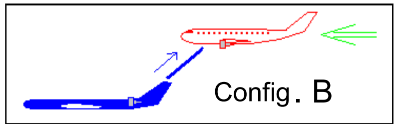


A B C D

Criteria \ Configuration	Grades (1-9) A	B	C	D	Weigh	Score A	B	C	D
c1 Pilot's visibility of approaching aircraft	9	5	5	9	7	63	35	35	63
c2 Component detachment hazard	1	3	9	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c3 Ride quality of cruiser	1	1	9	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c4 Noise to the cruiser	1	2	9	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c5 Pump requirement	9	8	9	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c6 Fuel pipe fire hazard	5	9	7	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c7 Boom related weight	9	8	1	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
c8 Boom stability	9	9	1	1	15	135	135	[illegible]	[illegible]
c9 Maturity of boom technology	9	8	1	1	14	126	112	[illegible]	[illegible]
c10 Formation aerodynamics	6	9	9	9	4	24	36	[illegible]	[illegible]
c11 Training cost of approaching aircraft	1	1	9	9	9	9	9	[illegible]	[illegible]
c12 All weather refueling capability	1	1	9	9	10	10	10	[illegible]	[illegible]
TOTAL					100	520	536	584	628

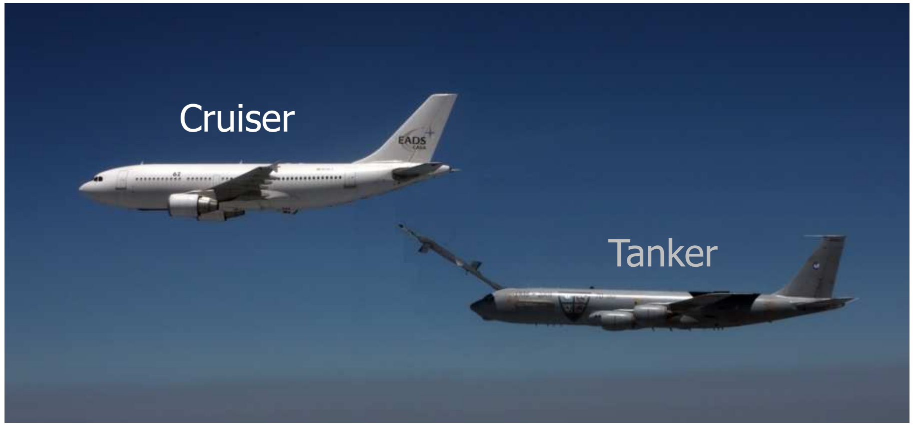






Cruiser-tanker IFR configurations

The trade off winning configuration:

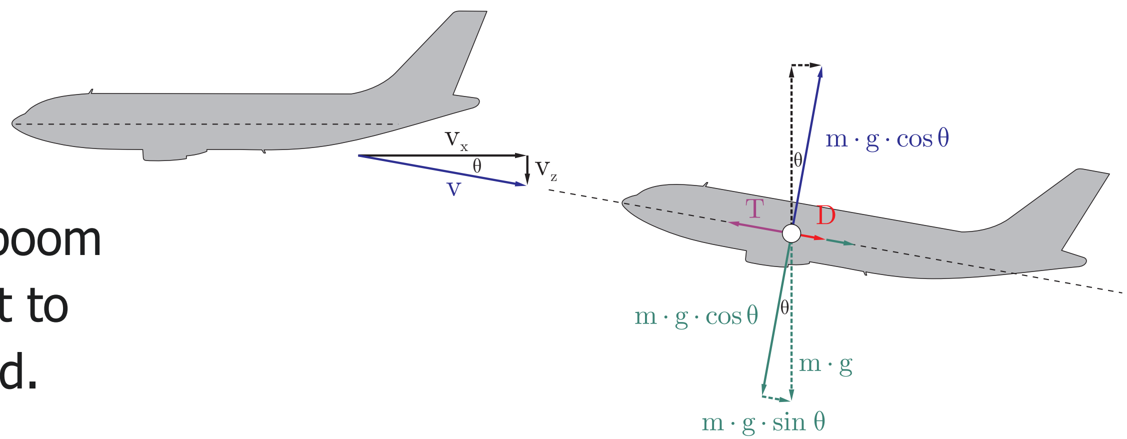


The tanker approaches the cruiser from behind and below

Cruiser-tanker IFR configurations

Advantages

- No hazard of collision with parts detaching from the tanker
- Cruiser pilots are not required to perform the approach maneuver
- Cruiser's architecture minimally affected by the presence of the refueling system.
- Only tanker aircraft to be provided with air-to-air radar
- Passengers not subjected to maneuvering acceleration
- no extra thrust requirement for passenger aircraft during refueling



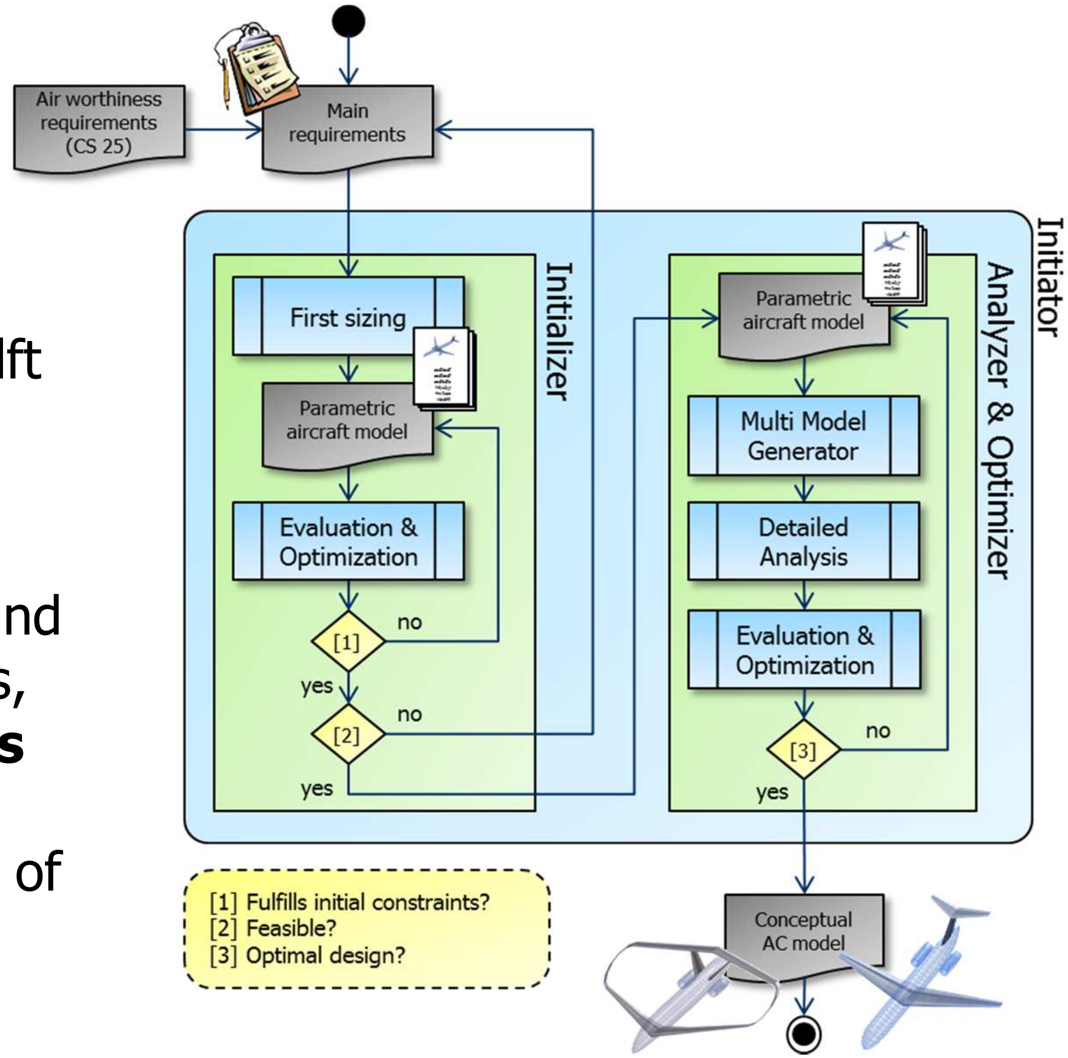
Disadvantages

- A forward extending boom (i.e., unstable, subject to divergence) is required.

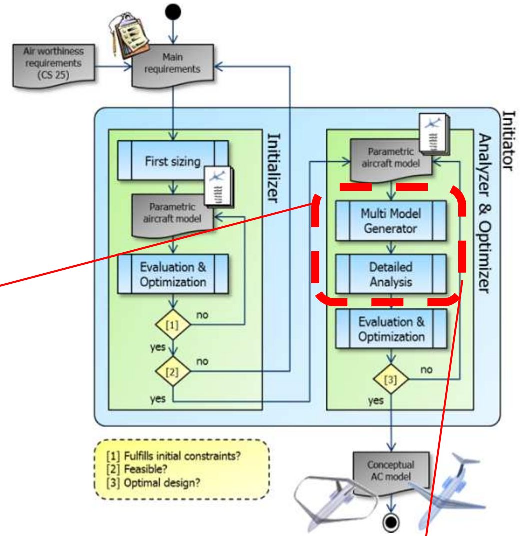
The Initiator

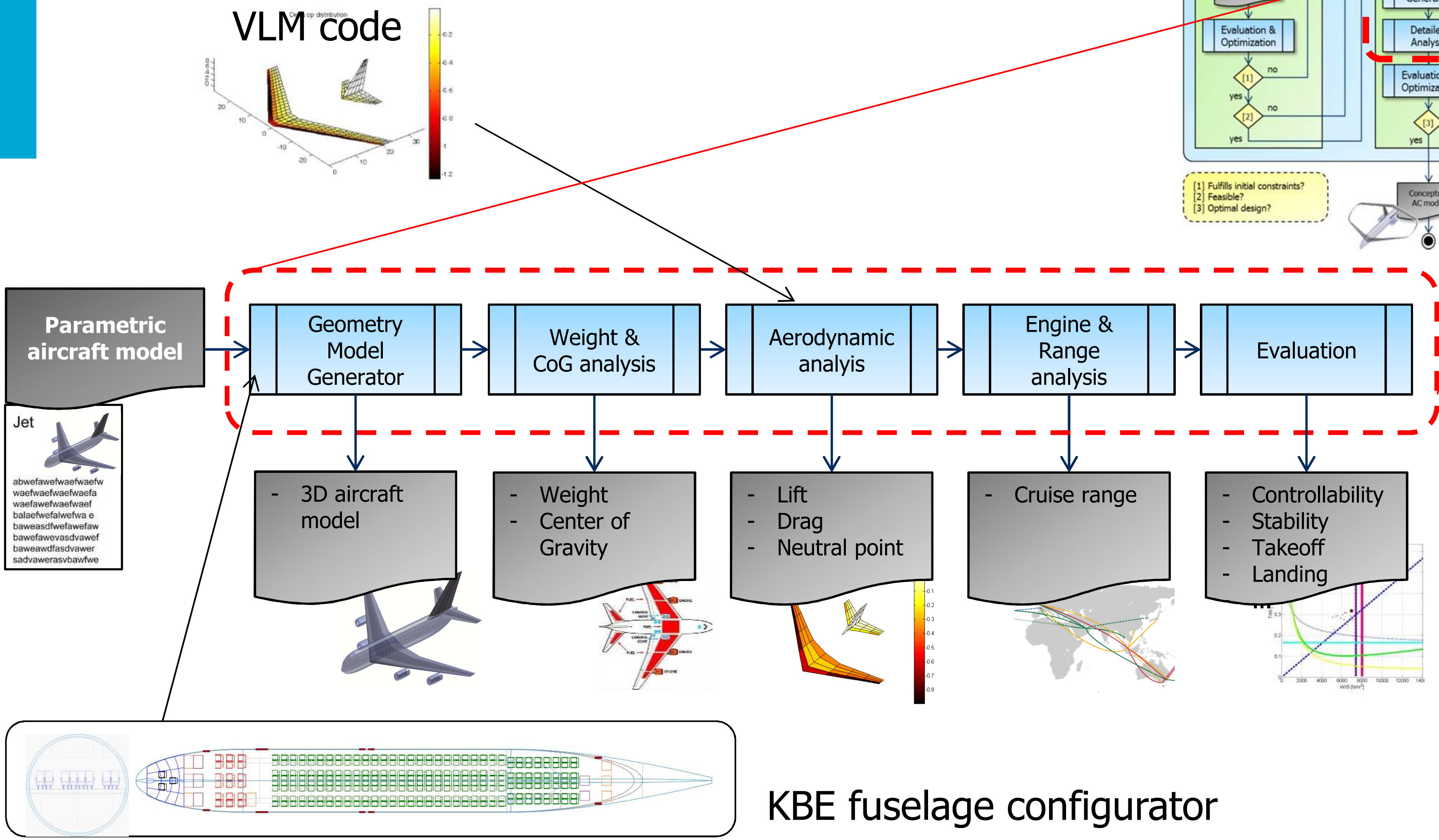
A software tool under development at the TU Delft for **augmented aircraft conceptual design**.

It makes use of statistics and semi-empirical design rules, **medium fidelity analysis tools**, and an optimizer to perform conceptual design of conventional and novel aircraft configurations

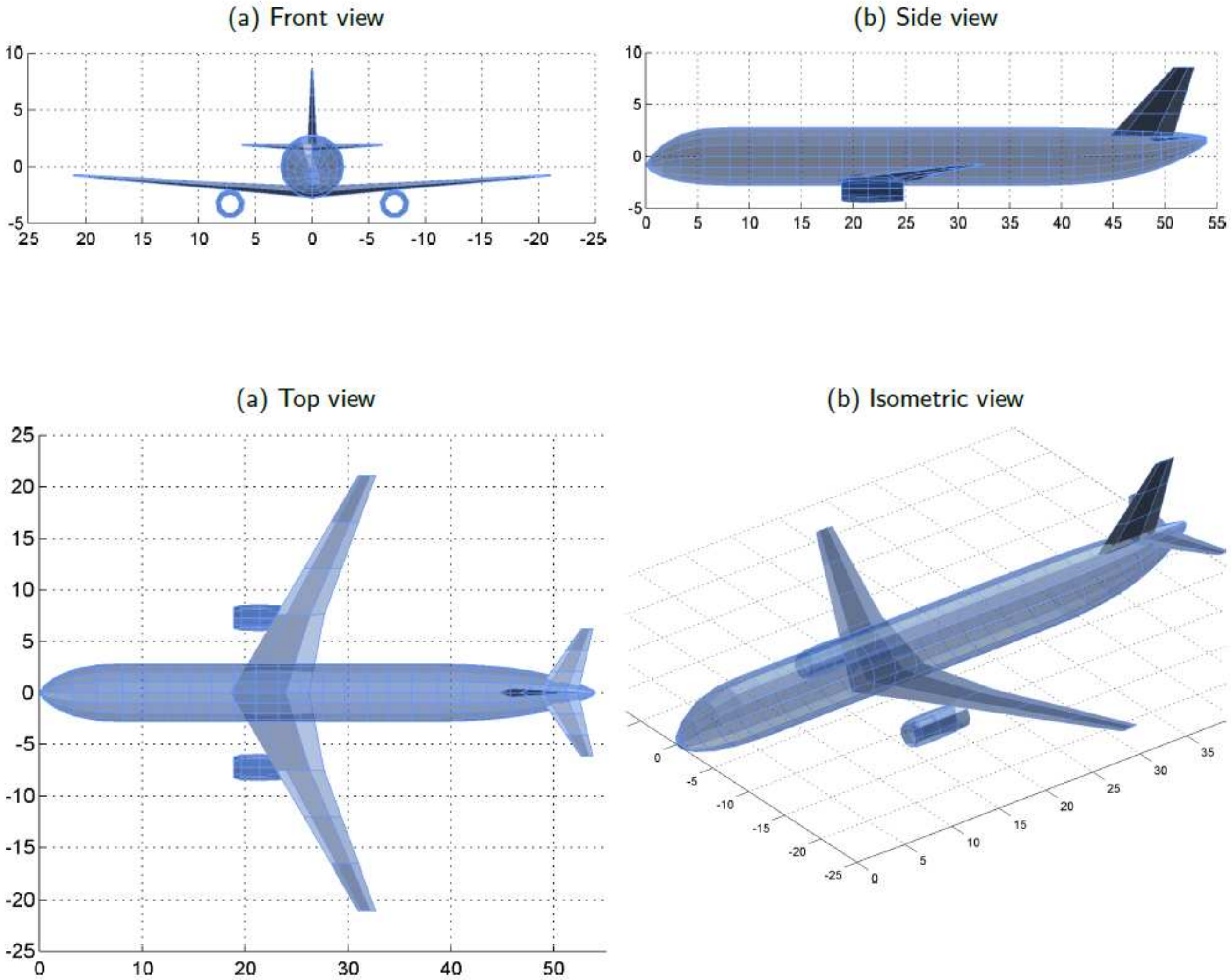


The Initiator



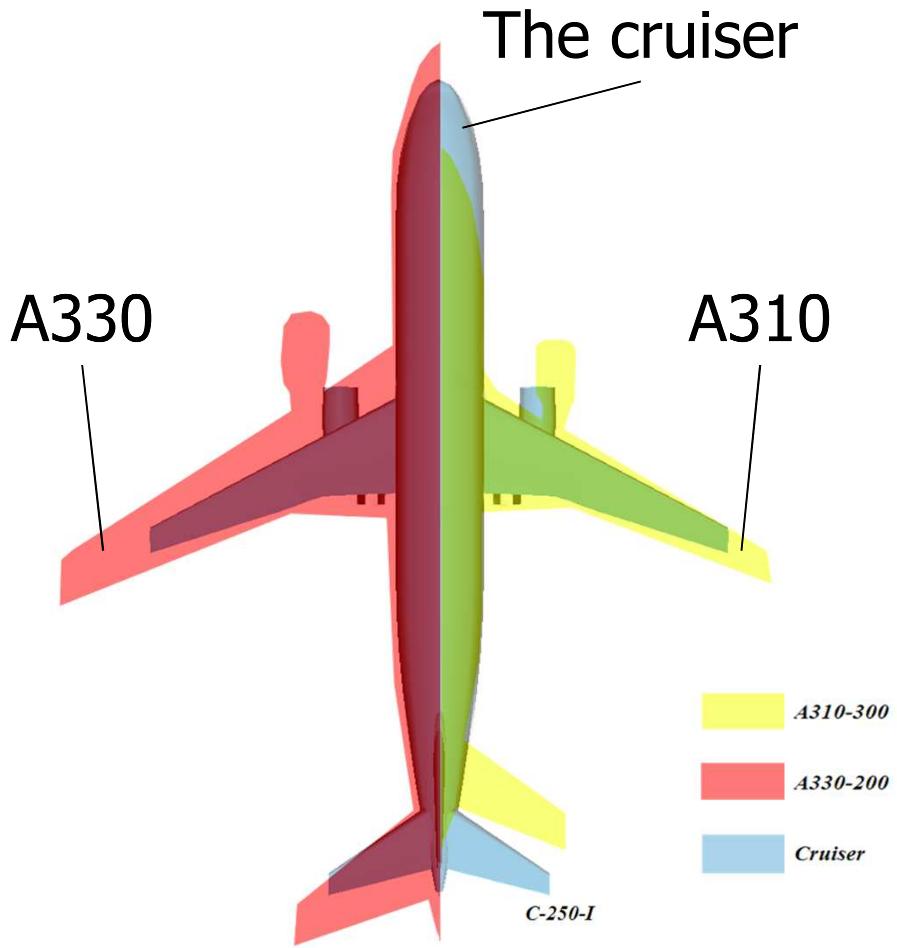


Cruiser design



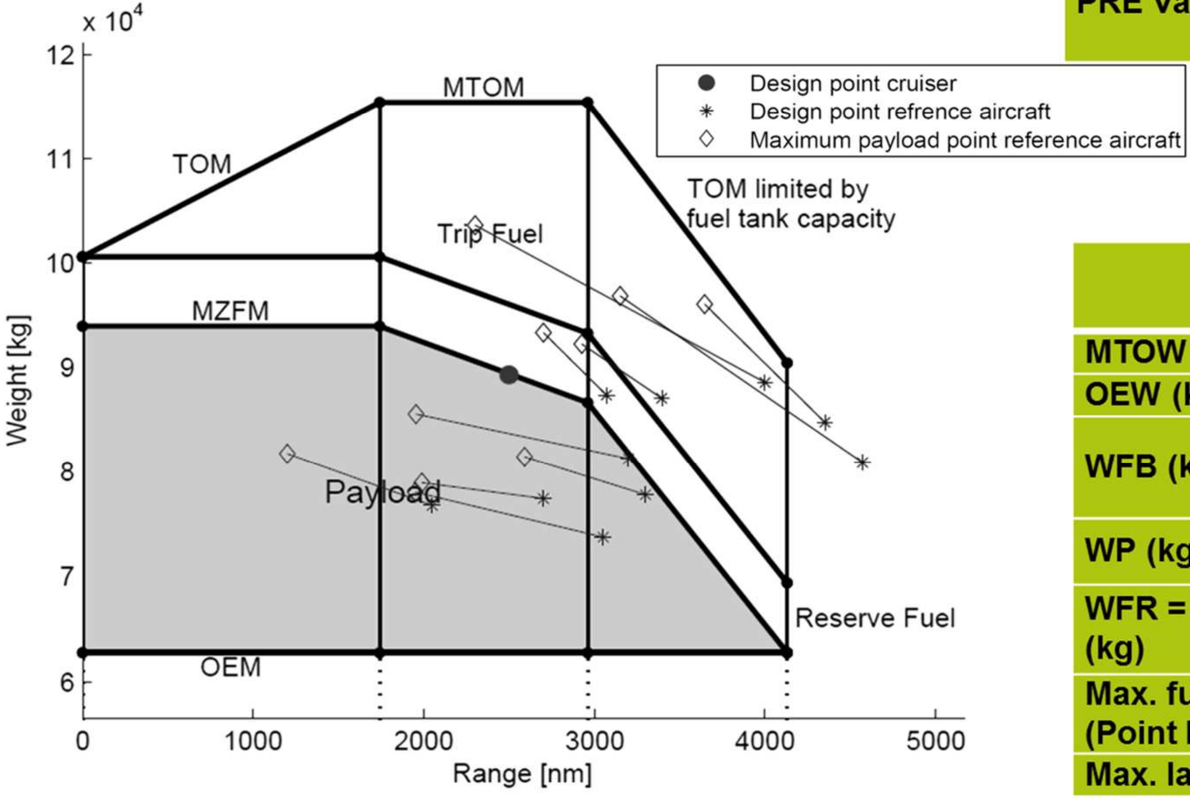
Cruiser design

Fuselage	
Length (m)	54.0
Diameter (m)	5.64
Wing	
Ref Area (m^2)	178.2
Span (m)	42.21
Aspect Ratio	10
Taper Ratio	0. 23
1/4 Chord Sweep (degree)	27.27



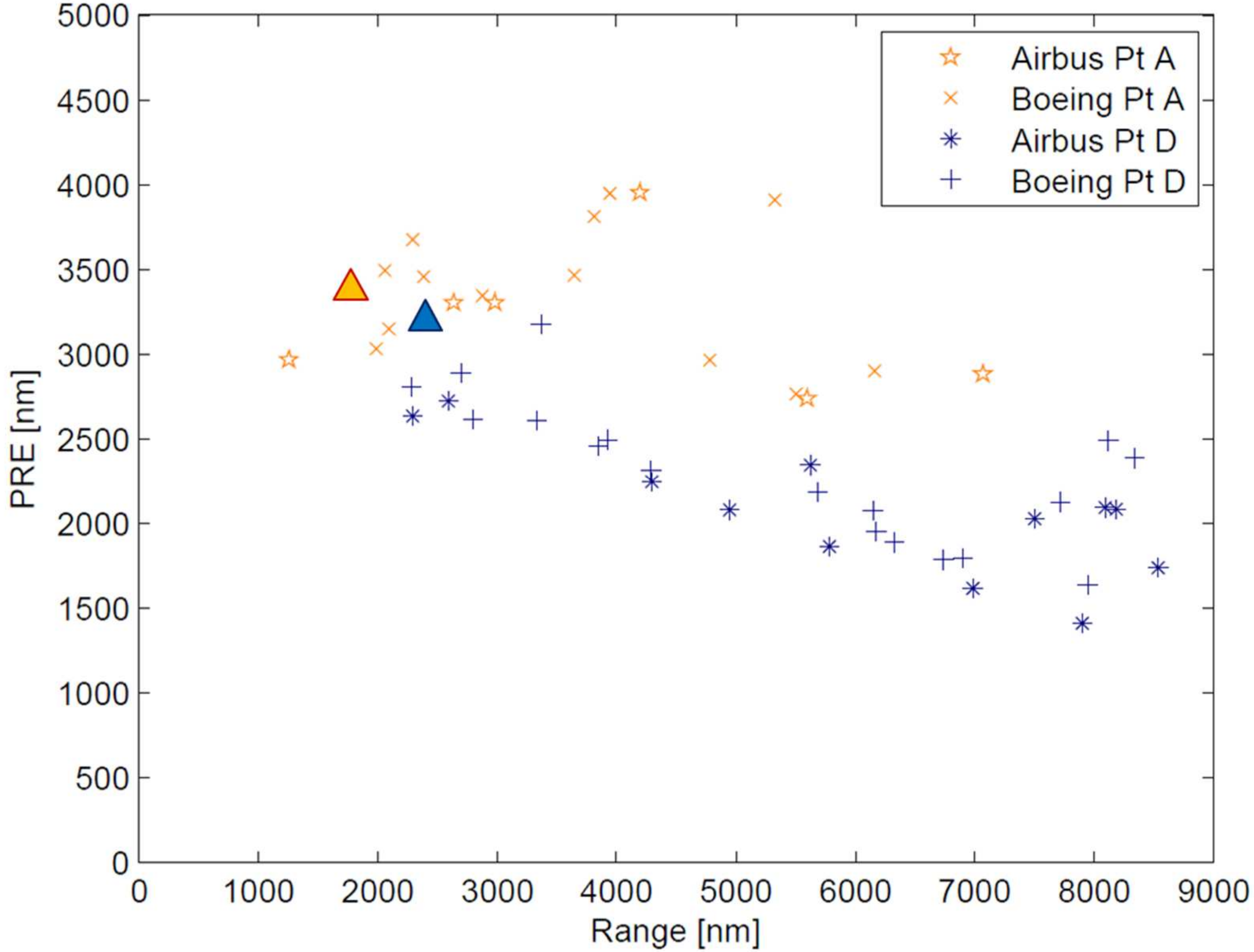
Payload range diagram

Performance			
L/D	17.9		
X	16116 [nm]		
Max. wing loading (kg/m²)	648		
Thrust/Weight Ratio	0.32		
PRE values (nm) @ pts.	A 3341	B 2992	D 3166

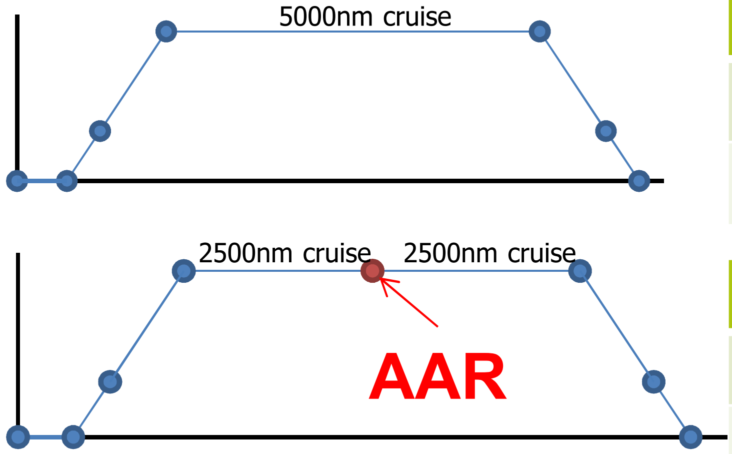


Weights and Weight Ratios			
MTOW (kg)	115396		
OEW (kg)	62774		
WFB (kg) @ pts.	A 16252	B 23578	D 20928
WP (kg) @ pts	31176	23850	26500
WFR = 4.5 % of MTOW (kg)	5192.8		
Max. fuel/MTOW (Point B)	0.25		
Max. landing/MTOW	0.83		

Payload range efficiency (PRE)



Non-stop versus IFR operations

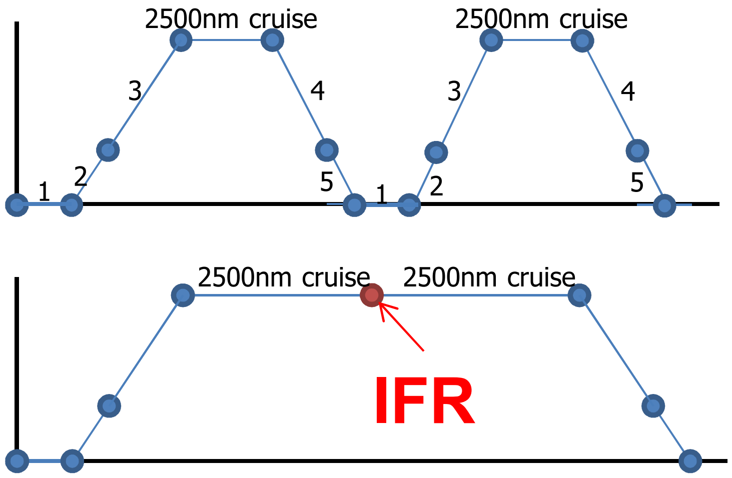


Aircraft	WFB_1 [kg]	WFB_2 [kg]	WFB_T [kg]
Cruiser	18955	18182	37137
5000nm non-stop	-	-	46652

5000nm, IFR vs. Non-stop	
Fuel received by tanker [kg]	16259
Fuel saved by cruiser w.r.t non-stop (tanker fuel not accounted!) [kg]	**9515**
Fuel_saved/Fuel_received	**0.58**

IF the fuel burnt by tanker to deliver the fuel required by cruiser (16259 Kg) < 9515 Kg, **THEN** IFR operation yields fuel saving!

Staged-flight versus IFR operations



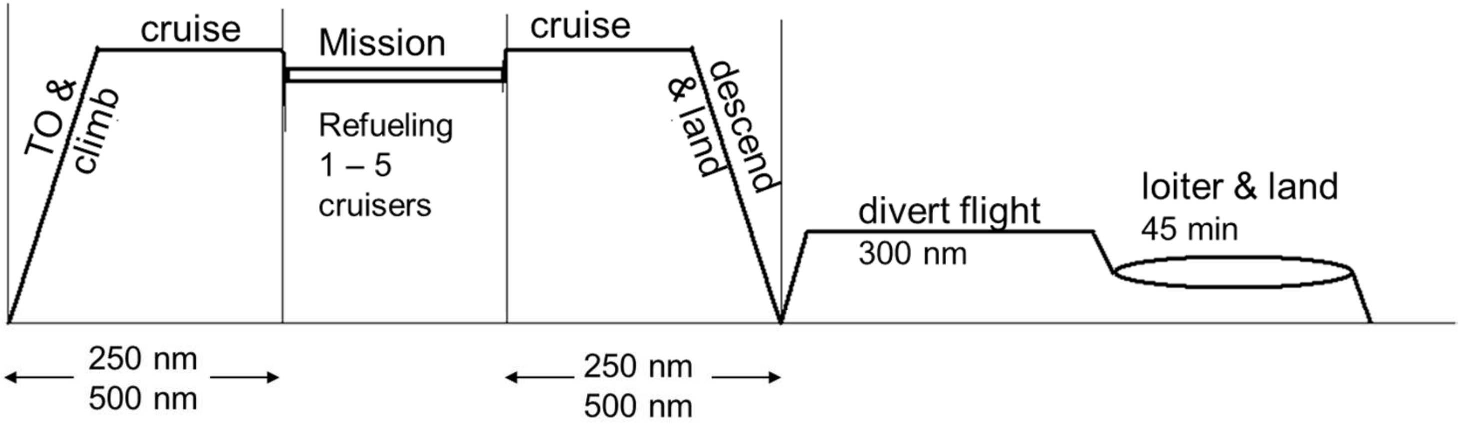
Aircraft	WFB_1 [kg]	WFB_2 [kg]	WFB_T [kg]
In-flight refueling	18955	18182	37137
Staged flight	20928	20928	41856

5000nm, IFR vs. Non-stop	
received fuel for AAR operation [kg]	16259
saved fuel by AAR operation [kg]	**4719**
Fuel_saved/Fuel_received	**0.29**

- In term of flight duration (comfort) and fatigue life, IFR is obviously better than staged-flight
- IFR with small tankers can be more fuel efficient than staged-flight operations

Tanker Design

2 families of tankers designed for **10 specific missions** (radius & no ref. ops.)



Tanker coding:

T-250-3:

Conventional tanker

Design refueling radius: 250nm

Refueling num. of cruisers: 3

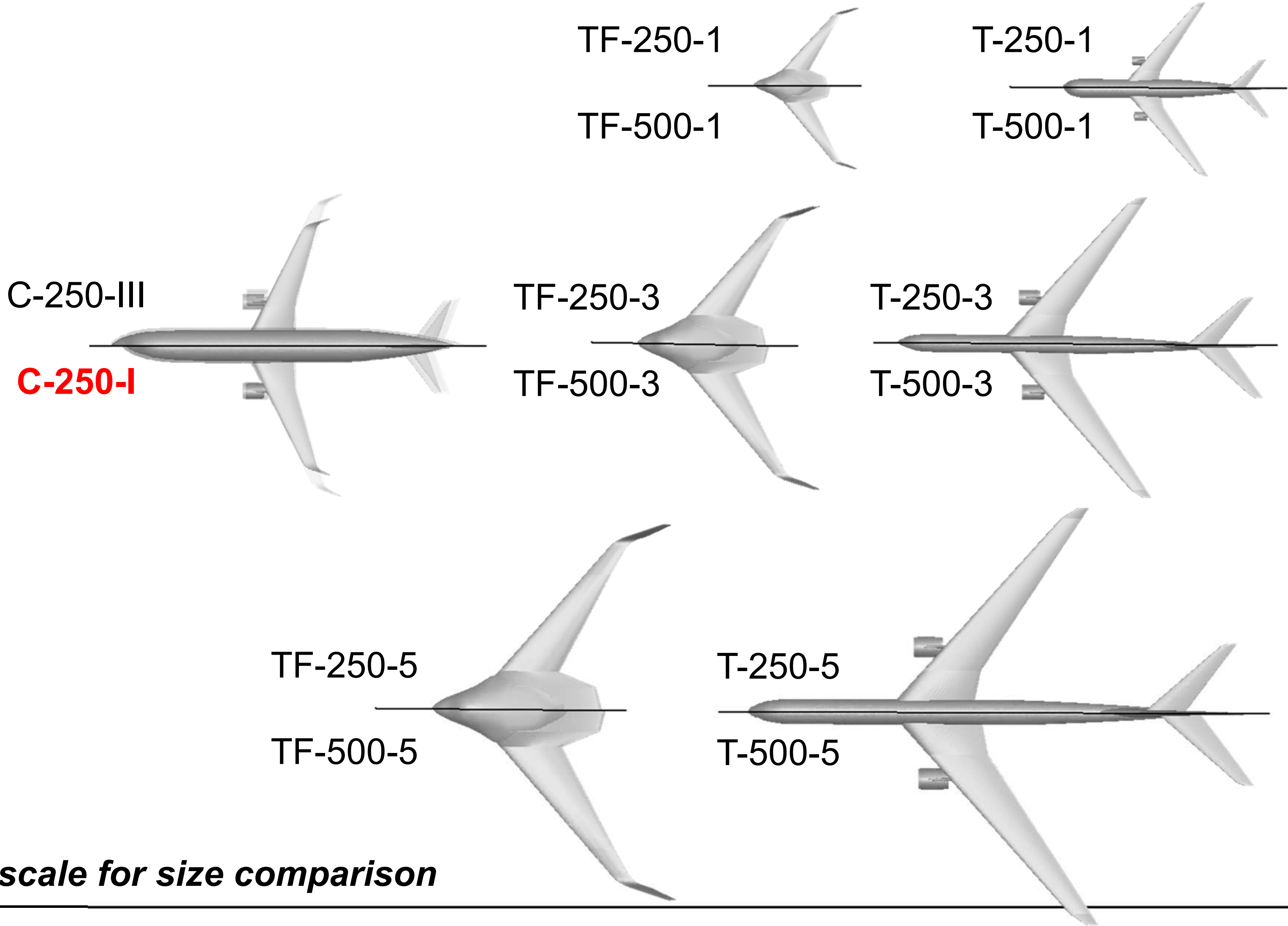
TF-500-5:

Flying-wing tanker

Design refueling radius: 500nm

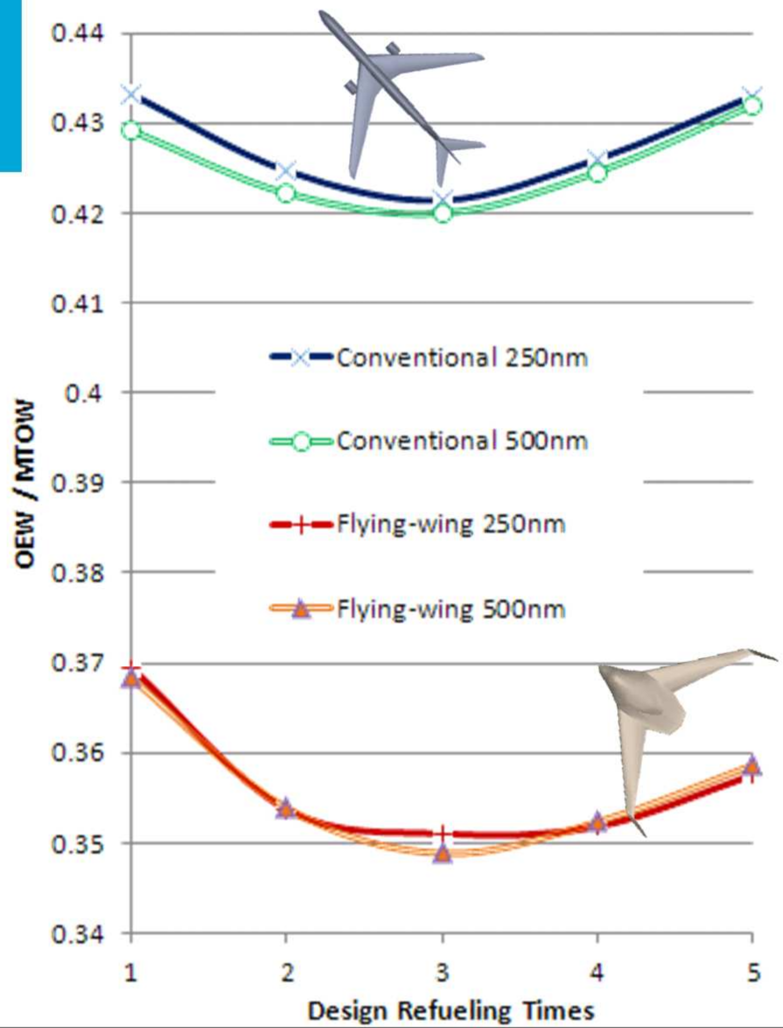
Refueling num. of cruisers: 5

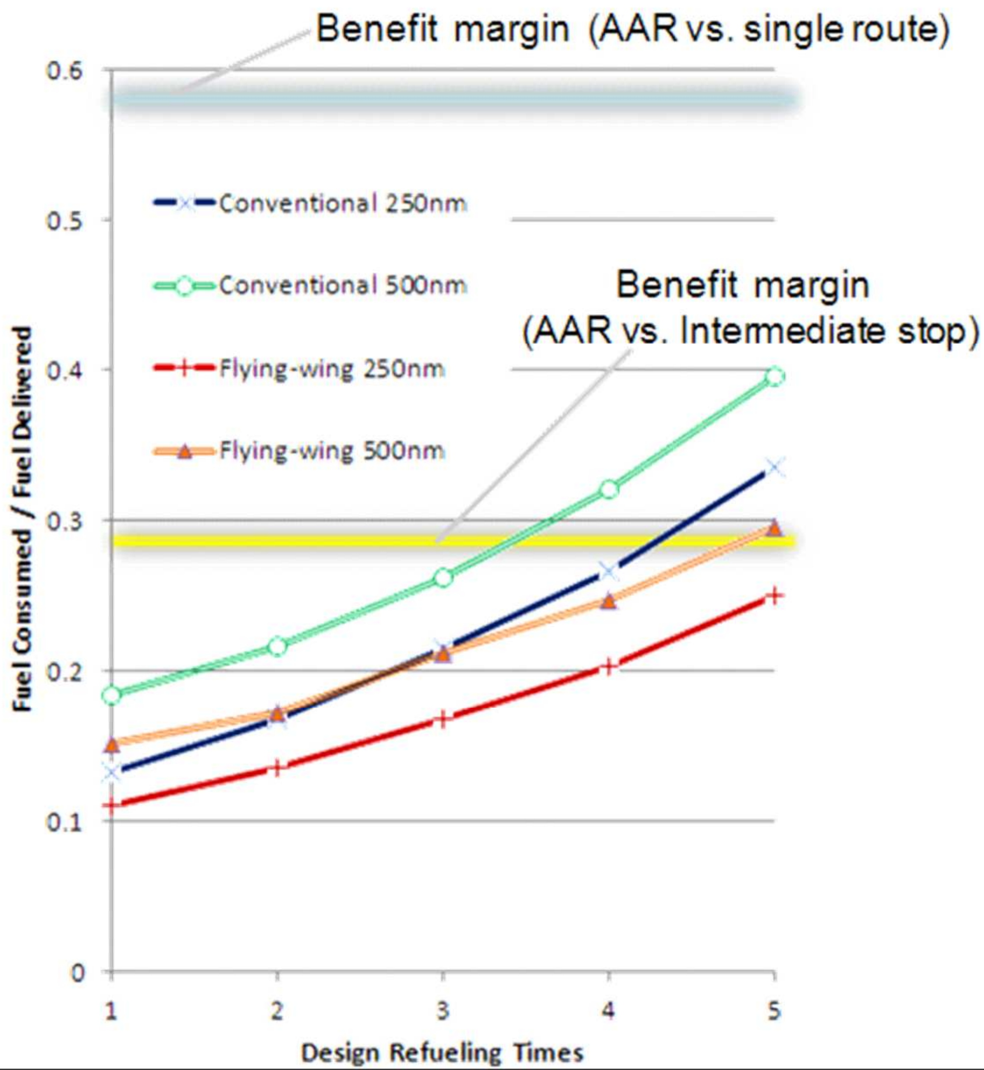
Tankers family



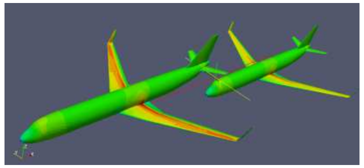
Aircraft to scale for size comparison

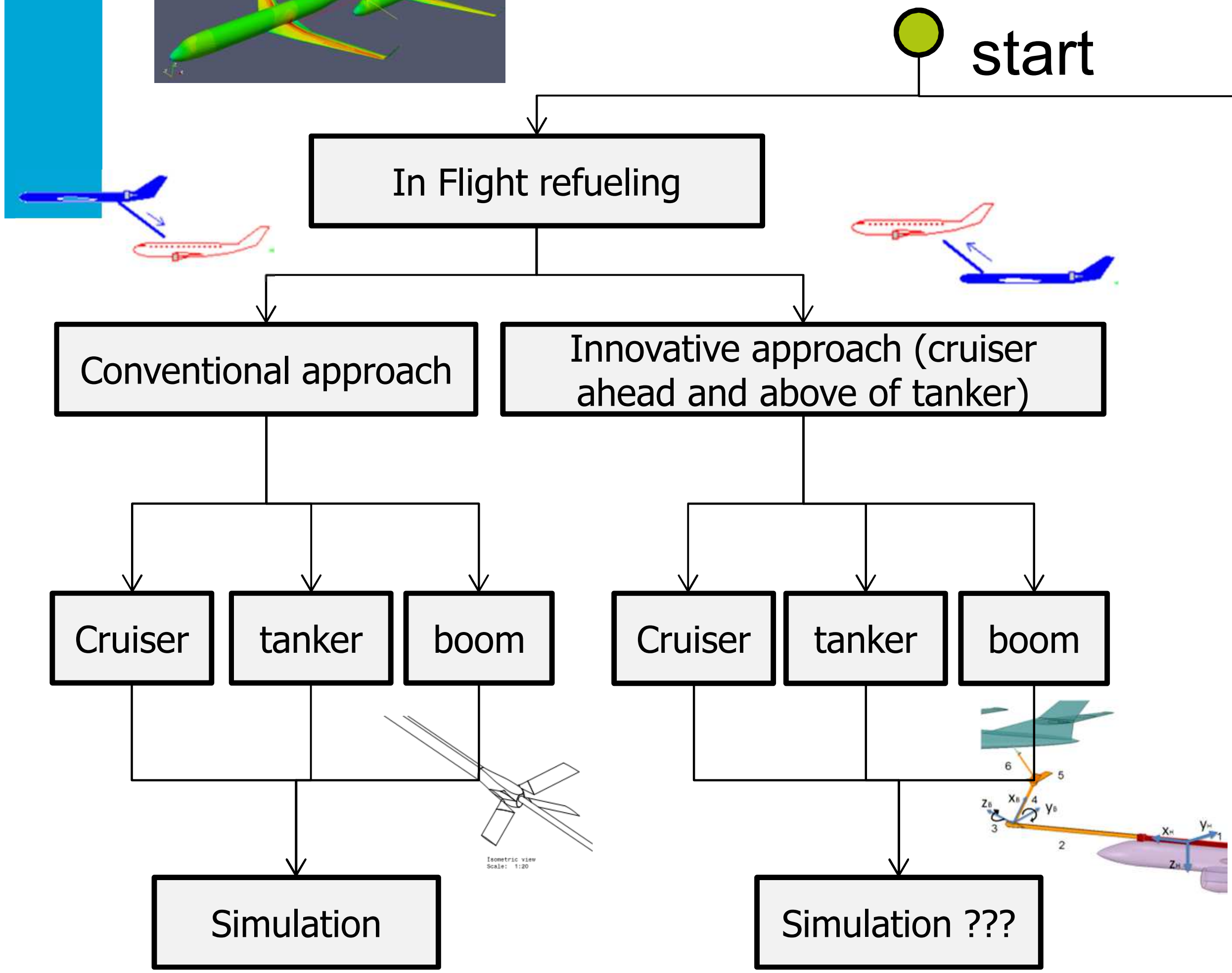
IFR benefit – Flying Wing VS Conventional tankers





The RECREATE design agenda





See next presentation:
Feasibility study of a nuclear propelled blended wing body aircraft for the cruiser/feeder concept

SEVENTH FRAMEWORK PROGRAMME

The research leading to the results presented in this paper was carried within the project RECREATE (REsearch on a CRuiser Enabled Air Transport Environment) and has received funding from the European Union Seventh Framework Programme under grant agreement no. 284741.

RECREATE

EWADE 2013
11th European Workshop on Aircraft Design Education
17 to 19 September 2013, Linköping University, Sweden

MARGARET: A PERSONAL TRANSPORTATION AIRCRAFT OF TOMORROW USED TODAY FOR COLLABORATION AMONG UNIVERSITIES

Sergio CHIESA, Dieter SCHOLZ, Giovanni Antonio DI MEO,
Marco FIORITI, Andrea FURLAN
POLITECNICO di TORINO – ITALY
HAMBURG UNIVERSITY OF APPLIED SCIENCES - GERMANY

A: Aero
S: Space
S: System
E: Engineering
T: Team

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546443

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Table of Contents

Section 1:

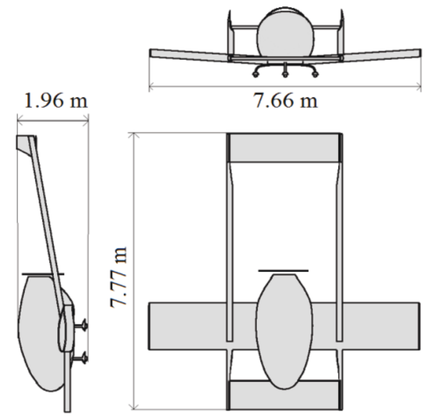
Introduction to MARGARET

WHAT IS IT?

MARGARET stand for: **M**odular safe and **A**ffordable not t**R**aditional **G**reen light **A**ircraft **R**esearch for **E**veryday personal **T**ransportation

MARGARET is a concept of ULM (Ultra Light Machine) Aircraft for Everyday Personal Transportation designed to be:

- Easy to pilot to be safe
- Passively Safe
- Modular & Affordable for Mass Diffusion
- Green
- Attractive and comfortable for everyday use

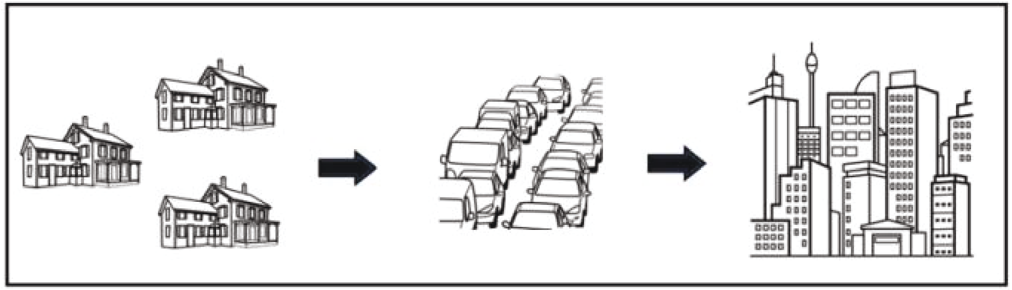


WHY?

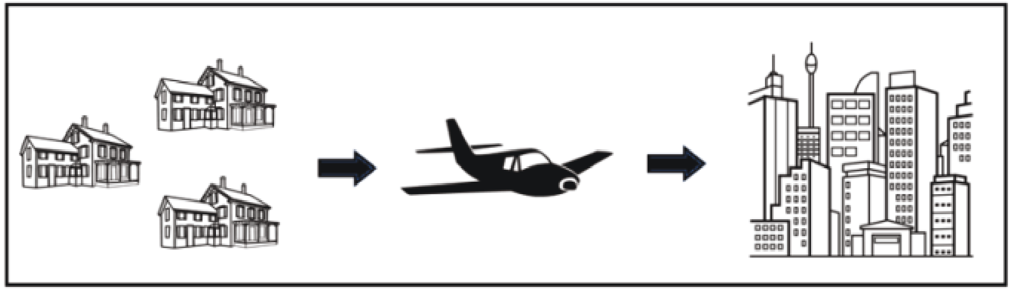
Why could be useful for the European society to have a Personal transportation system based on ULM (Ultra Light Machine)?

The idea is that a small, but important, percentage of people could use an aircraft for their daily travel from their house in the countryside to the job place in the city center.

TODAY

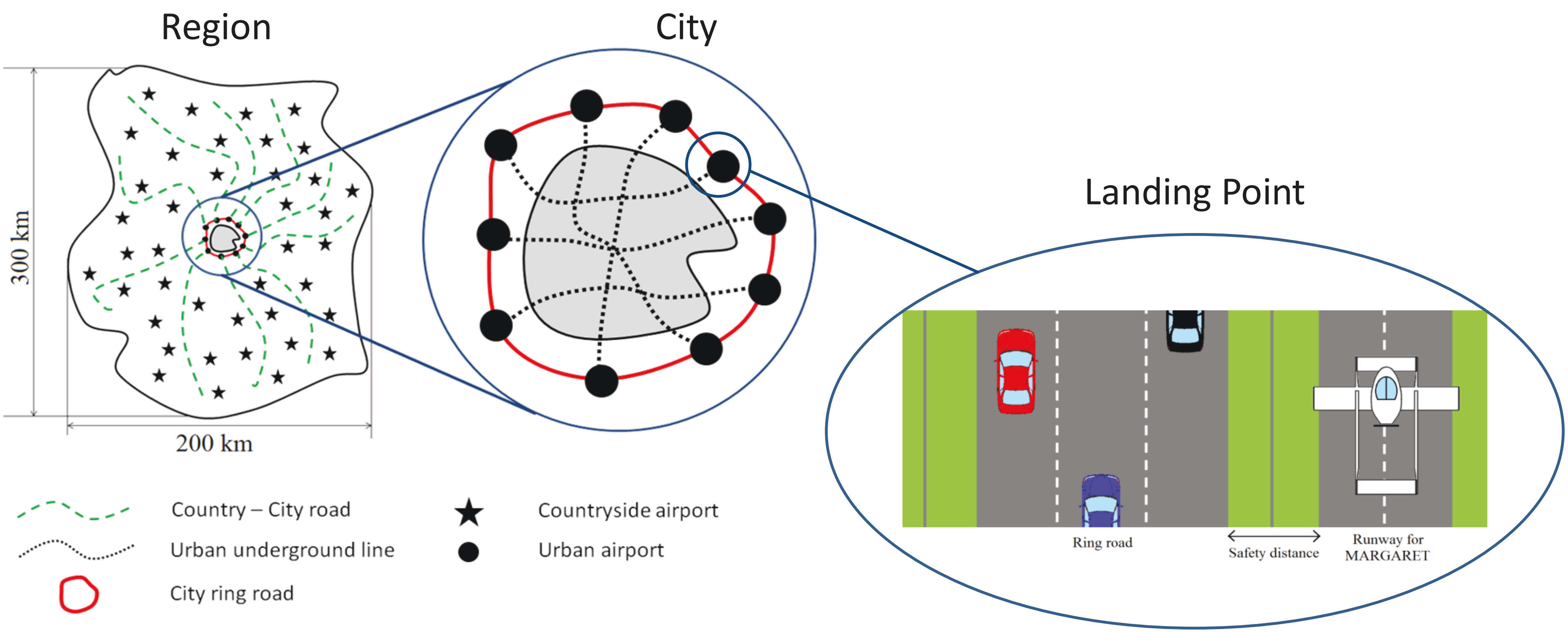


IN SECOND HALF OF THE CENTURY



HOW?

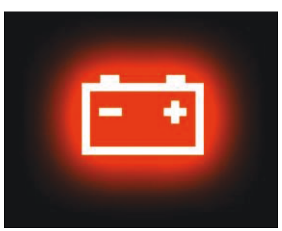
Every big city has a ring road around it, the idea to create dedicated runways parallel to existing ring road and strategic urban airports served by public transportations such as bus services, tram lines or subways.



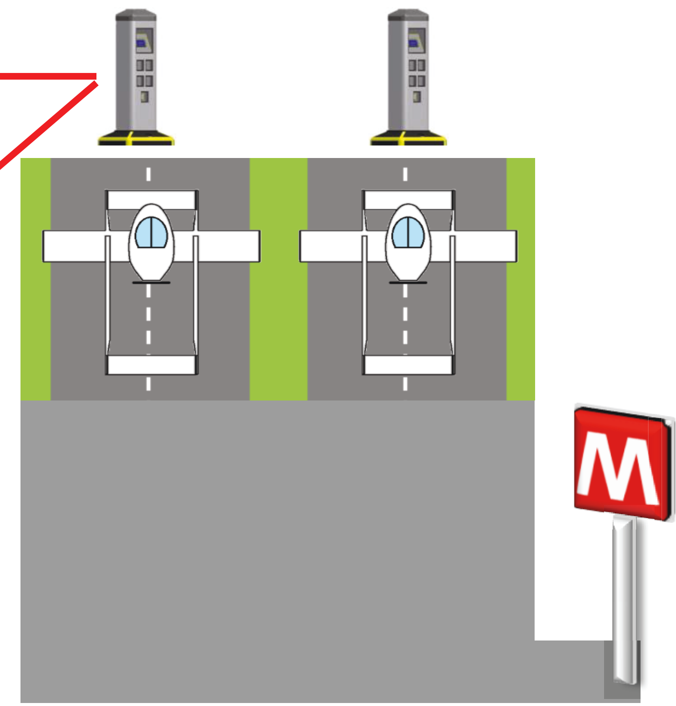
HOW?

Once landed MARGARET aircraft will be parked in dedicated parking point where it will be possible to recharge batteries for long stops or change them for short stops as showed in Figure. Parking points will be connected to the city center with Metro stations.

Possibility to park and charge batteries while the user is at work for long parking



Possibility to park and change batteries for short parking



Section 2:

MARGARET Aircraft Technologies

MARGARET

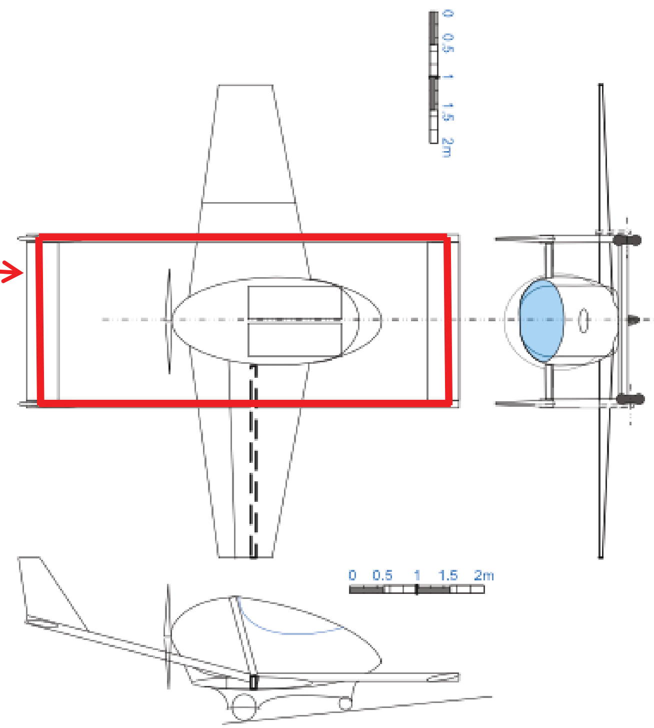
MARGARET technologies for a future everyday personal transportation:

1) Safety
2) Easy to pilot to be safe
3) Green Mobility
4) Integrated with the future Single European Sky

MARGARET
1 - Safety

Innovative and completely new architecture of the aircraft

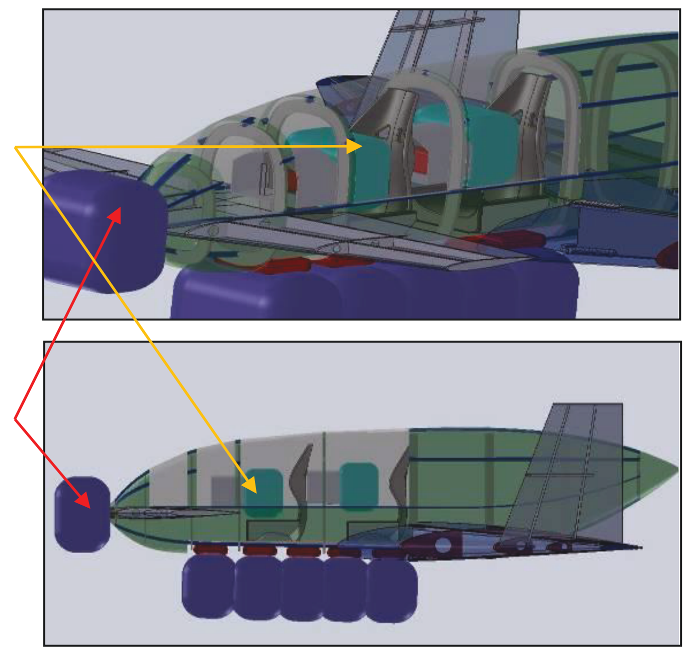
•Enhanced protection of the cabin due to the **fuselage completely surrounded on its four sides** from structural elements



MARGARET
1 - Safety

Thanks to the enhanced protection of the cabin a radical increase in passive safety is provided by **Air-Bags**

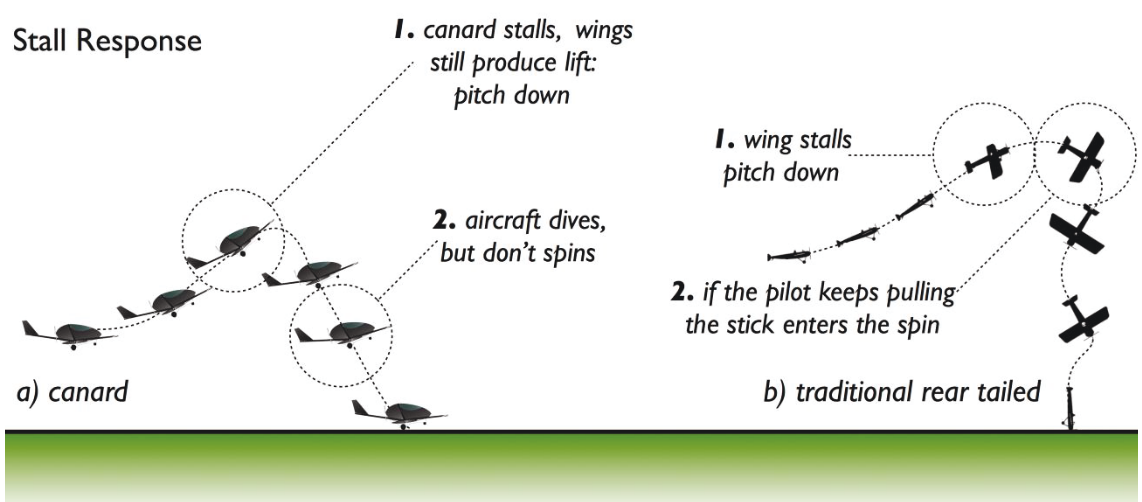
The synergic use of internal and external airbags allow the radically increase passive safety and survival probability in event of crash



MARGARET
2 - Easy to pilot to be safe

Aerodynamic Configuration to ease the piloting experience

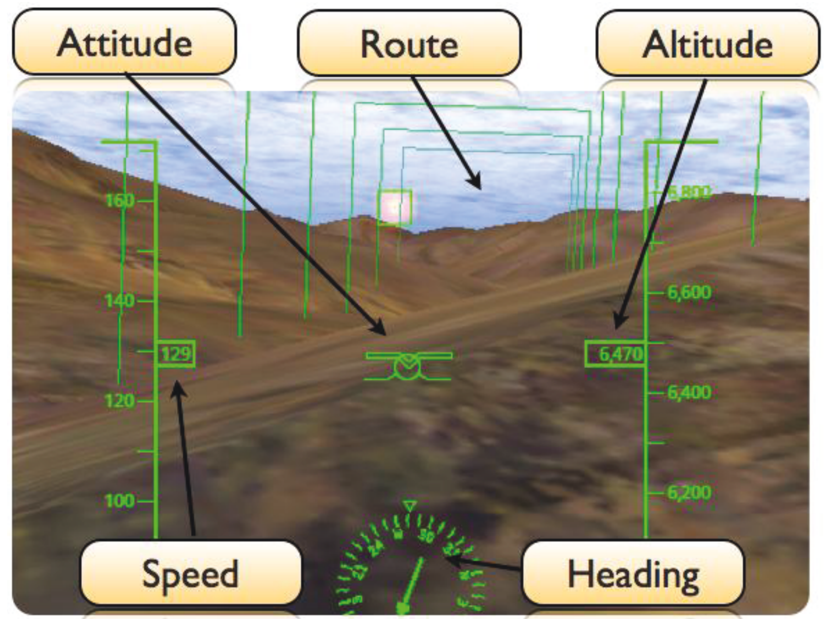
- Three Lifting Surfaces
- High Wing Area but Low Aspect Ratio



MARGARET
2 - Easy to pilot to be safe

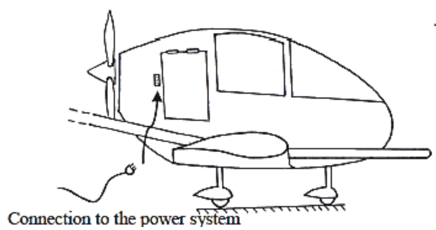
Innovative Avionic System

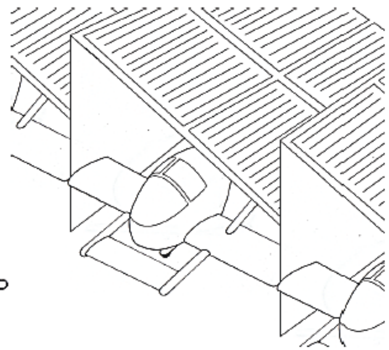
- HMI (Human Machine Interface) for Enhanced Situational Awareness
- All Weather Flight
- Auto-piloting capability
- Interactive HMI

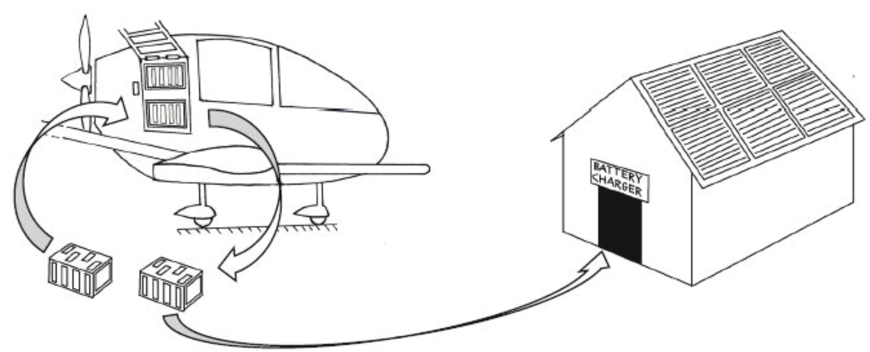


MARGARET
3 - Green Mobility

A greener mobility concerns <u>zero emissions</u>







MARGARET
4 - Integrated with the future Single European Sky

SESAR JOINT UNDERTAKING

Adaptation of MARGARET on the base of the foreseen evolution of the European ATM system designed by SESAR:

- Dedicated access to SES(Single European Sky) Web Net for Planning and Sharing of a 4D Trajectory
- Use of ADS-B technology for separation and collision avoidance

Section 3:

MARGARET Consortium:

Collaboration among Universities and

Educational Initiatives

MARGARET
The Consortium

Leader

POLITECNICO DI TORINO 1859 1906

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Scuola universitaria professionale
della Svizzera italiana
SUPSI

Cranfield UNIVERSITY

MARGARET
Collaboration and Educational Initiatives

Participation to EWADE 2013 (TODAY)

Sergio CHIESA, Dieter SCHOLZ, Giovanni Antonio DI MEO, Marco FIORITI, Andrea FURLAN

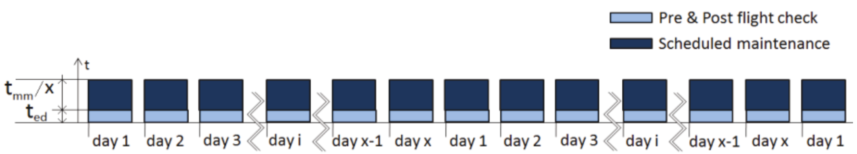
"MARGARET: A PERSONAL TRANSPORTATION AIRCRAFT OF TOMORROW USED TODAY FOR COLLABORATION AMONG UNIVERSITIES"

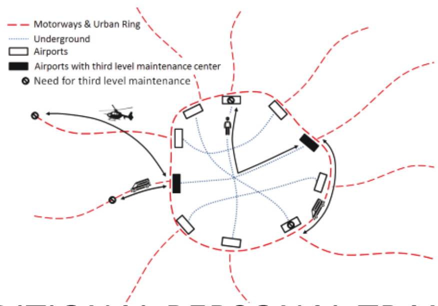
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Participation to World Maintenance Forum 2013 4-6 September 2013 in Lugano, Switzerland.

Sergio Chiesa, Giovanni A. Di Meo, Marco Fioriti, Andrea Furlan

"SUPPORT AND MAINTENANCE STRATEGIES FOR FUTURE, INNOVATIVE AND LARGELY WIDESPREAD AIR PERSONAL TRANSPORTATION SYSTEMS"



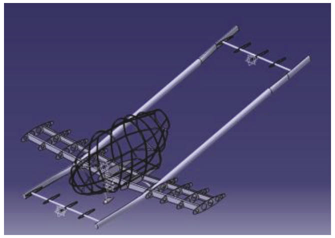


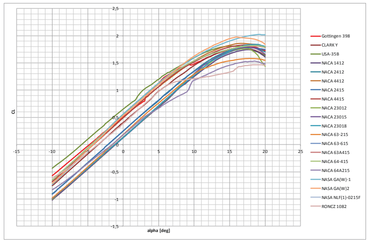
Scuola universitaria professionale
della Svizzera italiana
SUPSI

Master Degree Thesis

Andrea Furlan *"SAFE AND AFFORDABLE NON TRADITIONAL PERSONAL TRANSPORTATION AIRCRAFT"*

MSc Thesis in Aerospace Engineering –POLITECNICO di TORINO, March 2013





Cranfield UNIVERSITY

Section 4:

Future of MARGARET

We Submitted MARGARET to 7th Framework in a Level 0 Call on March 14th 2013

SEVENTH FRAMEWORK PROGRAMME

FP7 – AAT – 2013 –Transports (Aeronautics) Call
Level 0 - CP-FP –
Call: FP7-AAT-2012-RTD-L0
AAT.2012.6-2. Radical new concepts for air transport

SEVENTH FRAMEWORK PROGRAMME (FP7)

SEVENTH FRAMEWORK PROGRAMME

AERONAUTICS and AIR TRANSPORT (AAT)-2013-RTD-L0 (Opencall for long term innovation)
Identifier: FP7-AAT-2012-RTD-L0

MARGARET

Modular safe and **A**ffordable not t**R**aditional **G**reen light **A**ircraft **R**esearch for **E**veryday personal **T**ransportation

Collaborative Project Level 0 (CP-FP)

Activity 7.1.6. Pioneering the air transport of the future
Topic: *AAT.2012.6-2.*
"Radical new concepts for air transport"

Proposal PART B

Name of the coordinating person: Prof. Sergio Chiesa
Email: sergio.chiesa@polito.it

List of participants:

Participant no. *	Participant organisation name	Part. Short name	Country
1 (Coordinator)	Politecnico di Torino	POLITO	IT
2	Hochschule für Angewandte Wissenschaften Hamburg	HAW	DE
3	Cranfield University	CRU	UK
4	Scuola universitaria professionale svizzera italiana	SUPSI	CH

MARGARET has been positively evaluated even if not financed due to lack of founding

We are not discouraged.....

WE ARE READY FOR HORIZON 2020

Thanks for the attention
Any question?

Feasibility study of a nuclear powered blended wing body aircraft for the Cruiser/Feeder concept

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546482

G. La Rocca - TU Delft

M. Li - TU Delft

M. Chiozzi - La Sapienza, Uni Roma

11th European Workshop on Aircraft Design Education
Linköping, Sweden

September 2013

Introduction

- One of the biggest challenges for future aviation is represented by the increasing **cost and scarcity of fossil fuel**.
- The demand of air transportation is steadily increasing, while the constraints on the allowed environmental impact by authorities are getting more stringent
- **New designs and operational concepts** are required to meet the ambitious challenges devised by ACARE

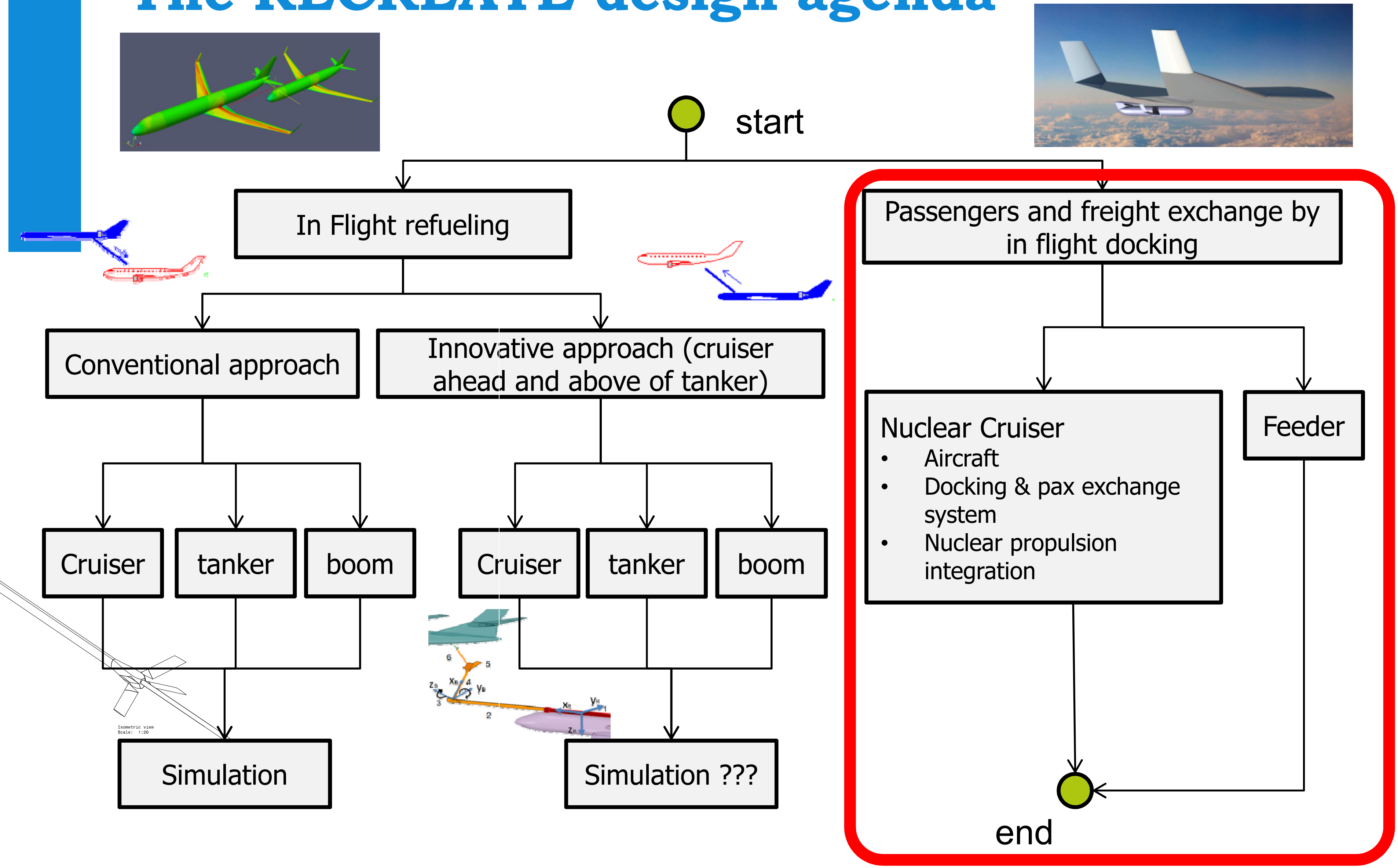
+60 years

The RECREATE project

- In the RECREATE (**RE**search on a **CR**uiser **E**nabled **A**ir **T**ransport **E**nvironment) project, European research institutes, universities and small businesses work together to investigate a future air transportation system based on the **cruiser-feeder** concept

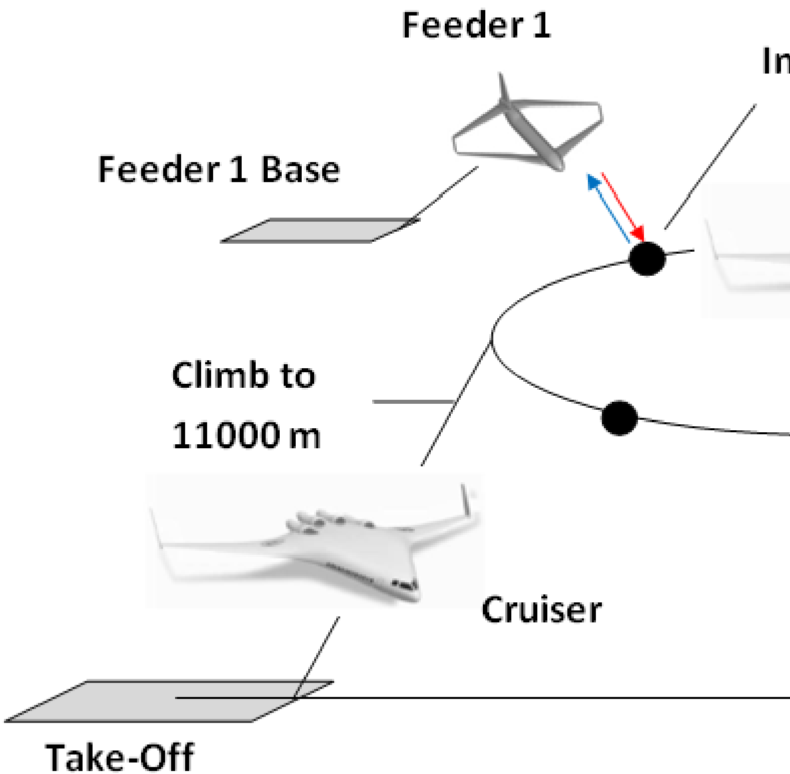
- Next to **In Flight Refueling operations** for passenger aircraft, the **feasibility study of Nuclear Powered Blended Wing body aircraft for in flight exchange of payload** is second concept addressed by RECREATE.

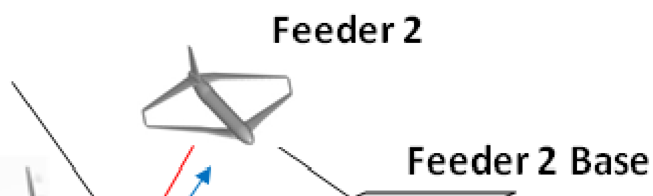
The RECREATE design agenda



The Cruiser/Feeder concept

Mission Profile and Requirements



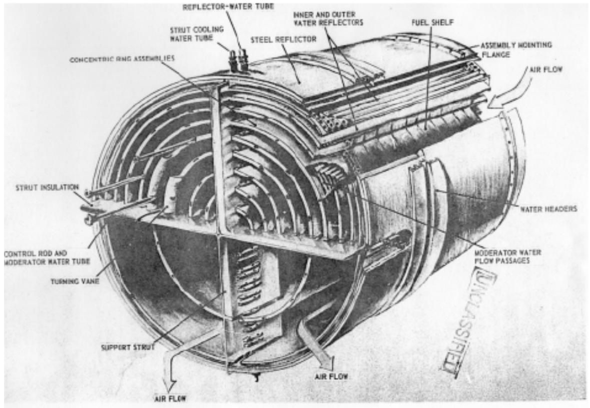


Capacity, nr of passengers	1000 PAX
Maximum Take Off Weight	$900 \bullet 10^3$ kg
Range	$> 112 \bullet 10^3$ km / 1 week endurance
Cruise speed	M = 0.8
Docking Speed	M= 0.7
L/D	>20
Cruise altitude	$h_{cruise} > 11000$ m
Docking Altitude	TBD
Fuel	Uranium 235
Payload Transfer Concept	Single container station concept (100 pax each)

Nuclear Power for aircraft propulsion

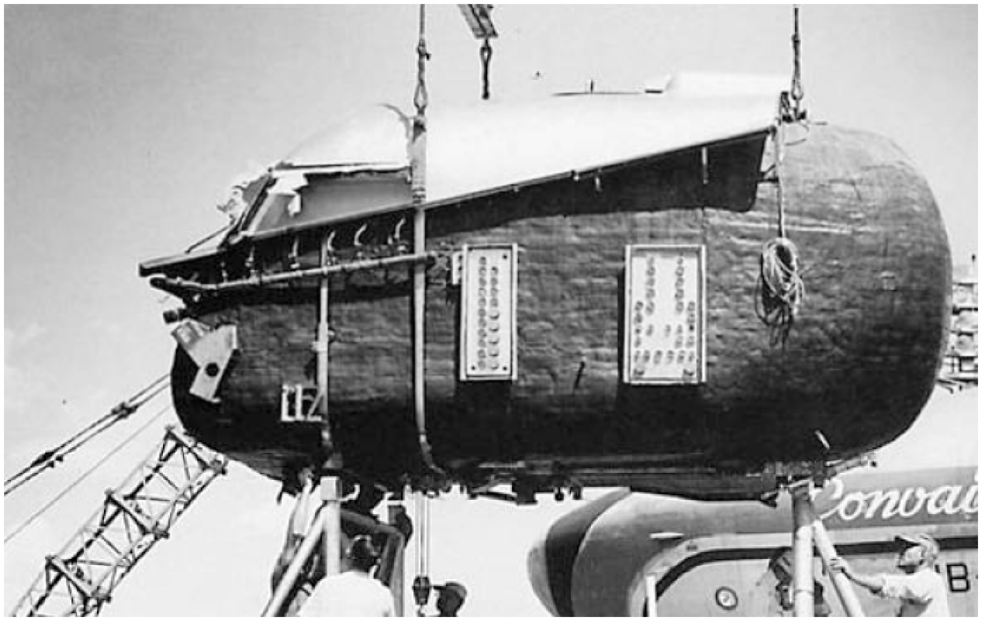
Early 1950ies. A B-36 and some Tupolev TU-119 converted for testing of nuclear radiations shielding.

The B-36 carried a **1 MW**, air cooled nuclear reactor with a **4 ton** lead disc shield to protect crew from radiation.



TU Delft

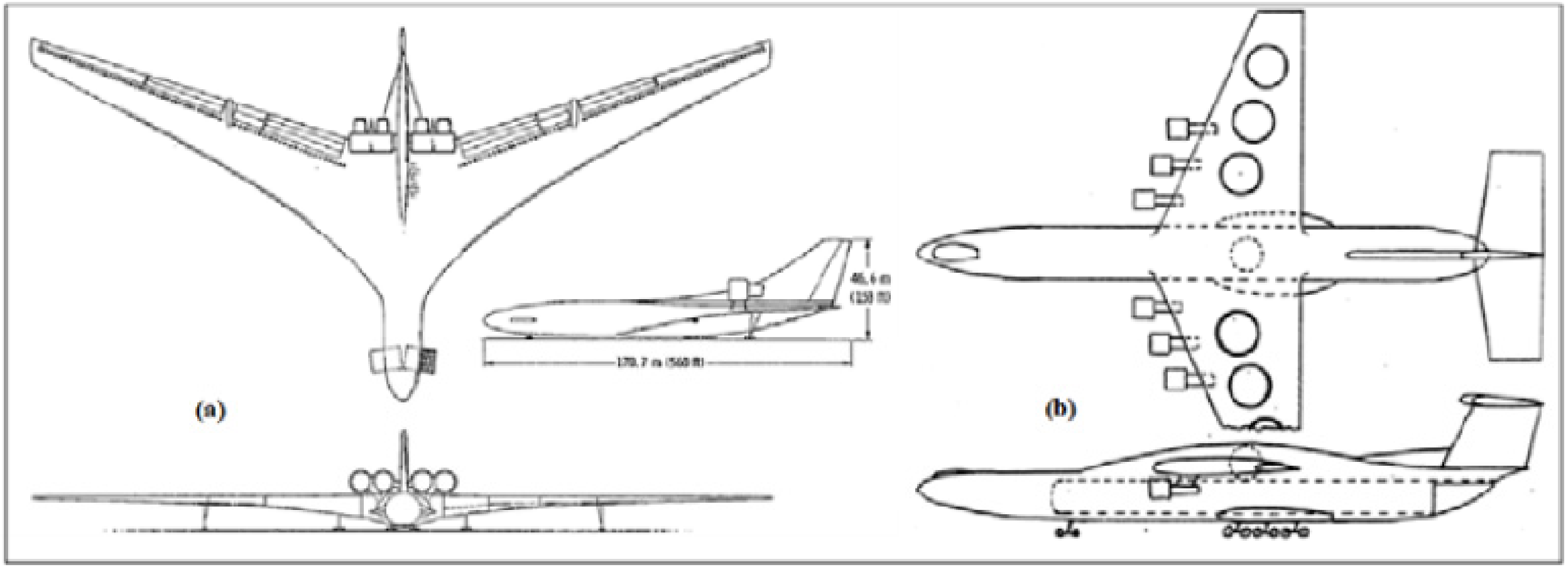
Nuclear Power for aircraft propulsion



The B36 cabin crew was situated in a massive **11 ton structure** from lead.

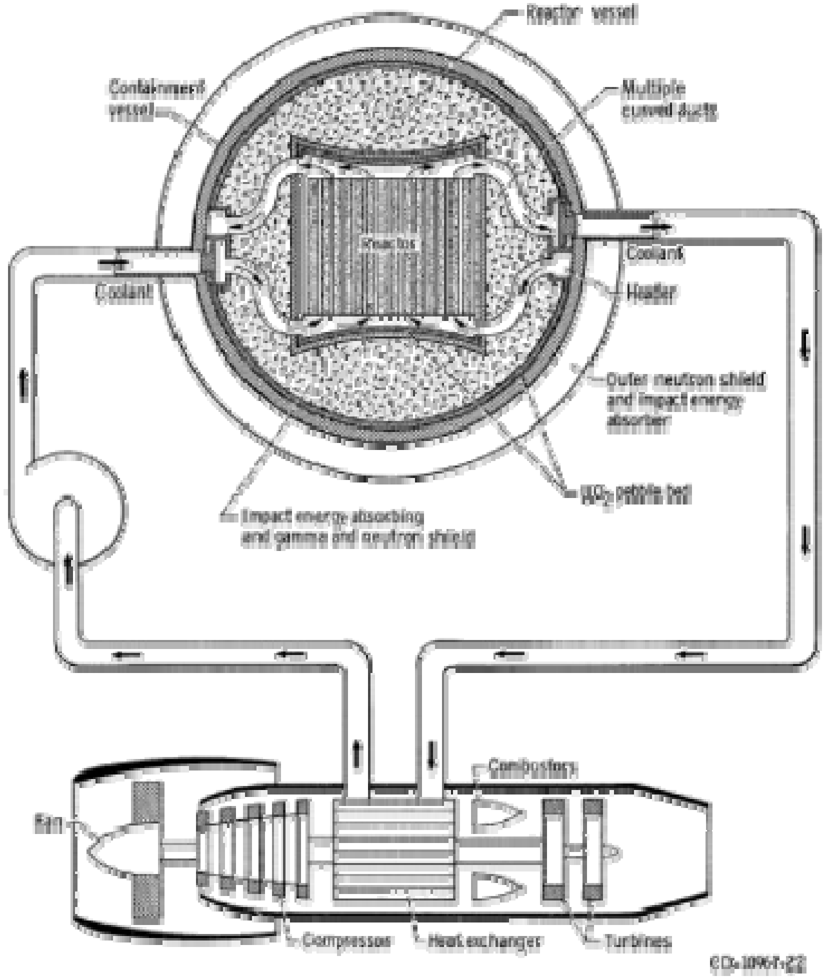
Rubber and water tanks were placed at the aft to absorb any escaping radiation

Nuclear Power for aircraft propulsion



Preliminary NASA studies from late 60ies, early 70-ies

Nuclear Power for aircraft propulsion



- **Indirect Brayton cycle**. A heat exchanger transfers the heat generated by the nuclear reactor (helium cooled) to the compressed air

- Possibility of **hybrid propulsion**:
  - Nuclear mode oversea
  - Standard kerosene mode overland

Payload exchange concepts

Considered air vehicles configurations:

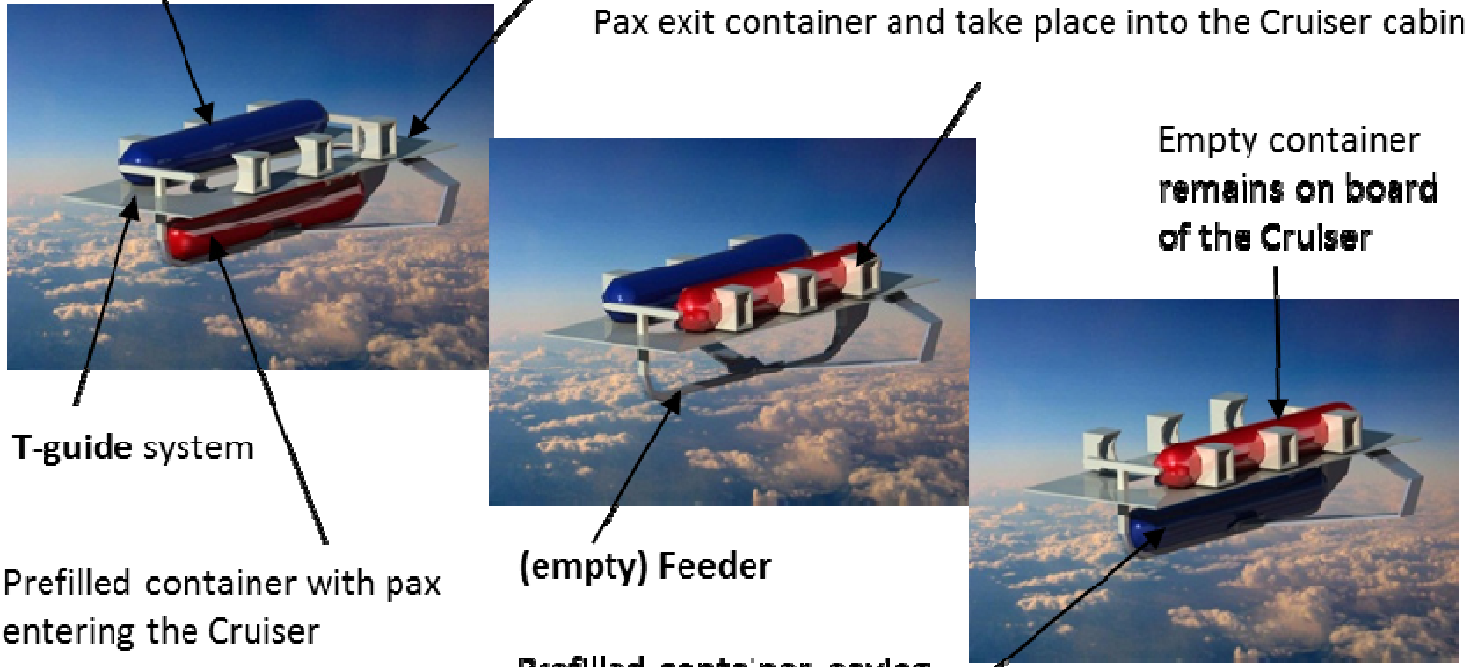
- **Cruiser: Nuclear powered BWB**
- **Feeder: Prandtl Plane**

Considered concept for pax exchange:

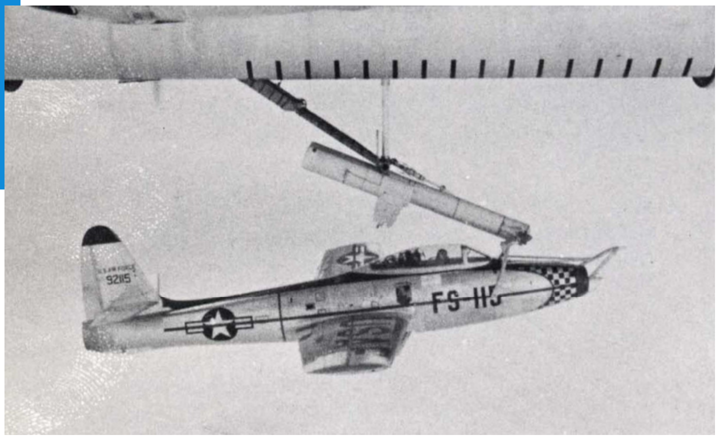
- **Through pressurized, prefilled containers (100 pax each)**

Payload exchange concepts

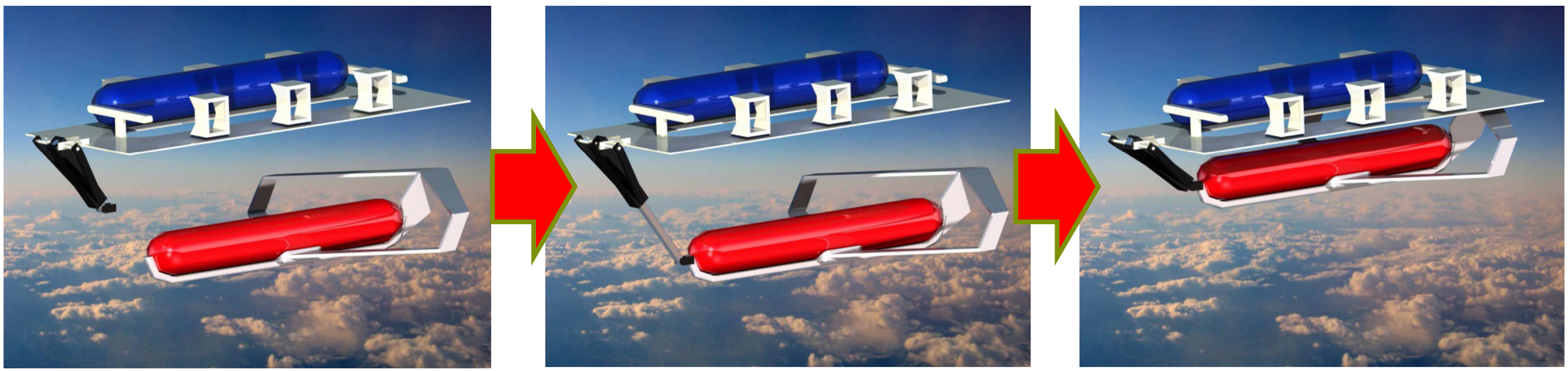
Passengers exchange approach (detachable containers)



Payload exchange concepts



Large aircraft use trapeze to catch small aircraft (USAF 1955)



Hook up mechanism feeder/cruiser (trapeze system)

Nuclear cruiser conceptual design

Conceptual design challenges:

- It is a blended wing body
  → payload collocation, aerodynamics, stability and control strongly affect each other
  → Very scarce statistics to support/initiate the design

- There is no fuel!…Breguet cannot help us : (

- Power and size of the reactor depend on aircraft weight,
  …….which depends on the weight of the reactor shielding,
  ……….which depends on the power and size of the reactor…

Nuclear cruiser conceptual design

A possible way out:

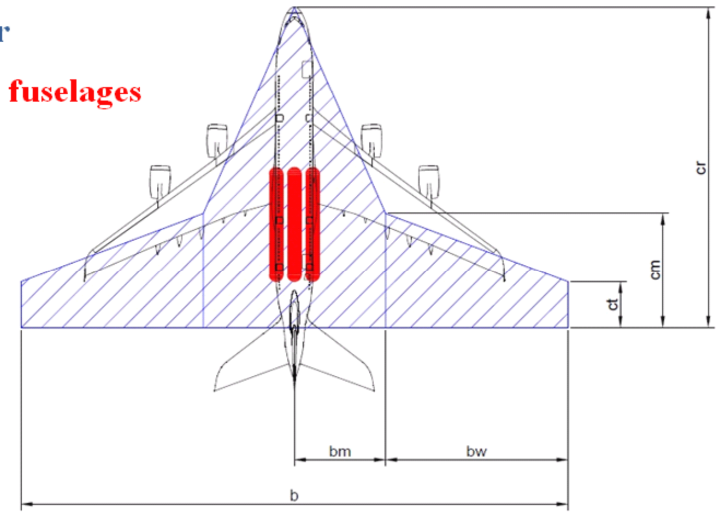
1. **Start sizing the planform:**

   - **Center body** size based on inside-out approach
     - 1000 pax
     - Containerized freight
     - Two reactors with shields (5 m X 10 m)
     - Two fuselage like containers (3 m X 25 m)

   - **Outer body** size based on required total span and surfaces to achieve L/D>20 (from reqs)

Nuclear cruiser conceptual design

Cruiser
Feeder fuselages
A-380



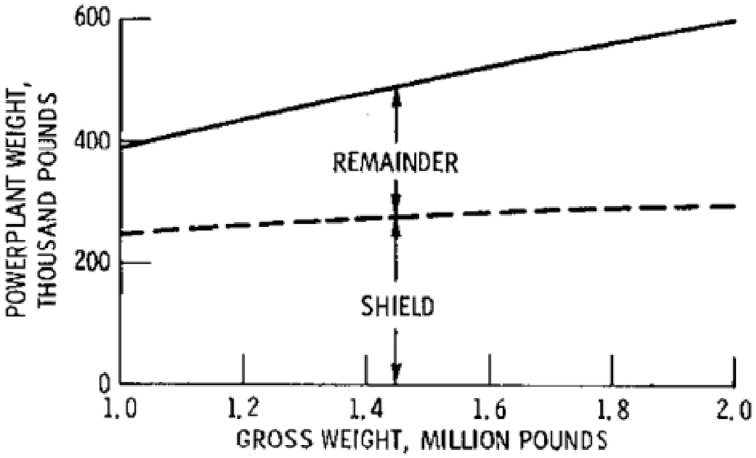
Payload: 1000 pax + freight
(100 pax X 10 docking operations)

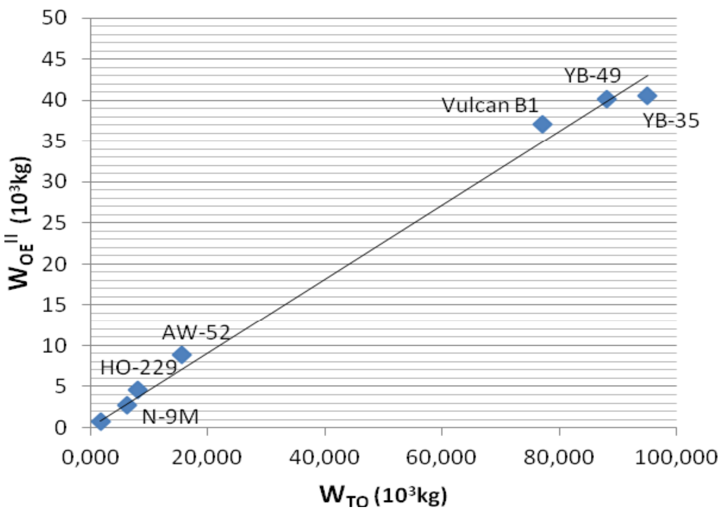
Description	*Symbol*	*Value*
Maximum root thickness	t_{root}	10m
Root chord length	c_r	60m
Inner part taper ratio	l_1 (c_m/c_r)	0.416
Main wing taper ratio	l_2 (c_t/c_m)	0.25
Inner part length	b_m	20m
Outer wing length	b_w	40m
Span length	**b**	120m
Wing Surface	**S**	2947m^2
Aspect ratio	**A**	4.89
Zero Lift Drag Coefficient	C_{D0}	0.006
Maximum aerodynamic efficiency	$(L/D)_{max}$	23.32

Nuclear cruiser conceptual design

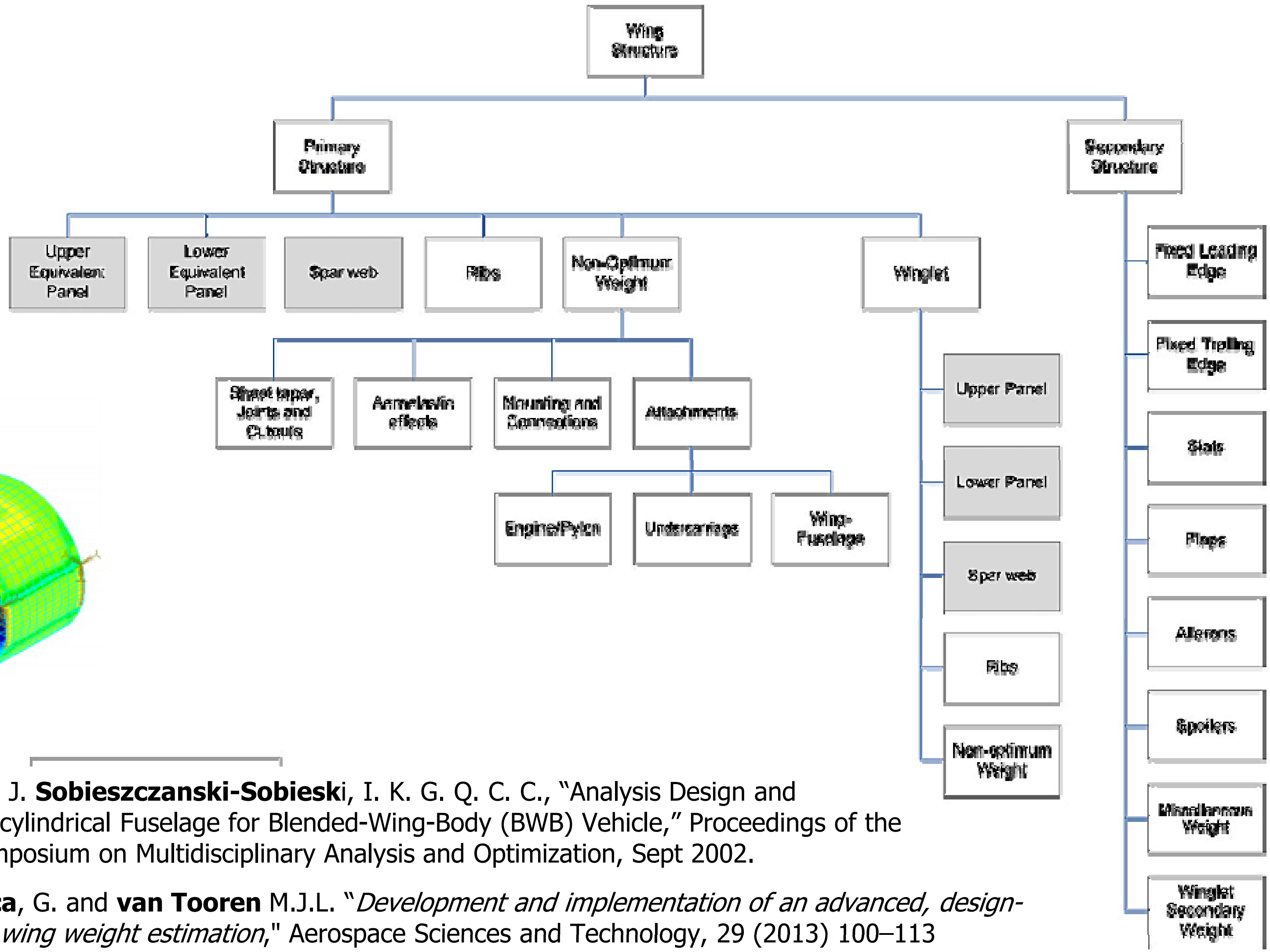
A possible way out (continued):

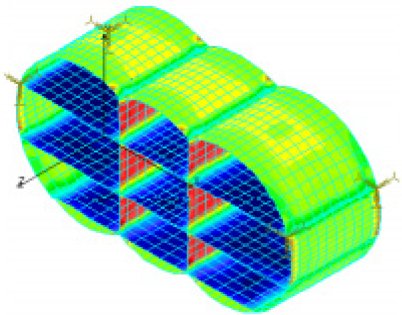
2. Breguet-less preliminary weight estimation
- Nuclear propulsion system weight estimation
- Some statistics (large aircraft, paper study, etc..)
- Class II-1.2 weight approach
- Iterate…





Class II-1/2 wing weight estimation tool





V. **Mukhopadhyay**, J. **Sobieszczanski-Sobiesk**i, I. K. G. Q. C. C., "Analysis Design and Optimization of Non-cylindrical Fuselage for Blended-Wing-Body (BWB) Vehicle," Proceedings of the 9th AIAA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, Sept 2002.

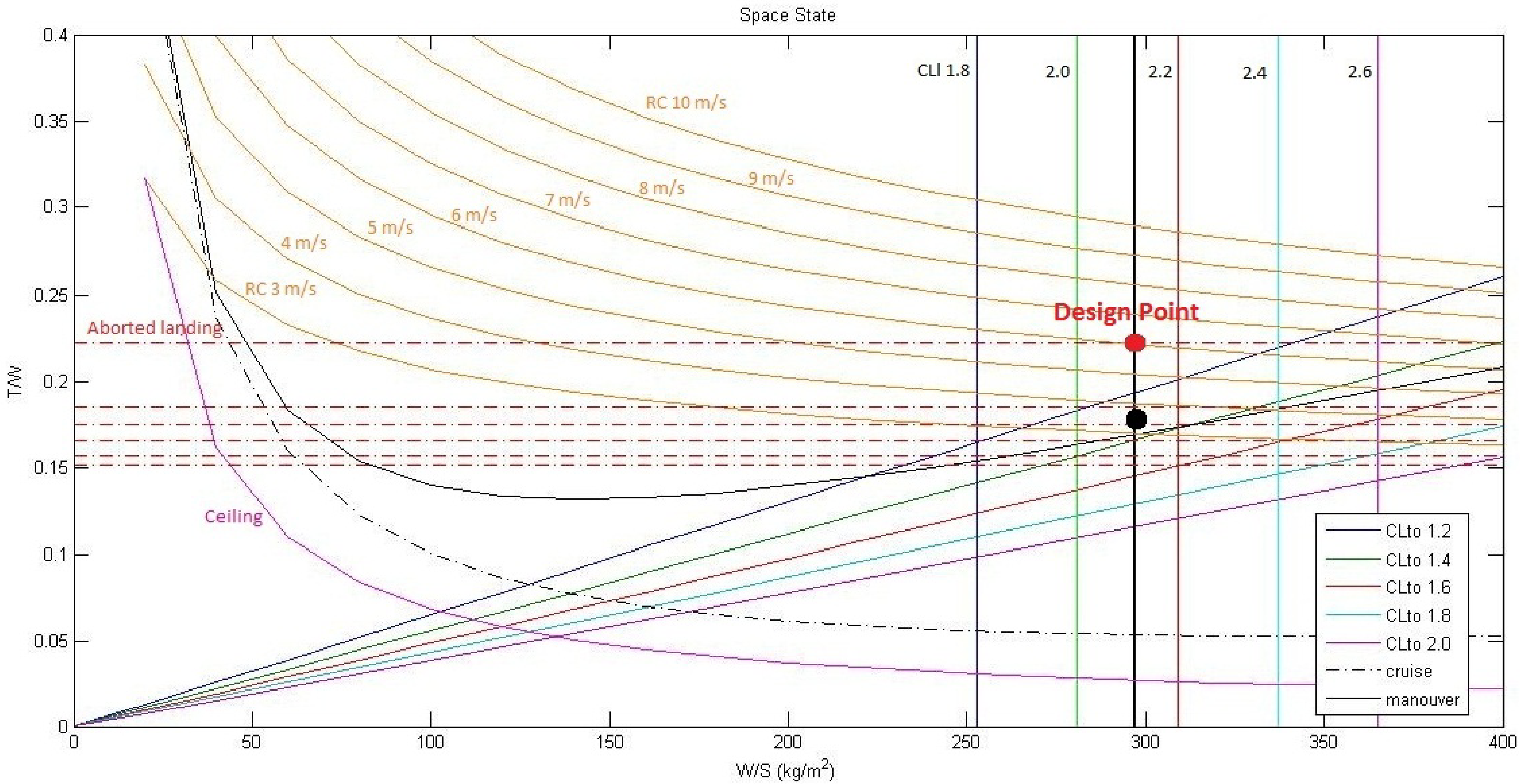
*__Elham__, A, **La Rocca**, G. and **van Tooren** M.J.L. "*Development and implementation of an advanced, design-sensitive method for wing weight estimation*," Aerospace Sciences and Technology, 29 (2013) 100–113

Nuclear cruiser conceptual design

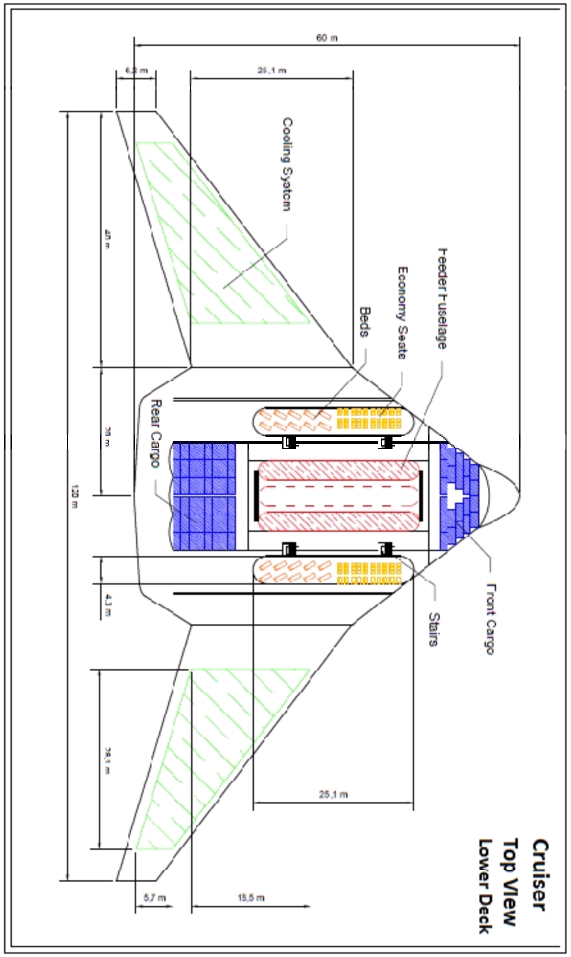
	Cruiser	% W_{TO}		A-380	% W_{TO}		B-747	% W_{TO}
W_{TO} (10^3kg)	875	-		560	-		343	-
W_{OE} (10^3kg)	383.3	43.7		277	49.5		212	61.8
W_{PL} (10^3kg)	250	28.6		85	15.2		60.5	17.6
W_P (10^3kg)	241.7	27.6		-	-		-	-

- W_{TO}: maximum take off weight (note the cruiser can takeoff empty and reach maximum weight during cruise)
- W_{OE}: Operational Empty Weight
- W_{PL}: passengers plus freight
- W_P: weight of propulsive system (shielding, fuel, core, cooling systems, but NO engines)

Nuclear cruiser conceptual design

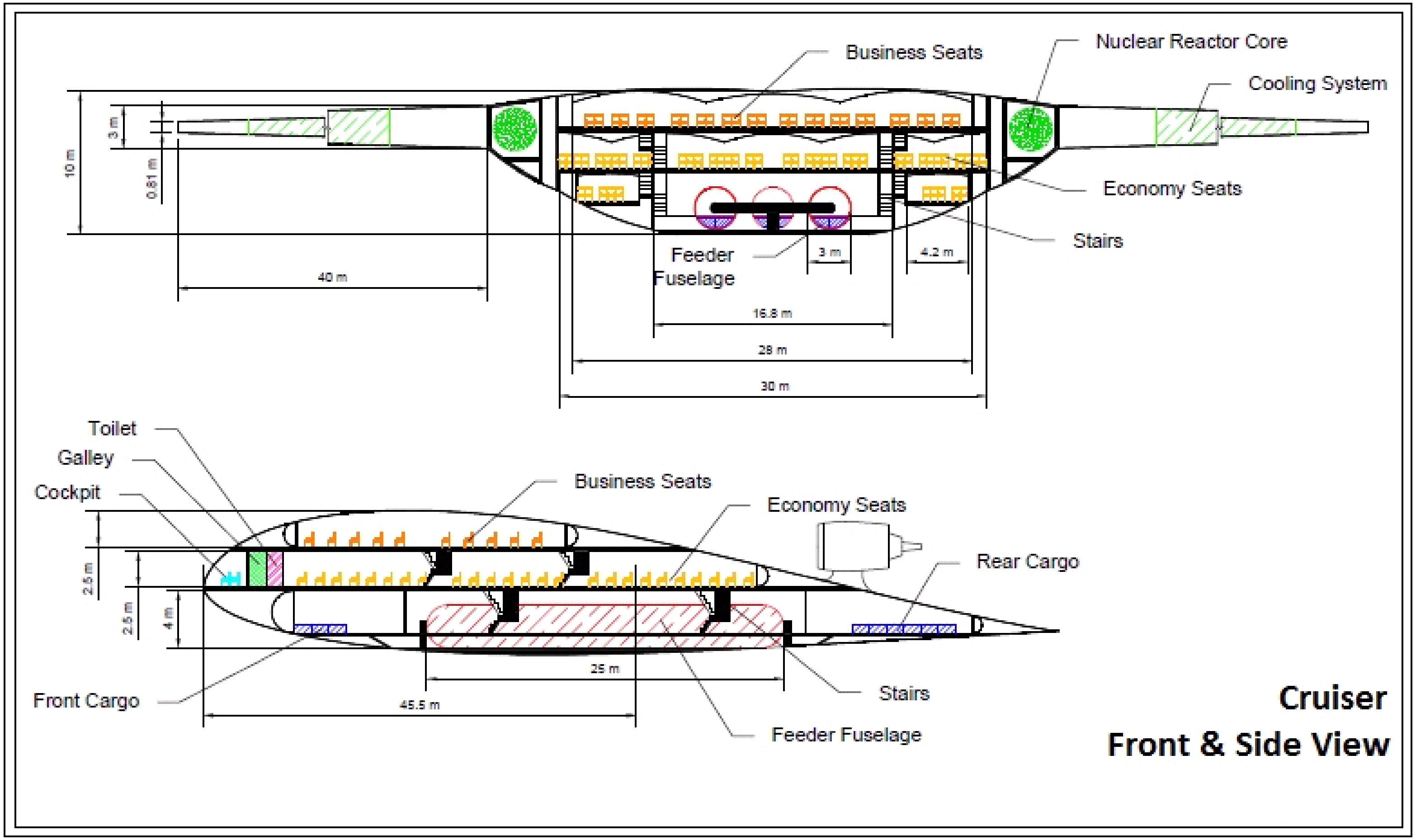


Nuclear cruiser conceptual design

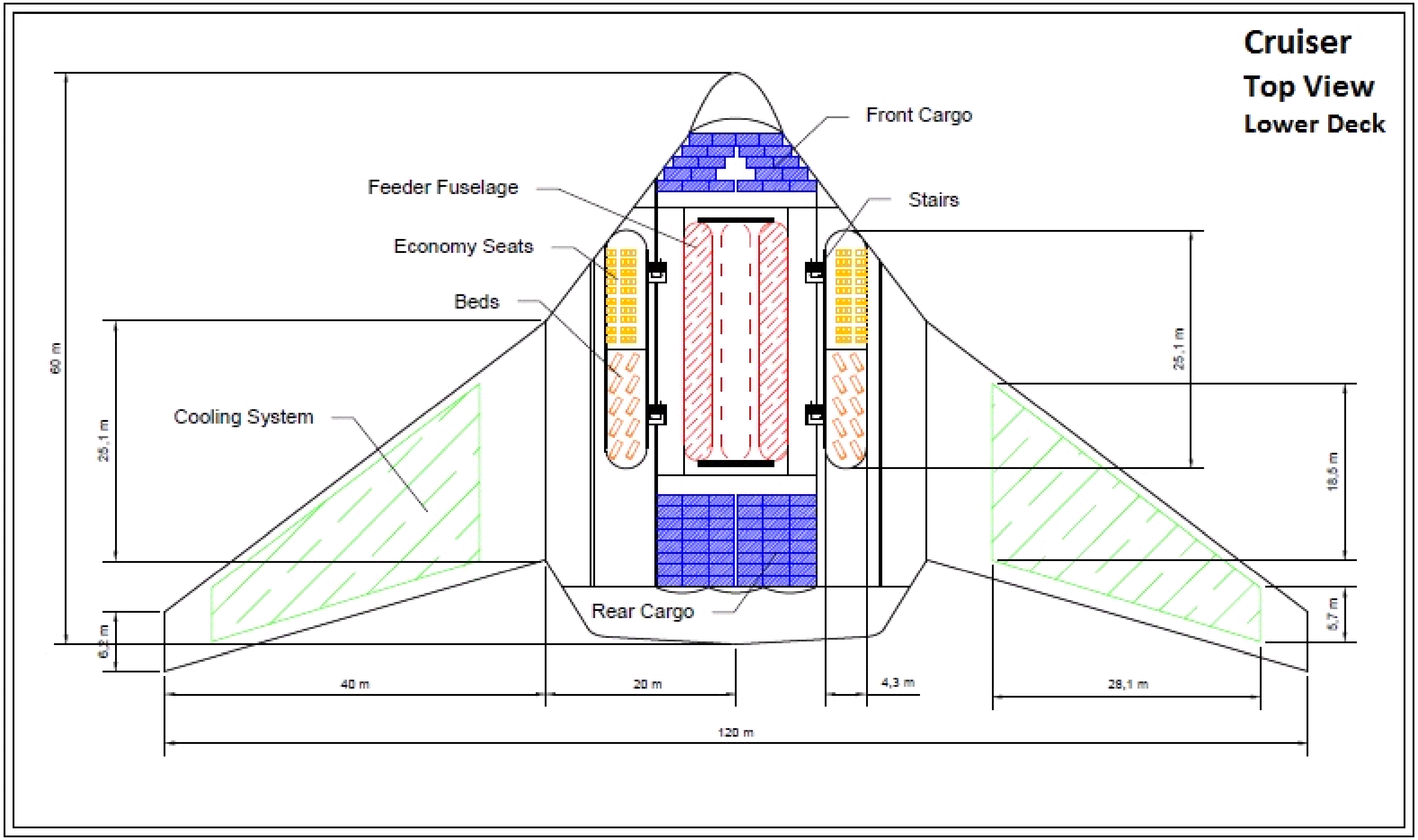


	Symbol	Value	Units
Root thickness	t_{root}	10	m
Span width	b	120	m
Wing Surface	S	2947	m^2
Aspect Ratio	A	4.89	-
Aerodynamic Efficiency	L/D	23.32	-
Take-Off Weight	W_{TO}	875	10^3 kg
Operative Empty Weight	W_{OE}	383.3	10^3 kg
Payload Weight	W_{PL}	250	10^3 kg
Power Plant Weight	W_P	241.7	10^3 kg
Wing loading	W/S	297	kg/m^2
Thrust	T	1900	kN
Power	P	344.5	MW
Rate of Climb	RC	6	m/s
C_{Lmax} take-off	C_{L-TO}	1.4	-
C_{Lmax} landing	C_{L-L}	2.2	-

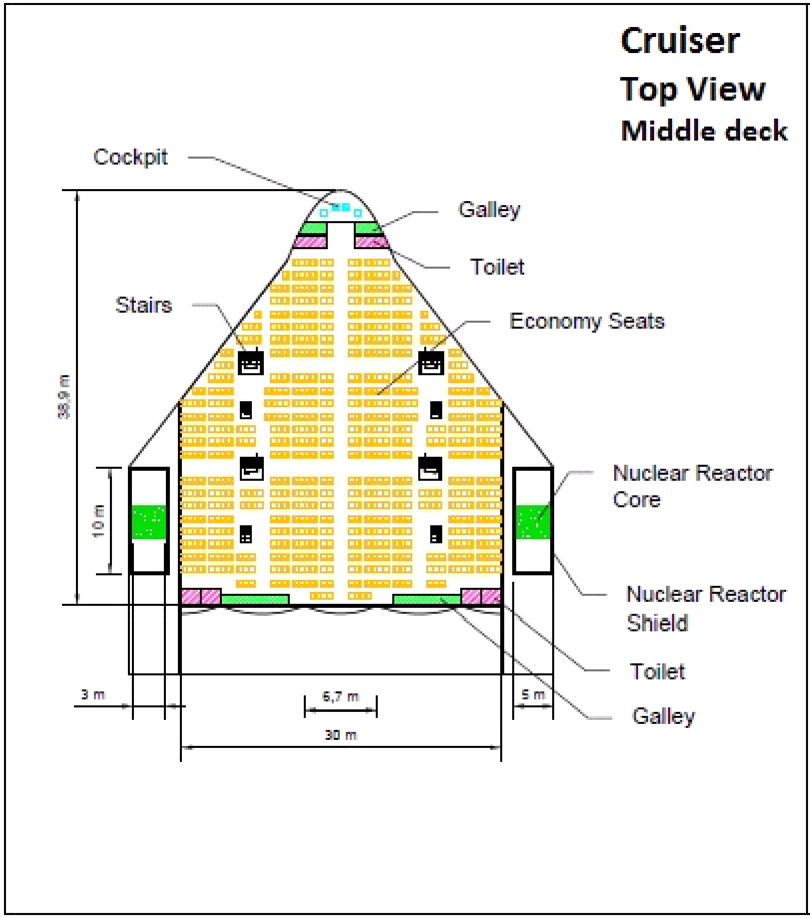
Nuclear cruiser conceptual design

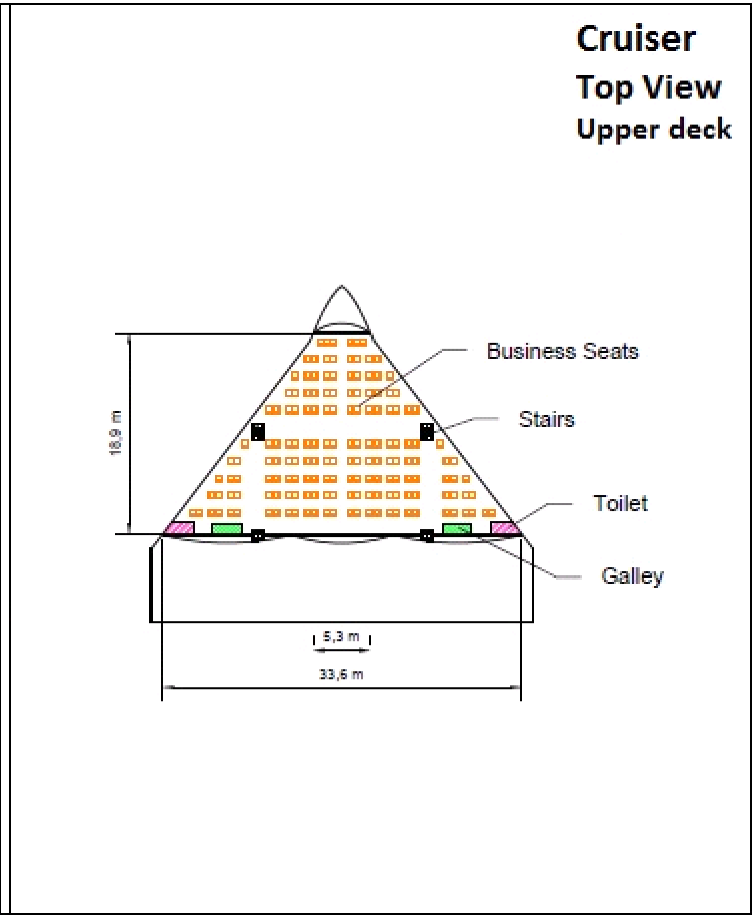


Nuclear cruiser conceptual design



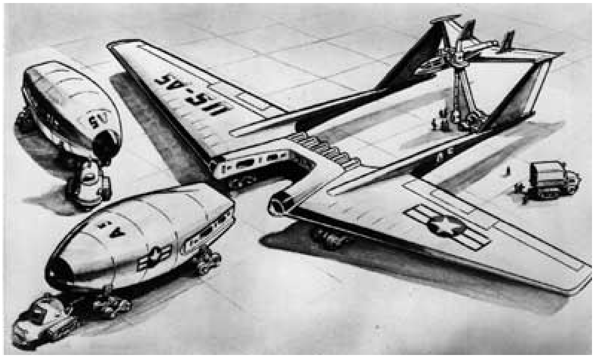
Nuclear cruiser conceptual design





What next?

- Revision and consolidation of the current conceptual design
- Focus on the design and integration of the nuclear propulsion system (including shielding analysis by means of NRG codes)
- Design of the docking and loading mechanism for pax exchange
- Hybrid propulsion (nuclear + standard fuel)
- Other engine concept (Rankine instead of Brayton?)



The research leading to the results presented in this paper was carried within the project RECREATE (REsearch on a CRuiser Enabled Air Transport Environment) and has received funding from the European Union Seventh Framework Programme under grant agreement no. 284741.

Nuclear cruiser conceptual design

Operative Condition	*Assumptions*	*T/W*	*T (kN)*	*P (MW)*
Cruise	• $C_{D0c} = C_{D0} + 0.03$ • $v = 236.3$ m/s • $h = 11000$ m	0.053	457 @ h 1254 @ s.l.	108 300
Maneuver	• $n_{max} = 2.5$ • $h = 11000$ m • $v = 236.3$ m/s	0.17	1458	**344.5**
Take-off	• $X_{TO} = 3000$ m • Sea level			
Landing	• $v_{st} = 43.73$ m/s • Sea level			
Rate of Climb	• $C_{LTO} = 1.4$			
Ceiling	• $RC_{ceiling} = 1.5$ m/s	0.0273	234 @ h 637 @ s.l.	55.3 150
Climb Gradient	• 4 engines • $C_{LTO} = 1.4$ • $C_{LL} = 2.2$ • $v_2 = 1.2^* v_{st}$	Initial climb 0.157 Transition climb 0.165 Second part climb 0.174 Route climb 0.151 Aborted landing 0.184 Aborted landing 0.222	**1900**	100

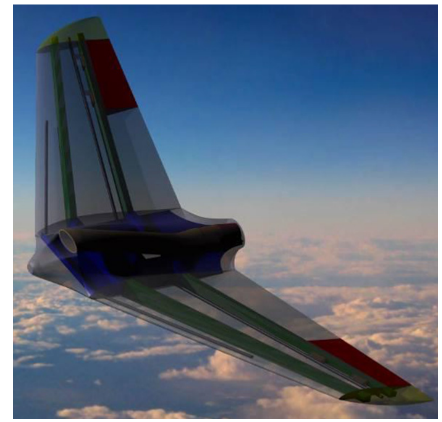
Class I weight estimation

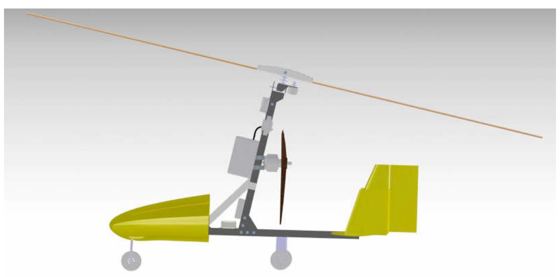
WTO is the sum of the following three weight components:

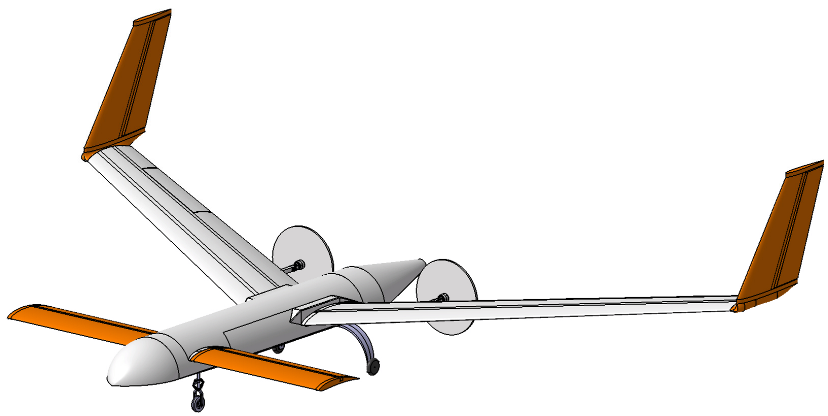
- **WPL (Payload Weight).** It is the sum of passengers weight Wpax and cargo weight Wcargo.
- **WOE (Operative Empty Weight).** It includes the weight contributions of structures, engines, lubricants, and crew.
- **WP (Power Plant Weight).** It includes the weight of the nuclear reactors, the cooling system and the shielding. It does not include the weight of the engines, whose contribution is accounted in WOE).

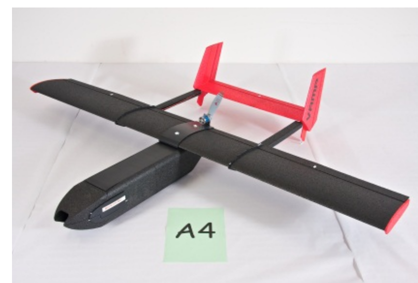
Development of UAS for scientific monitoring

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546608









11th European Workshop on Aircraft Design Education, Linköping, 17.-19.09.2013

17/9/2013

R. De Roo, J. Verbeke, I. Becuwe

Aeronautical training

vives

ASSOCIATIE K.U.LEUVEN

khbo
KATHOLIEKE HOGESCHOOL
BRUGGE - OOSTENDE

vives university college
KU Leuven association

KATHOLIEKE UNIVERSITEIT LEUVEN

Prof. Bachelor
-ATPL
-Technology

Academic Bachelor
Master

Aeronautical training

vives @ Flanders aerospace Competence center

Faculty Engineering Sciences & Technology – Dept. Aeronautics:

Located in Belgium at International airport of Ostend-Bruges (EBOS)

UAS?

UAS (Unmanned Aerial System)

UAV

(Unmanned Aerial vehicle)

Groundstation

(Telemetry, communications, command)

UAS developments

Creating a UAS competence centre:

- 2004~2010: uncoupled projects/theses
  - Conceptual design of a mini-UAV with methanol fuel cell
  - UAV data monitoring
  - Telemetry and data acquisition for VUT 700 Specto UAV
  - …

- 2010: Focus on scientific research with UAS

➔ Litus project

Litus

Project description:

- 3-year project (summer 2010 – summer 2013)
- Aim: Development of a UAS platform for scientific monitoring of the Flemish coast and North Sea
- Collaboration Vives/ KULeuven / foreign universities / industrial partners
- Extended to summer 2014

Litus

Application:

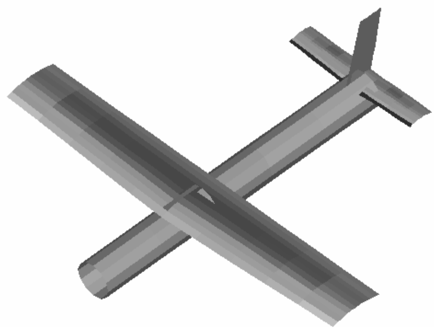
- To improve coastal weather forecasts models through daily measurements along the coast

- Flexible payload implementation
  - Payload test platform
  - Pollution detection
  - Coast police assistance
  - SAR
  - …

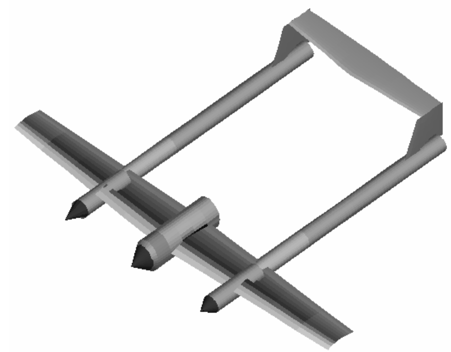
Litus

Conceptual design phase

- Exploration of legislation (or lack thereof)
- Aerodynamics and performance of three configurations investigated by Master students Vives



Conventional



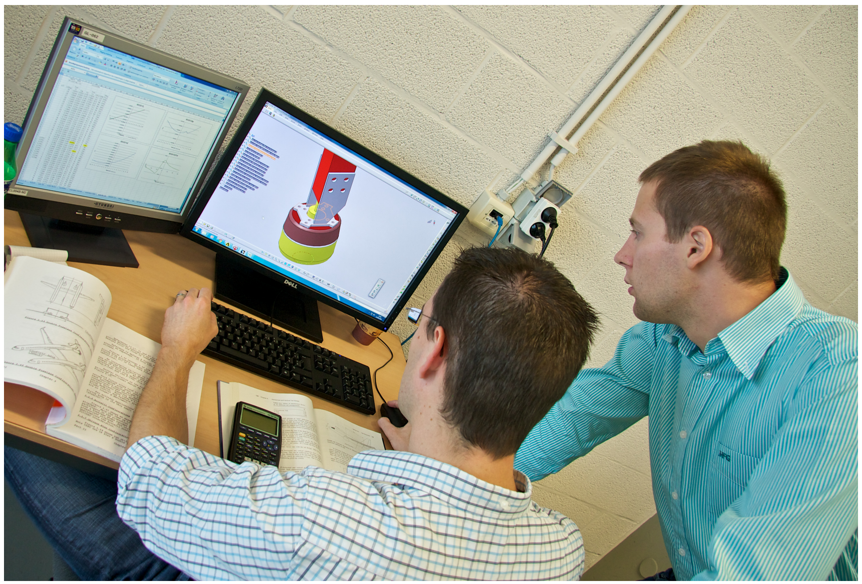
Twin boom

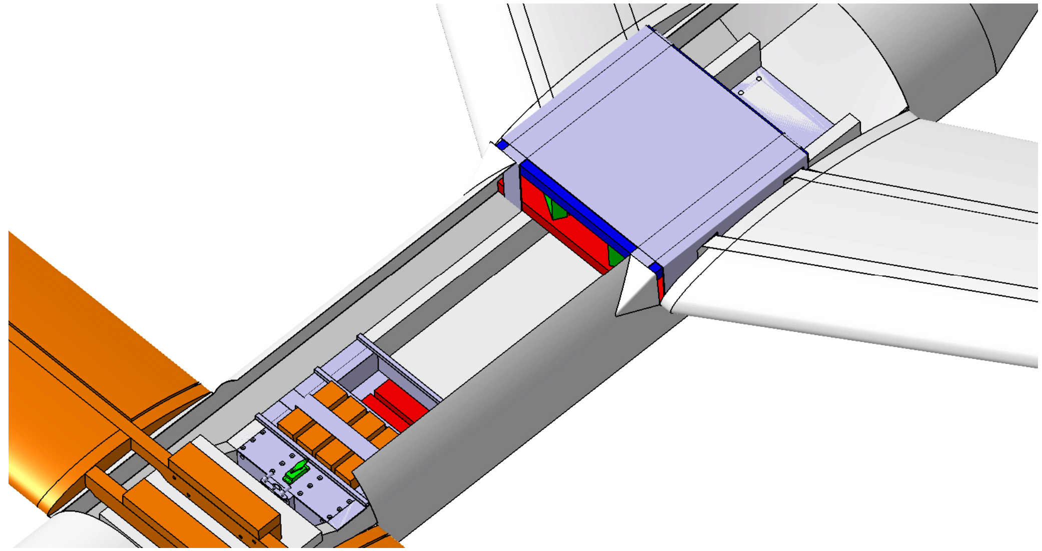
Canard

Litus

Detailed design phase – 3D design

- Mainly by design team



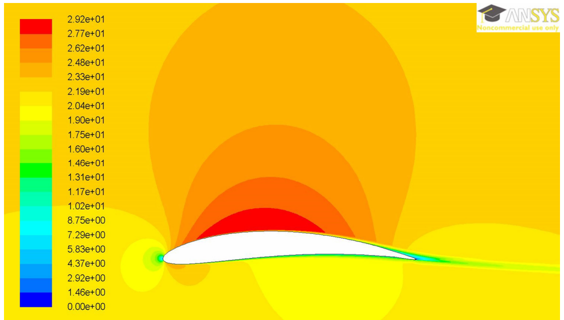


Useable volume =
0,7 x 0,5 x 0,3m

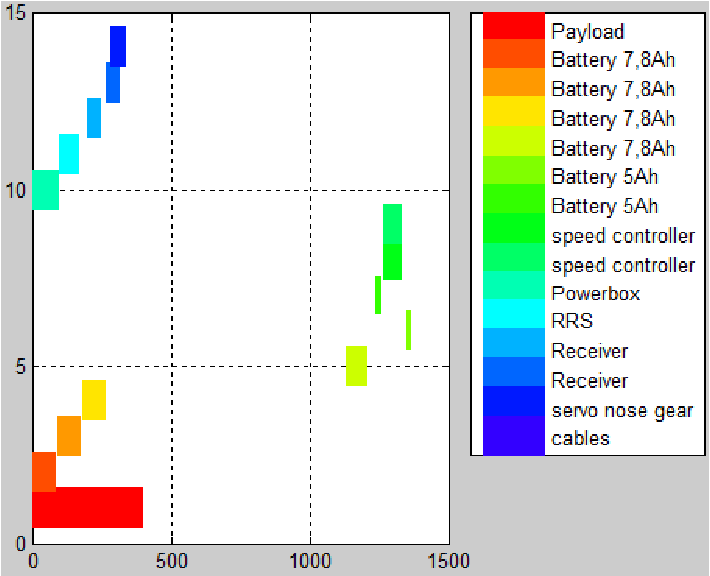
Litus

Detailed design phase – stability

- Basic CFD analysis: Master thesis Vives



- Weight & Balance for stability: Master students KULeuven

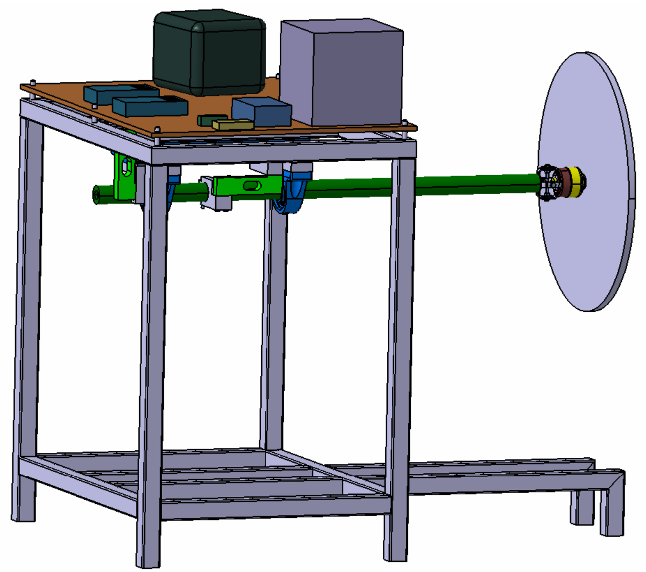


Litus

Detailed design phase – motor

- Unknown performance COTS motor/propeller

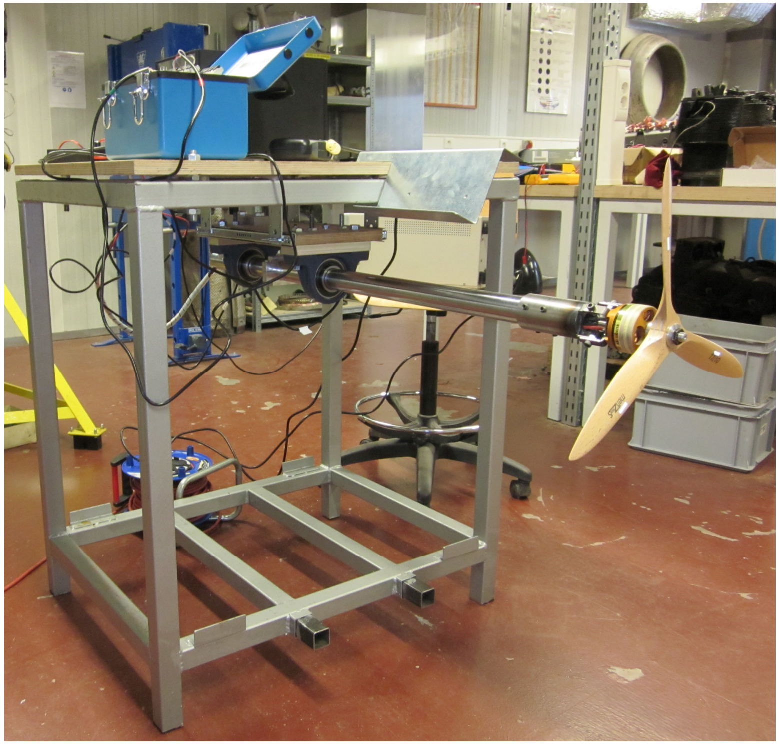
- Design and construction of test bench by a Vives and Erasmus (Brno) student



Litus

Detailed design phase – motor

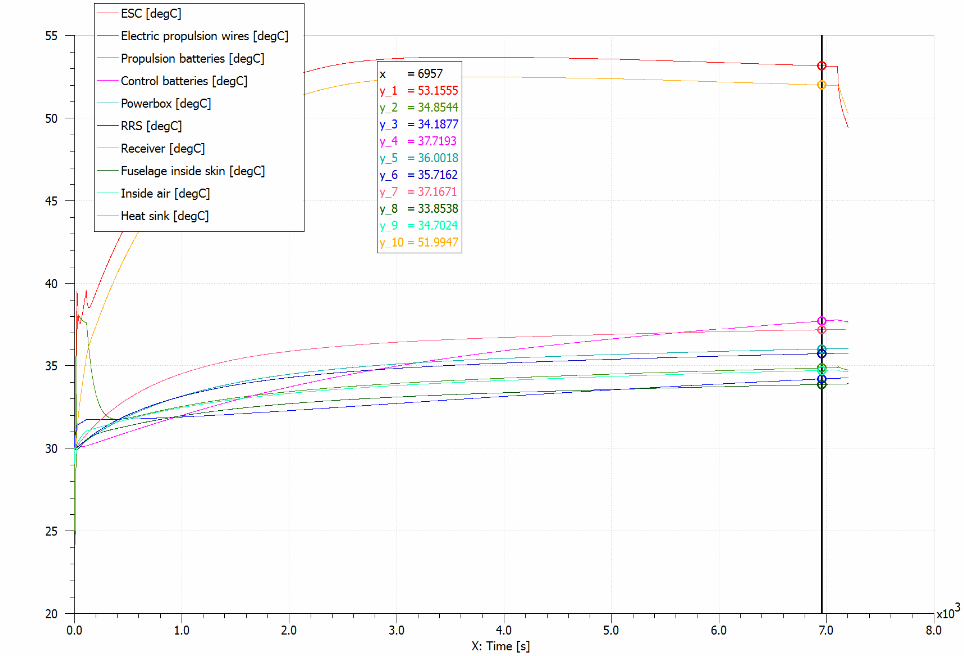
- Testing: Erasmus student (Madrid)

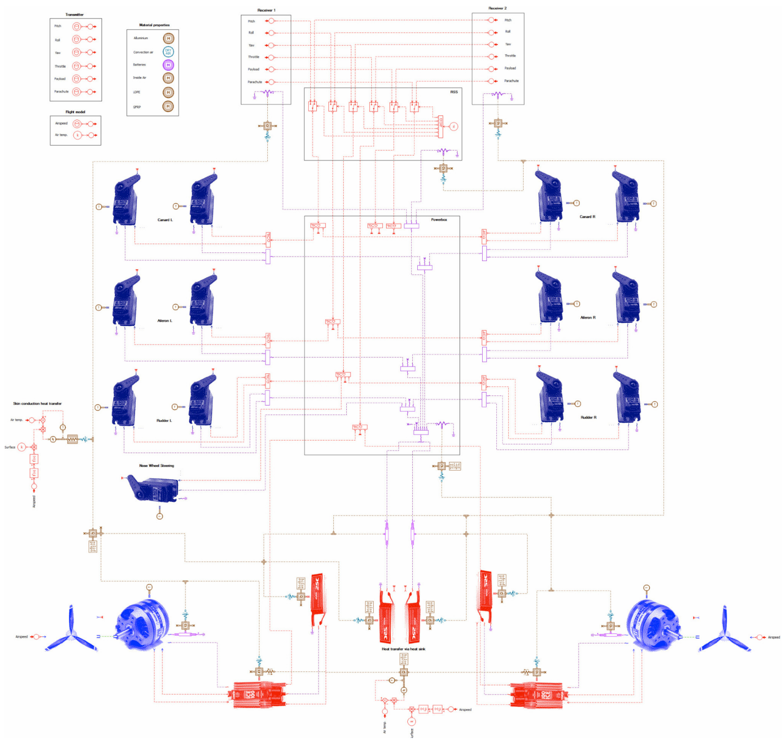


Litus

Detailed design phase – performance

➢Energy management and thermal simulations: Master thesis Vives & LMS

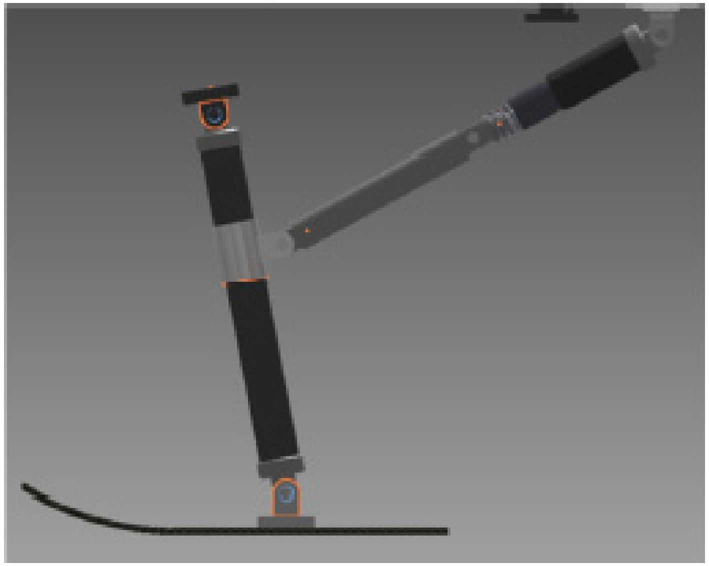


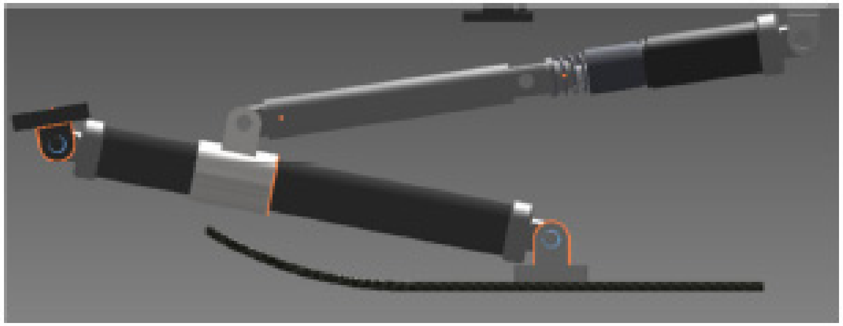


Litus

Detailed design phase – landing gear

- Development: Integrated practicum Master KULeuven
  - Too expensive and complex
  - New simple design by design team

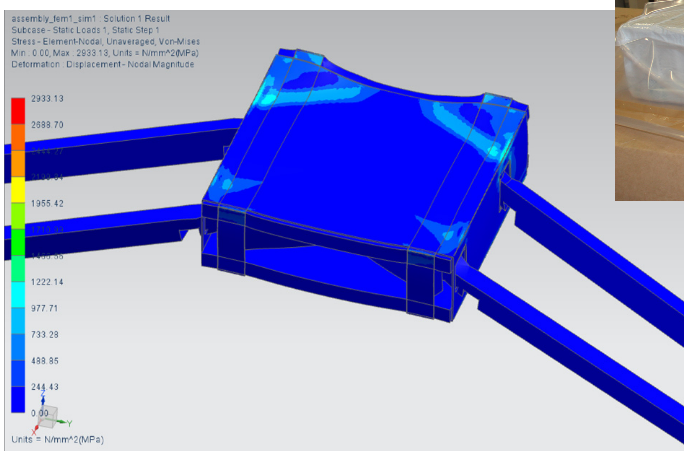




Litus

Detailed design phase – wing box

- Finite element modelling, prototyping and testing: Master Vives



Litus

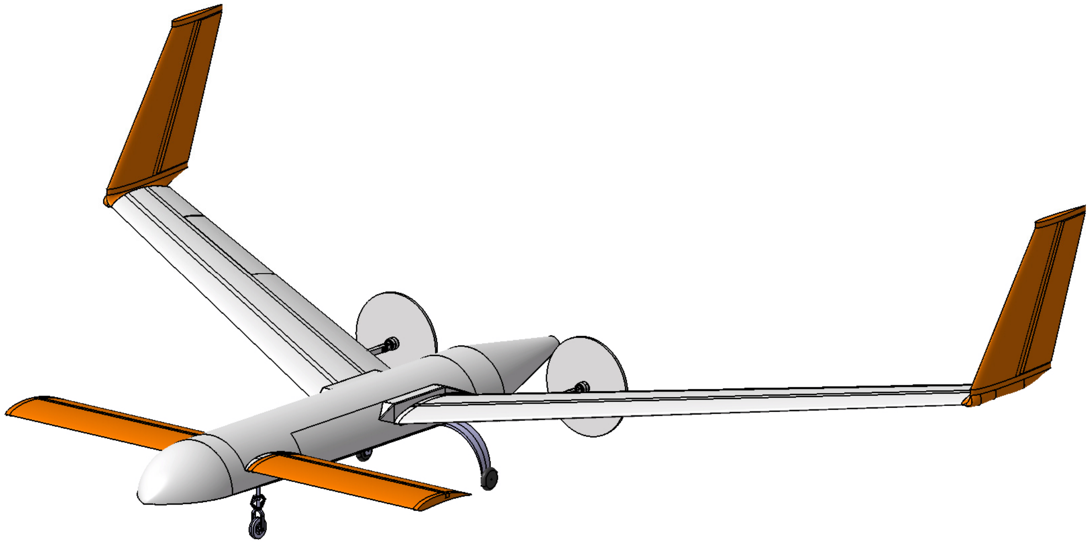
Detailed design phase – safety

- Separated electrical systems propulsion, flight control and payload
- Redundant control system (receivers, flight controls, …)
- Onboard aircraft monitoring sent through telemetry to ground station
- Autopilot (assisted) flight
- …

Litus

Detailed design phase

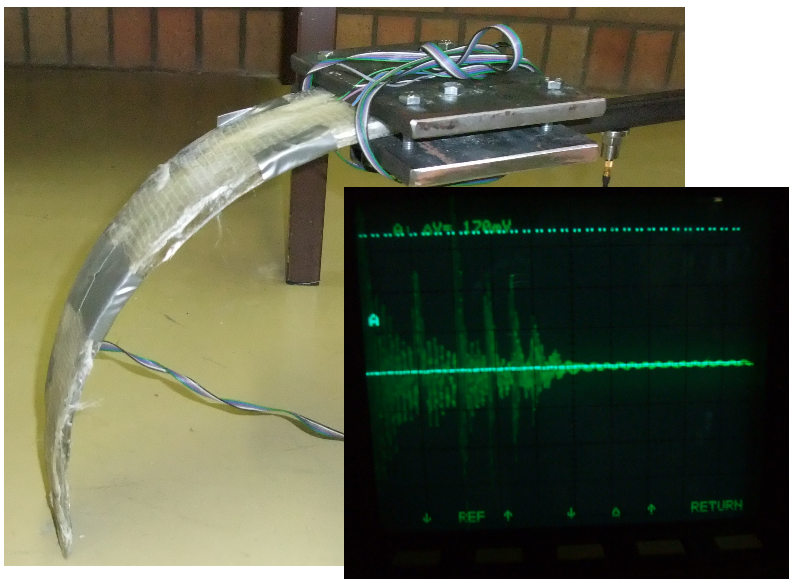
- Lifting canard configuration with two push propellers
- Lightweight glass fibre structure
- Brushless DC motors
- LiPo batteries
- Cruise speed: 80km/h
- Stall speed: 50km/h
- Max endurance: 2h
- Max range: 160km
- Total mass: 65kg
- Max payload: 15kg
- Wing span: 6m

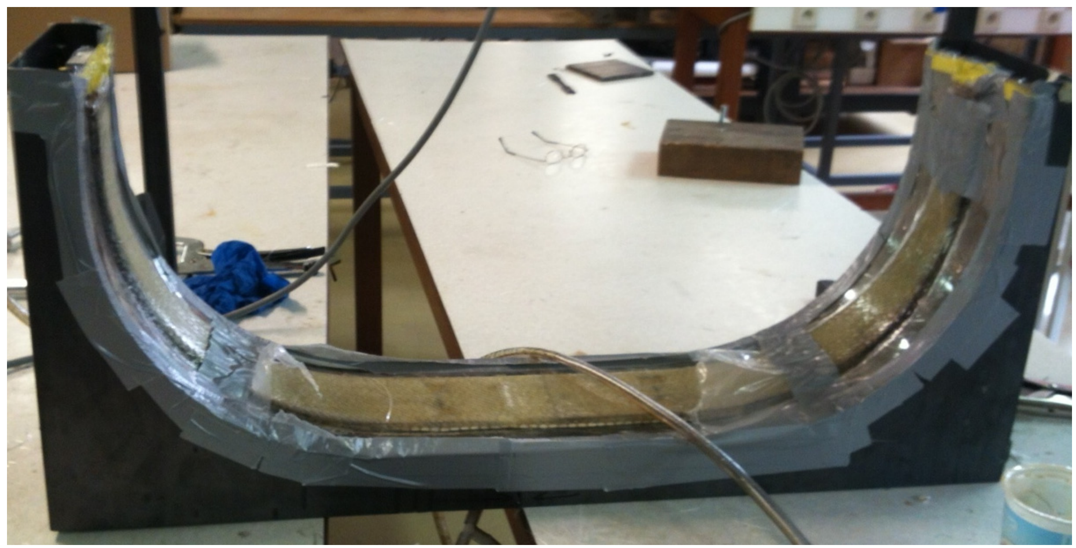


Litus

Production and testing– landing gear

➢Development, production and testing: Vives Polymer Engineering Master students

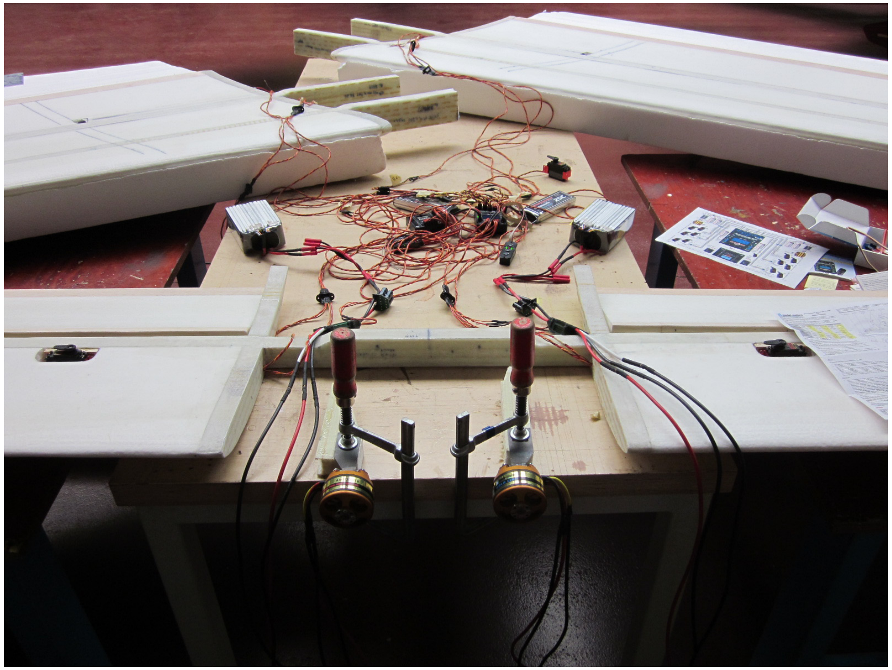


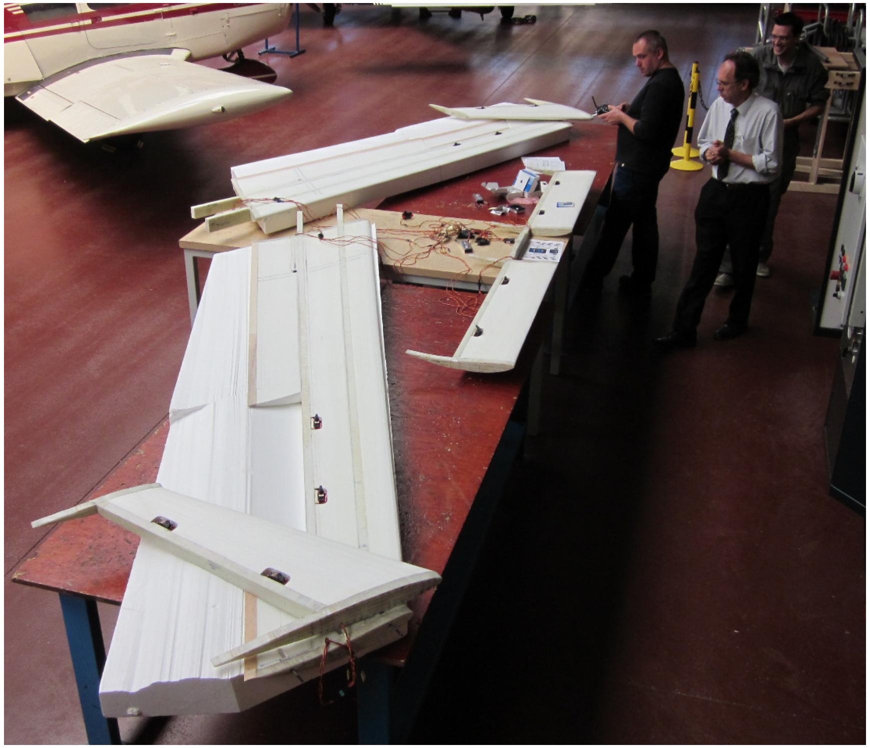


Litus

Production and testing – electrical system

- Design team and Erasmus student (Brno)





Litus

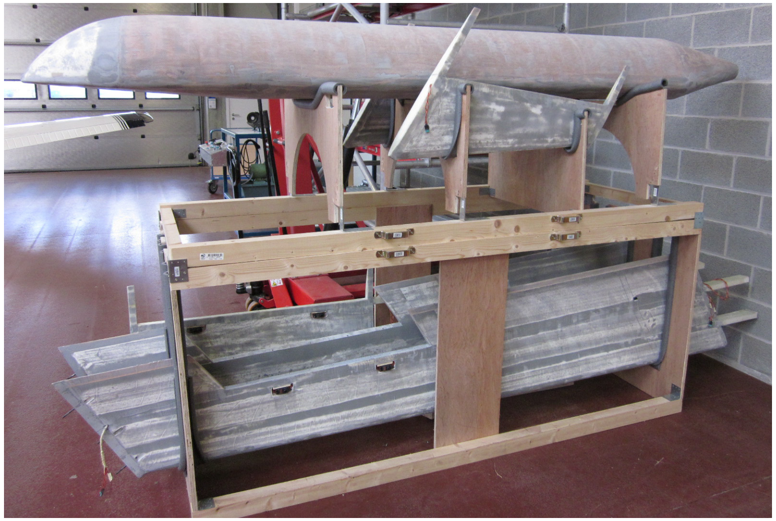
Production and testing – glass fibre structure

➢Design team, Erasmus student (Brno) and volunteers

Litus

Status

- Finished:
  - Production of most parts
  - Electrical system
  - Safety documents for BCAA
- In progress: Wing box
- To do 2013-2014:
  - Final assembly and painting of parts
  - Autonomous control capabilities



- First flight: summer 2014!!

Parallel research

Development of the G55 UAV for Federal Police

➢Police helicopters are equipped with cameras (visual, thermal, ...) for observation

- No permit to fly in danger zones (nuclear power plant, fires, ...)
- Very expensive
- Limited flight time

➢Request to Vives:

Develop a small UAV with 2kg payload

Parallel research

<u>Development of the G55 UAV for Federal Police</u>

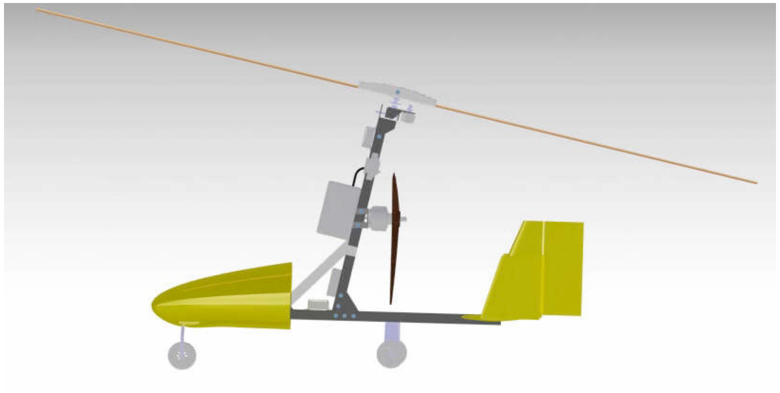
➢Two Vives Bachelor students calculated, designed and manufactured a 20kg UAV with 2m wingspan)

Successful test flight!

Parallel research

Development of a UAV autogyro

- ➢Two Vives Bachelor students designed and manufactured a UAV autogyro
- ➢Result:
  - Weight: 5kg (Payload: 0,5kg)
  - Rotor diameter: 2m



Parallel research

Development of a UAV airship

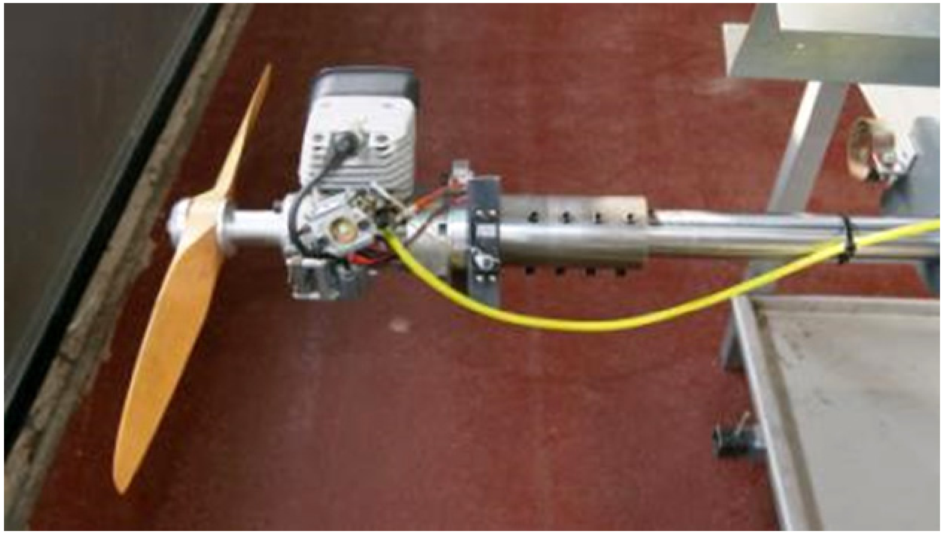
- A Vives Bachelor student manufactured and automated a UAV airship based on existing plans

- Result
  - 1,7m Mylar bag
  - Triple engine control
  - Glass fibre gondola
  - Helium filled
  - Ultrasonic sensors for altitude control and obstacle avoidance

Parallel research

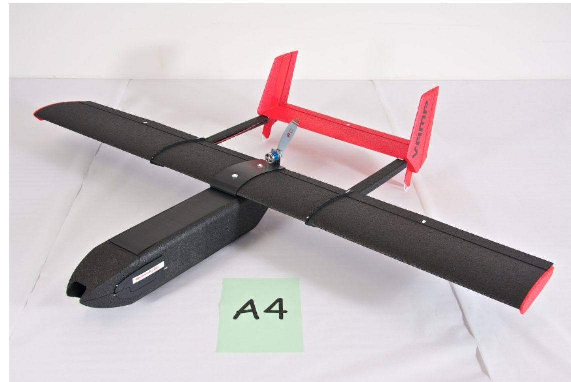
Modification of test bench for testing of small combustion engines

➢Request to Vives: UAV performance improvement by changing motor (Vives Bachelor student)



Parallel research

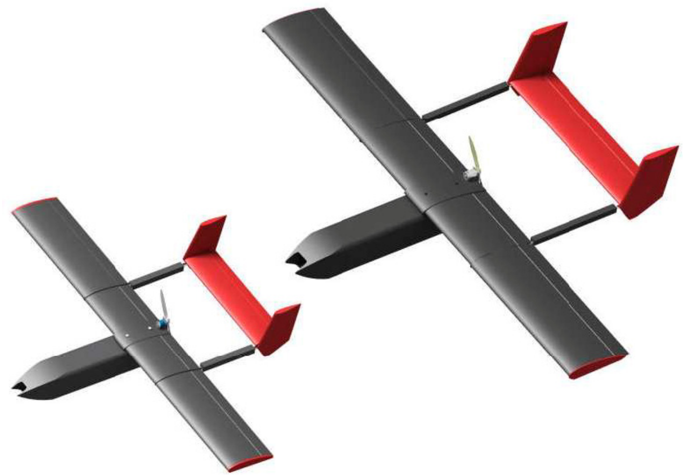
Reverse engineering of an existing UAV



- Reverse engineering
  - Aerodynamics
  - Performance
  - Stability and control

- Re-design with twice the payload

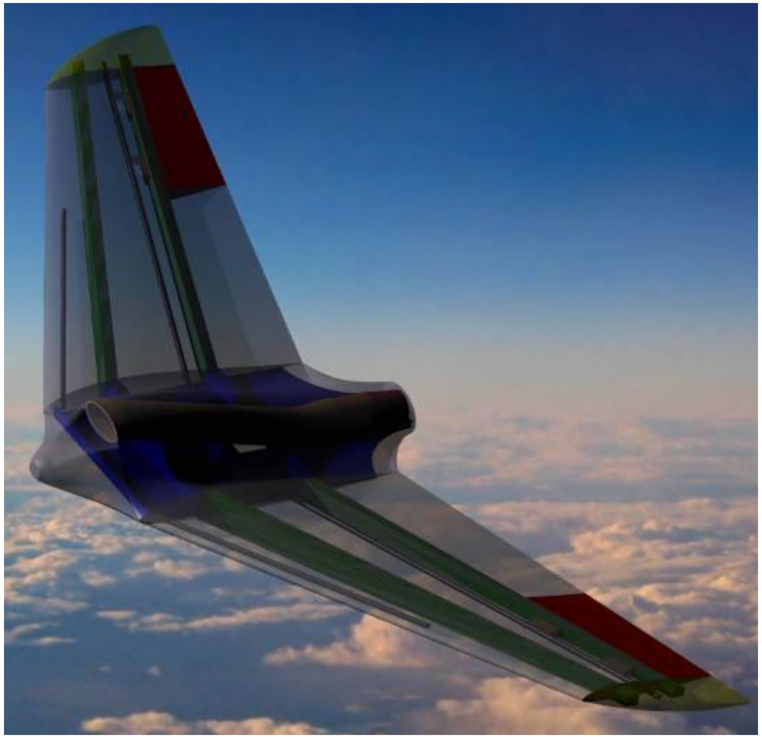
- Two Vives master students



Parallel research

Development of a UAV flying wing

- Two Vives Bachelor students designed a flying wing UAV
- Result
  - EDF tested
  - Production ready design

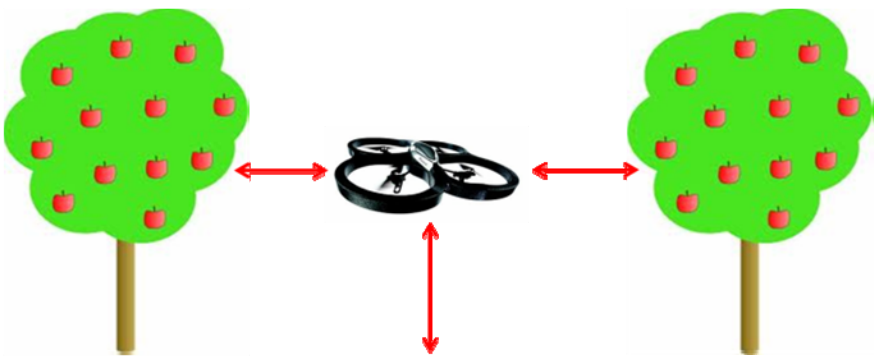


Parallel research

Doctoral research by Jon Verbeke

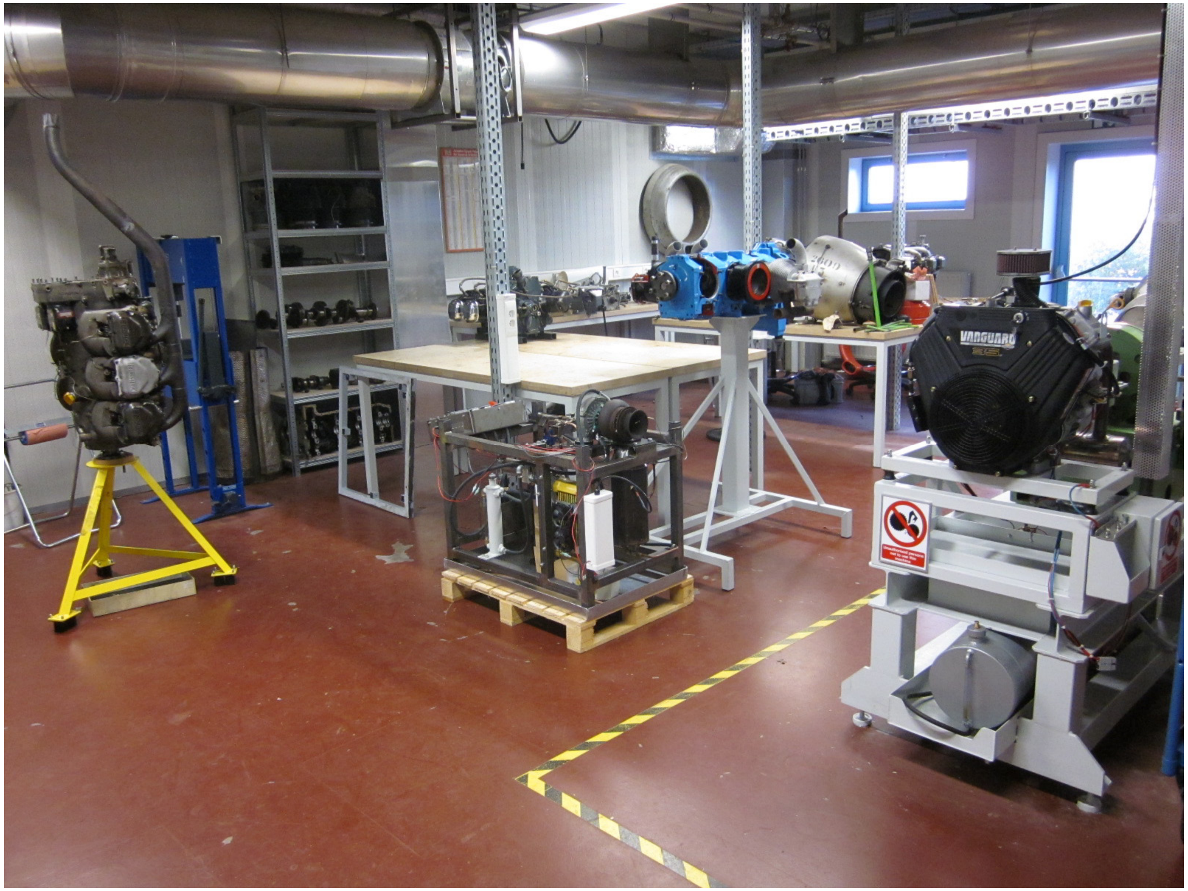
➢Autonomous rotary UAS for inspection of orchards and vineyards

- Autonomous navigation through orchards in between tree rows
- Cameras and image processing techniques perform fruit yield estimation
- Long endurance and innovative design for narrow passages



Testing @ VLOC

Acoustic isolated engine test lab



Testing @ VLOC

Indoor flight lab for rotary UAS

- 7 x 7 x 4m volume
- Safety:
  - Net
  - Soft floor
- Near future: external camera positioning system

Governmental work

➢2012: Vives participates in BeUAS

➢Is a member of the legislation workgroup which writes the new upcoming legislation together with BCAA

➢Is working together with the Federal government in selecting a suitable commercial rotary UAS for the Civil Defence agency with the purpose of disaster monitoring

Conclusion

<u>The Vives UAS competence centre</u>

- Successful start
- More than 30 students, both national and international have been involved in UAS research and development
- UAS course from Sept. 2013
- In the future, the focus will lie on further expansion towards the industry and starting new projects together with other academia and companies.

Questions?

vives

vives

ASSOCIATIE KU LEUVEN

KU LEUVEN

LMS® A Siemens Business

ACROSOMA STRUCTURAL COMPOSITE TECHNOLOGY

Septentrio satellite navigation

UNIVERSIDAD POLITECNICA MADRID

BeUAS

FLAG

BRNO UNIVERSITY OF TECHNOLOGY

VON KARMAN INSTITUTE

ibz

Police

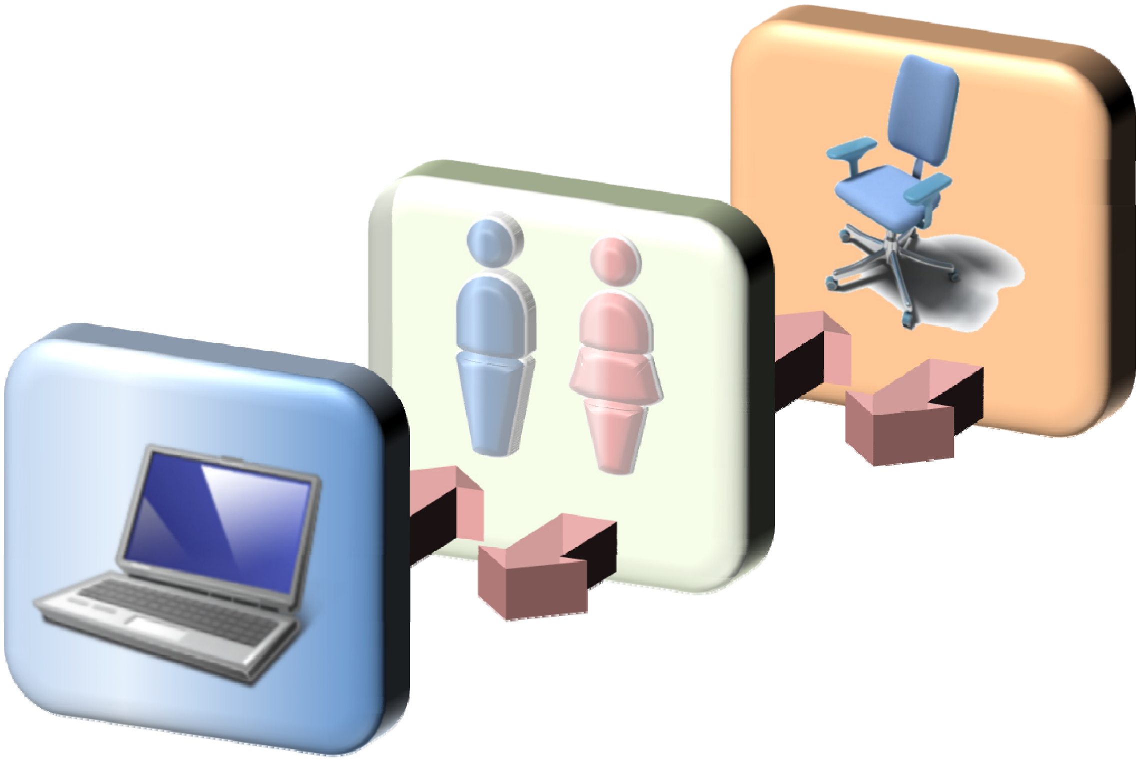
Collaborative understanding of disciplinary correlations using a low-fidelity physics based aerospace toolkit

Erwin Moerland
Richard-Gregor Becker
Björn Nagel

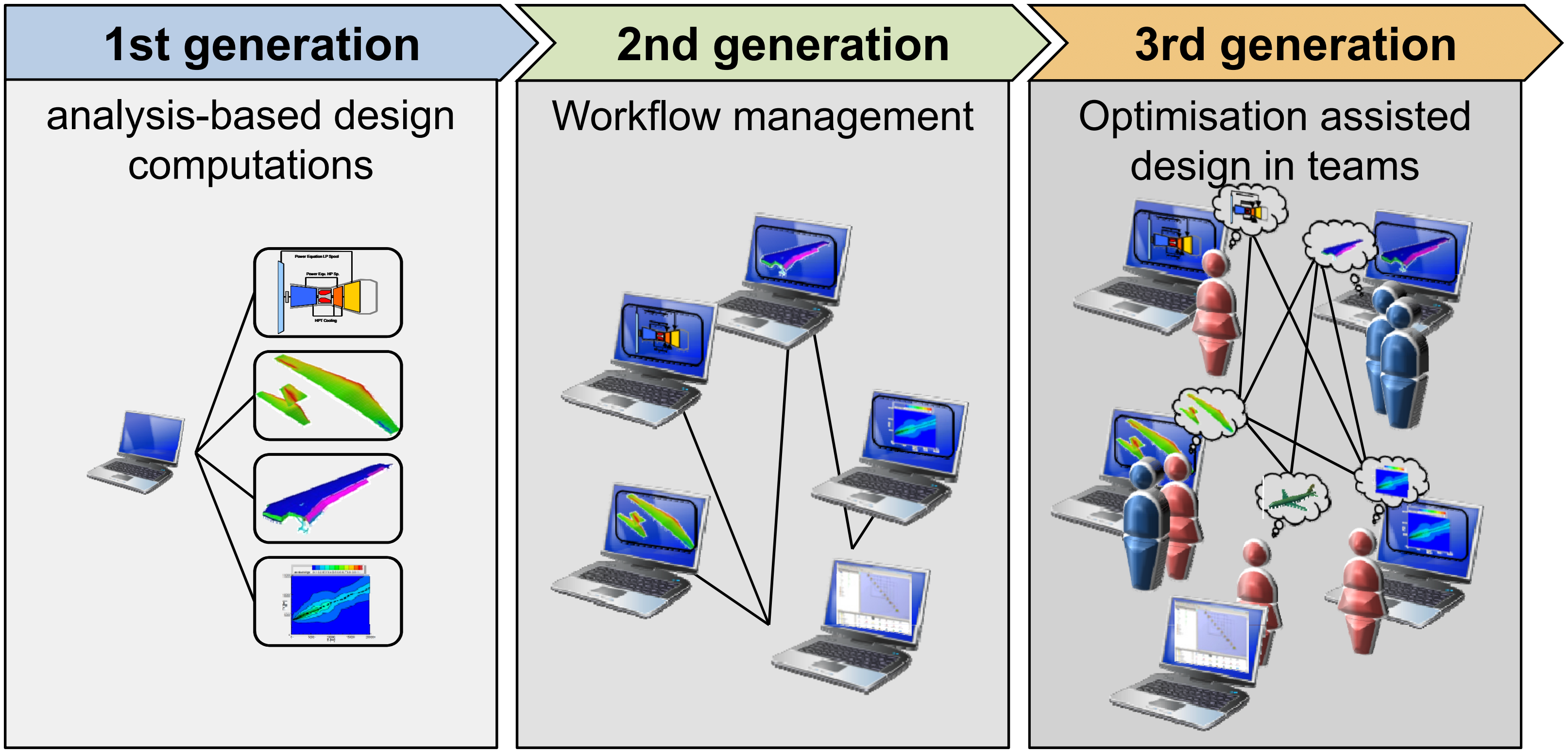
http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546610

4th CEAS Air & Space Conference
16th-19th September 2013
Linköping

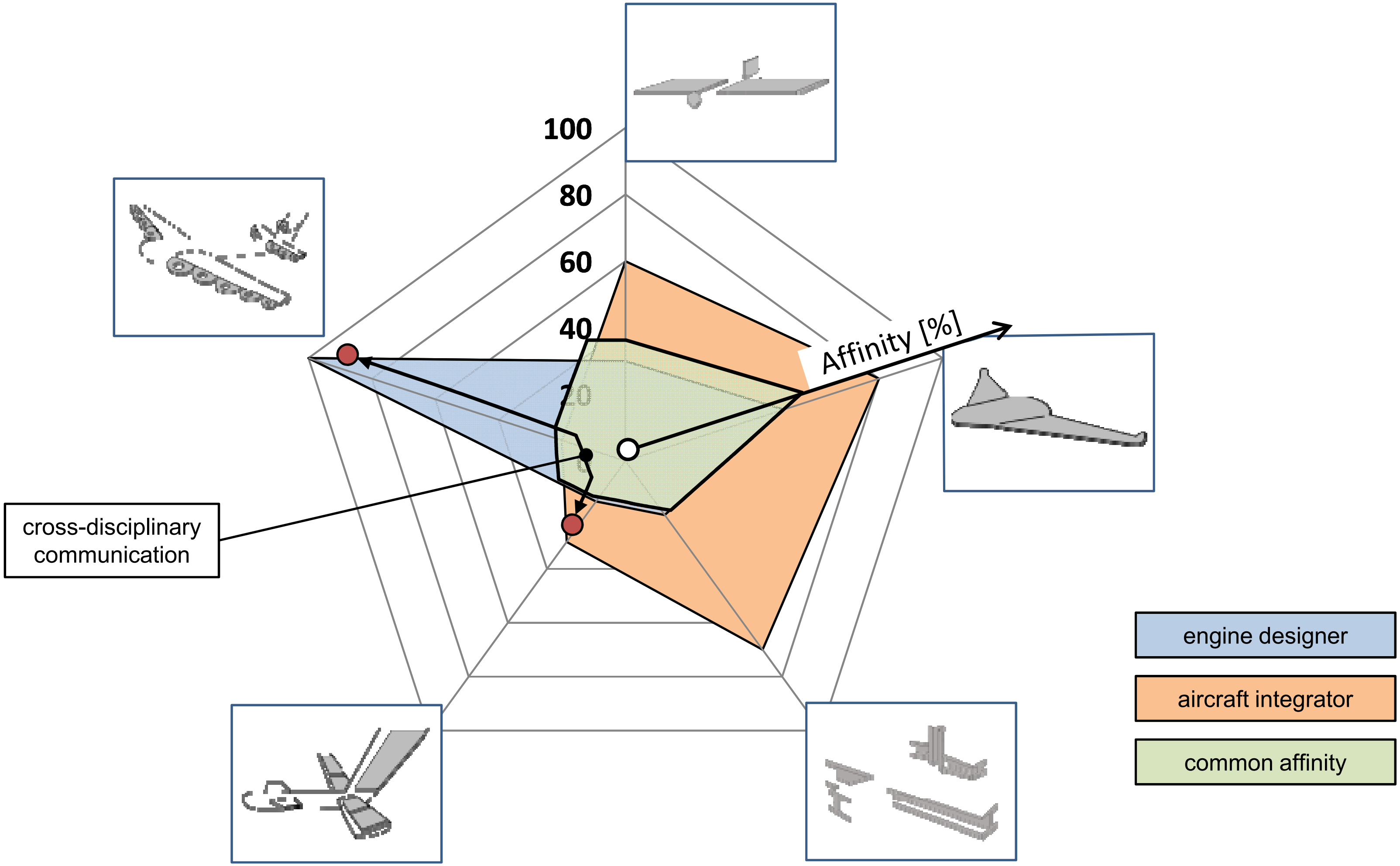
DLR



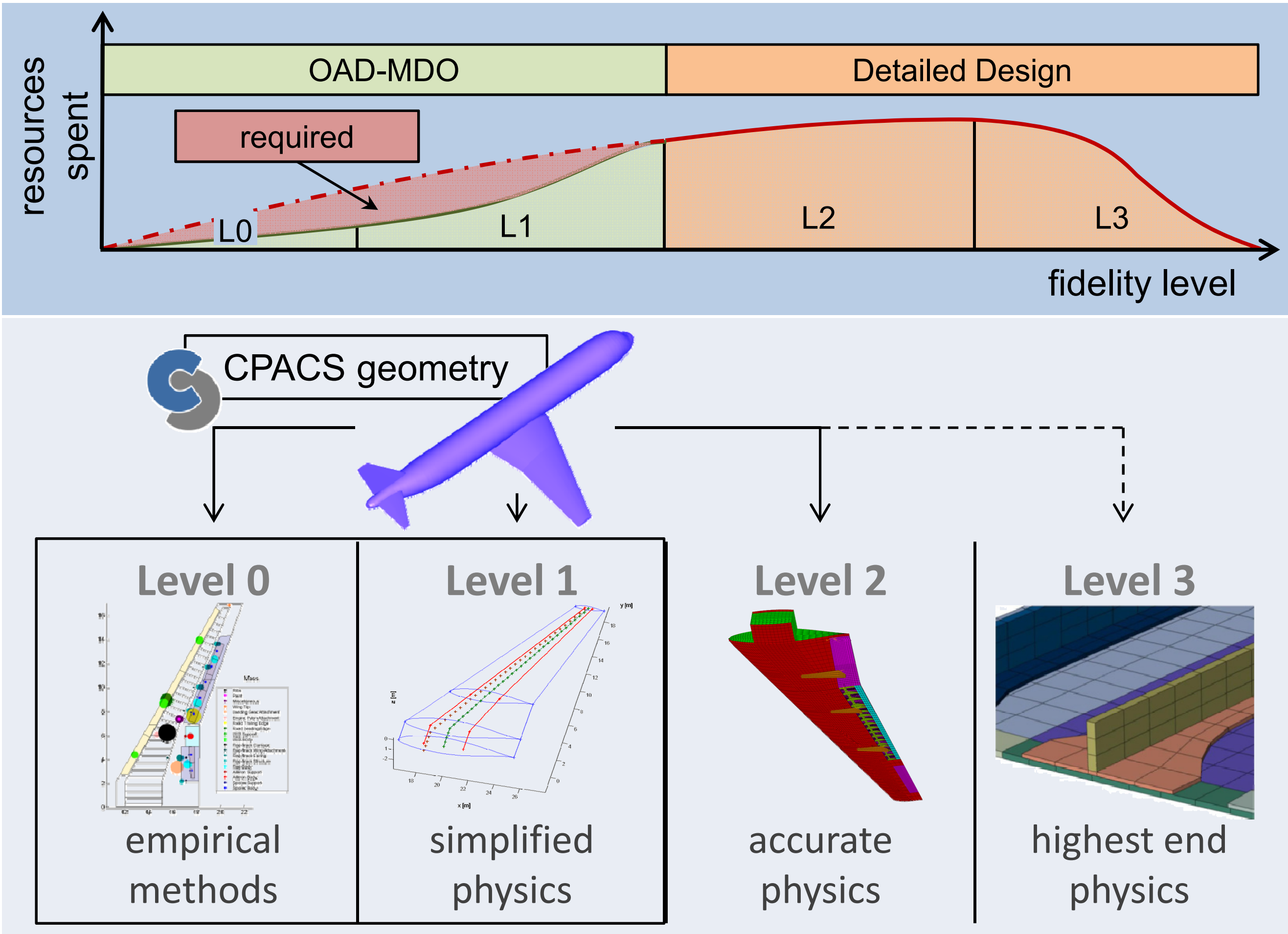
Advancements in MDO



Cross-disciplinary communication



Low-level toolkit



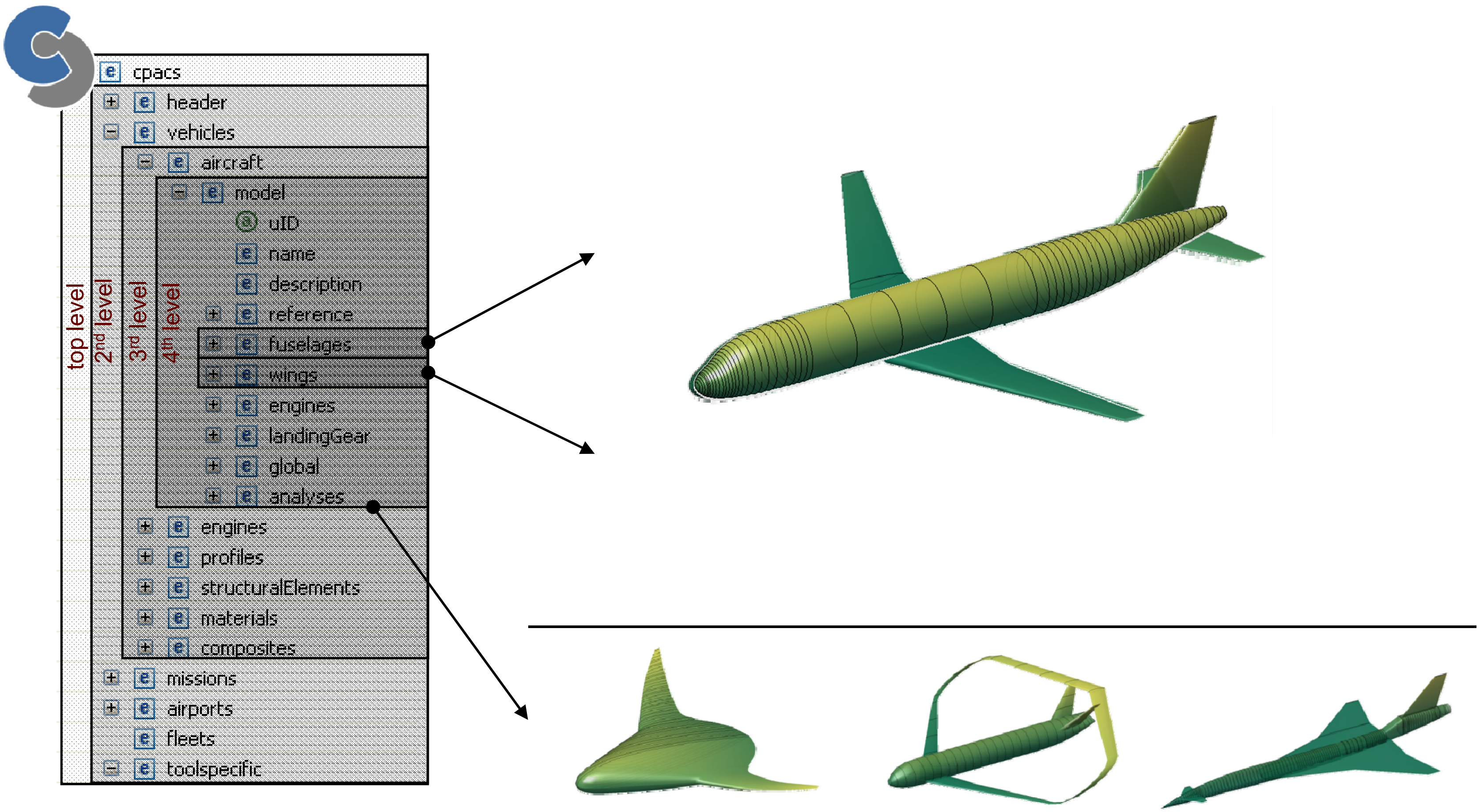
Level 0 figure:
PESTwing, Felix Dorbath

Level 1 figure:
FSI, Pier-Davide Ciampa, Erwin Moerland

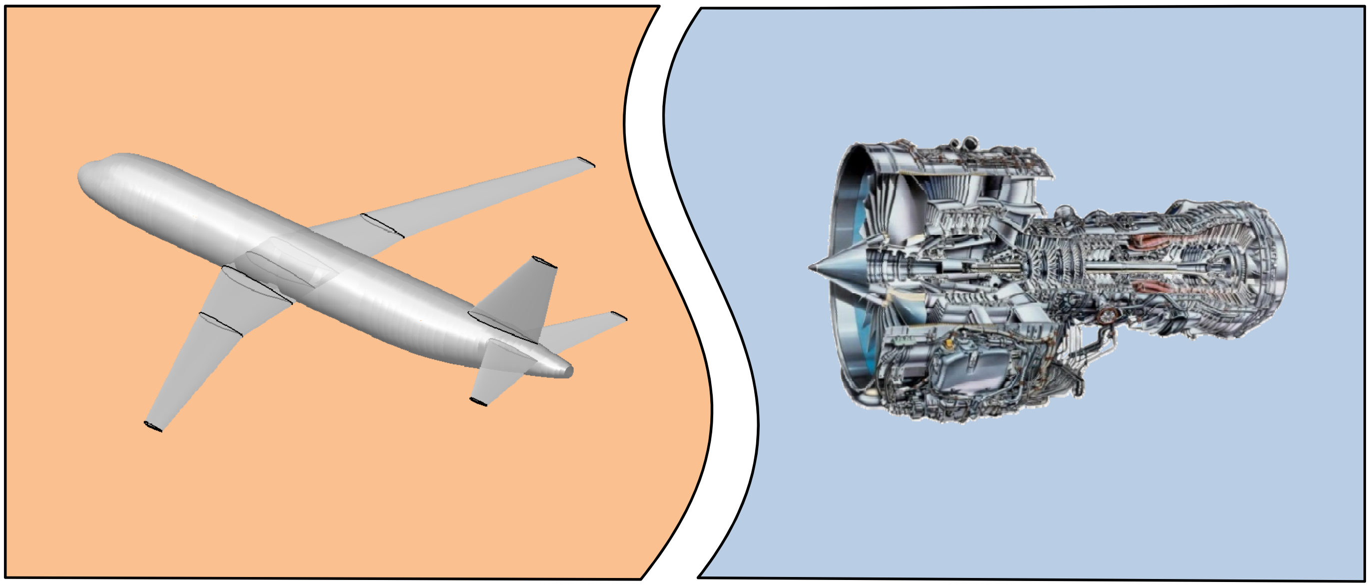
Level 2 figure:
WINGmass, Felix Dorbath

Level 3 figure:
Virtual testing of aircraft structures
Ostergaard et al.

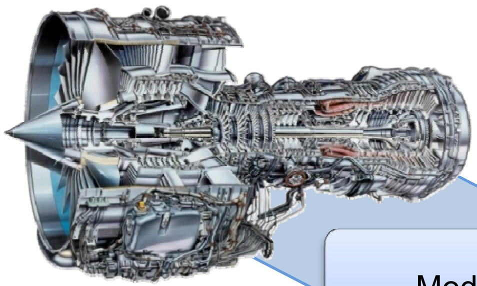
Common Parametric Aircraft Configuration Scheme - CPACS



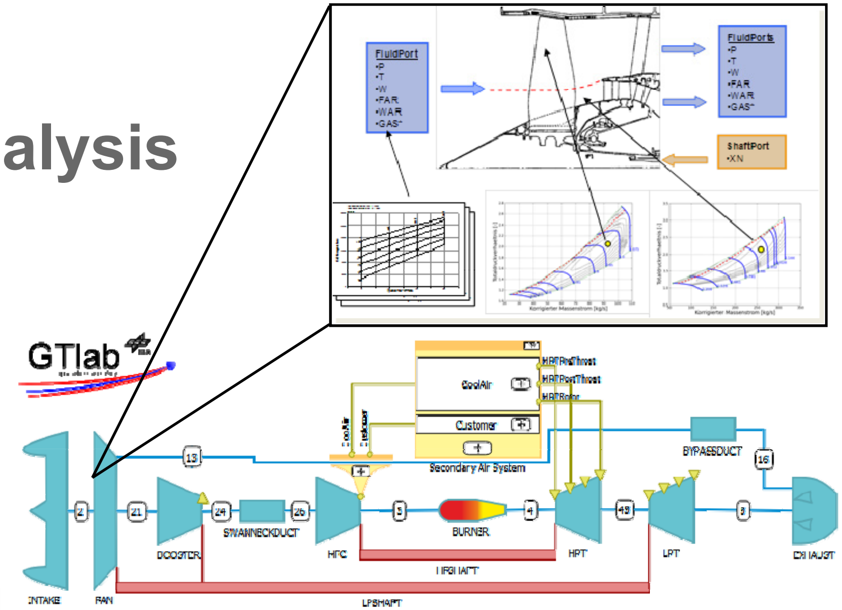
Interactive aircraft and engine design



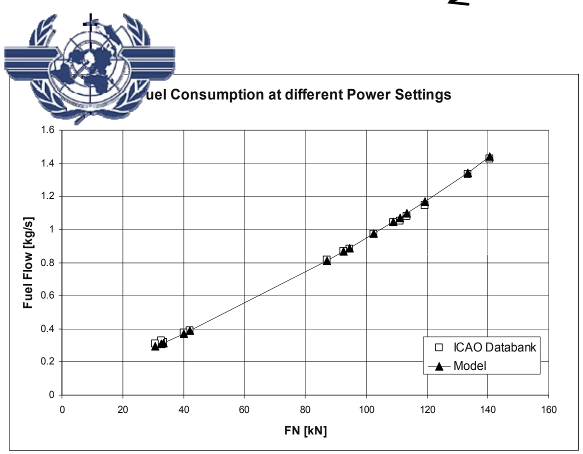
Engine data for aircraft analysis



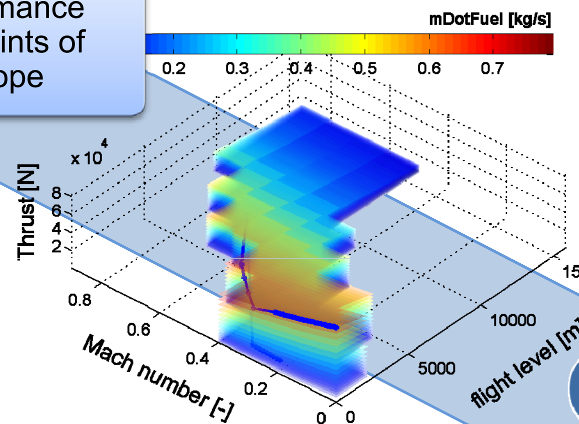
Modular engine component modelling



Model validation against ICAO certification data

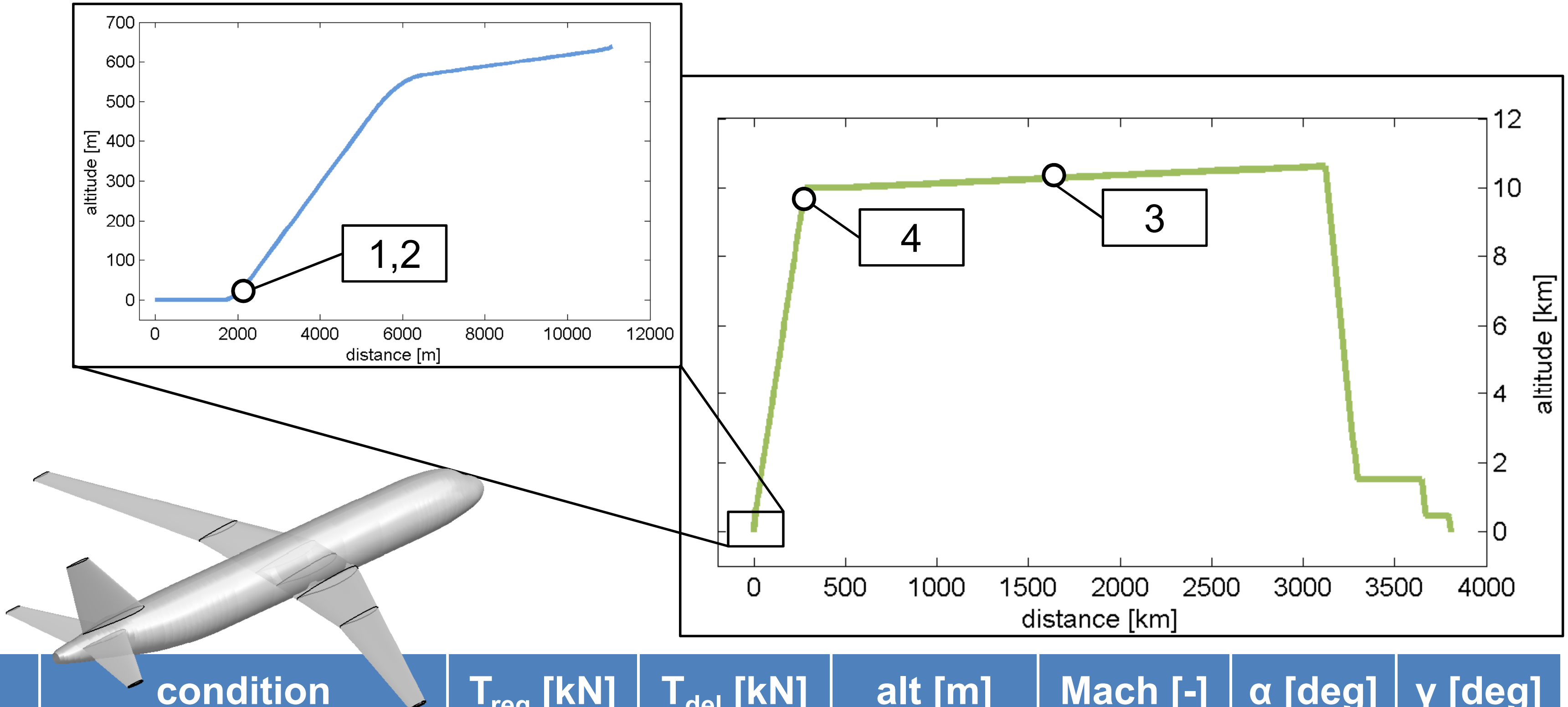


Engine performance for discrete points of flight envelope



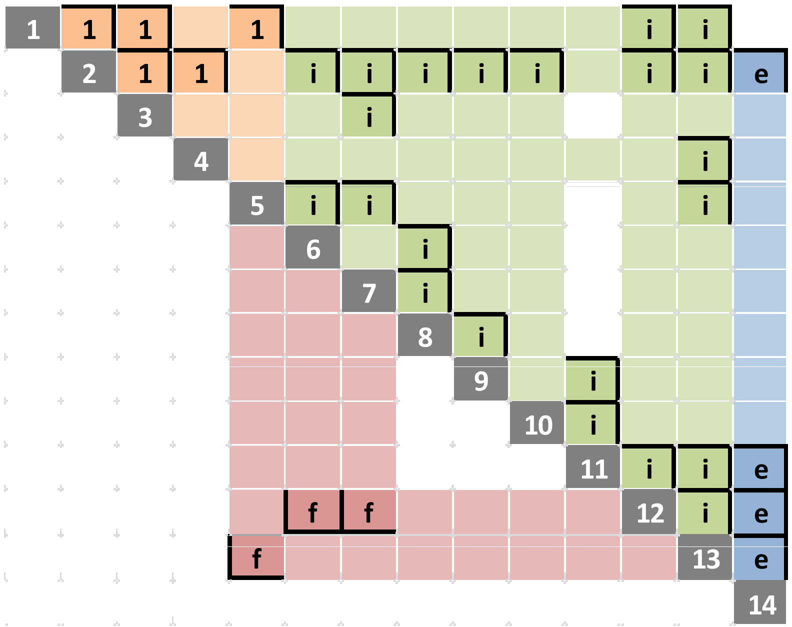
V2500 Engine – Source: Pratt&Whitney

Aircraft data for engine layout



	condition	T_{req} [kN]	T_{del} [kN]	alt [m]	Mach [-]	α [deg]	γ [deg]
1	one engine inoperative	82.4	80.9	64	0.23	9.4	2.4
2	end of field	78.3	78.3	45	0.26	8.0	8.0
3	mid cruise	19.9	19.9	$10.4 \cdot 10^3$	0.78	4.1	~ 0
4	top of climb	27.0	27.0	$10.0 \cdot 10^3$	0.78	3.6	1.1

Combined a/c & engine design – N2 Chart



#	purpose	tool
1	TLAR & basic aircraft geometry	user input
2	geometry variation	GPP
3	mass initialisation	VAMPzero
4	aerodynamic performance map	Tornado
5	engine mass & performance map	TWDat
6	loadCase determination	LCG
7	weight and balance	WandB
8	spanwise loading	TRIM_VL
9	wing primary mass	PESTwing
10	wing secondary mass	PESTsewi
11	mass tree update	CMU
12	aircraft mass synthesis	VAMPzero
13	fuel mass and engine scaling	FSMS
14	direct operating costs	DOC

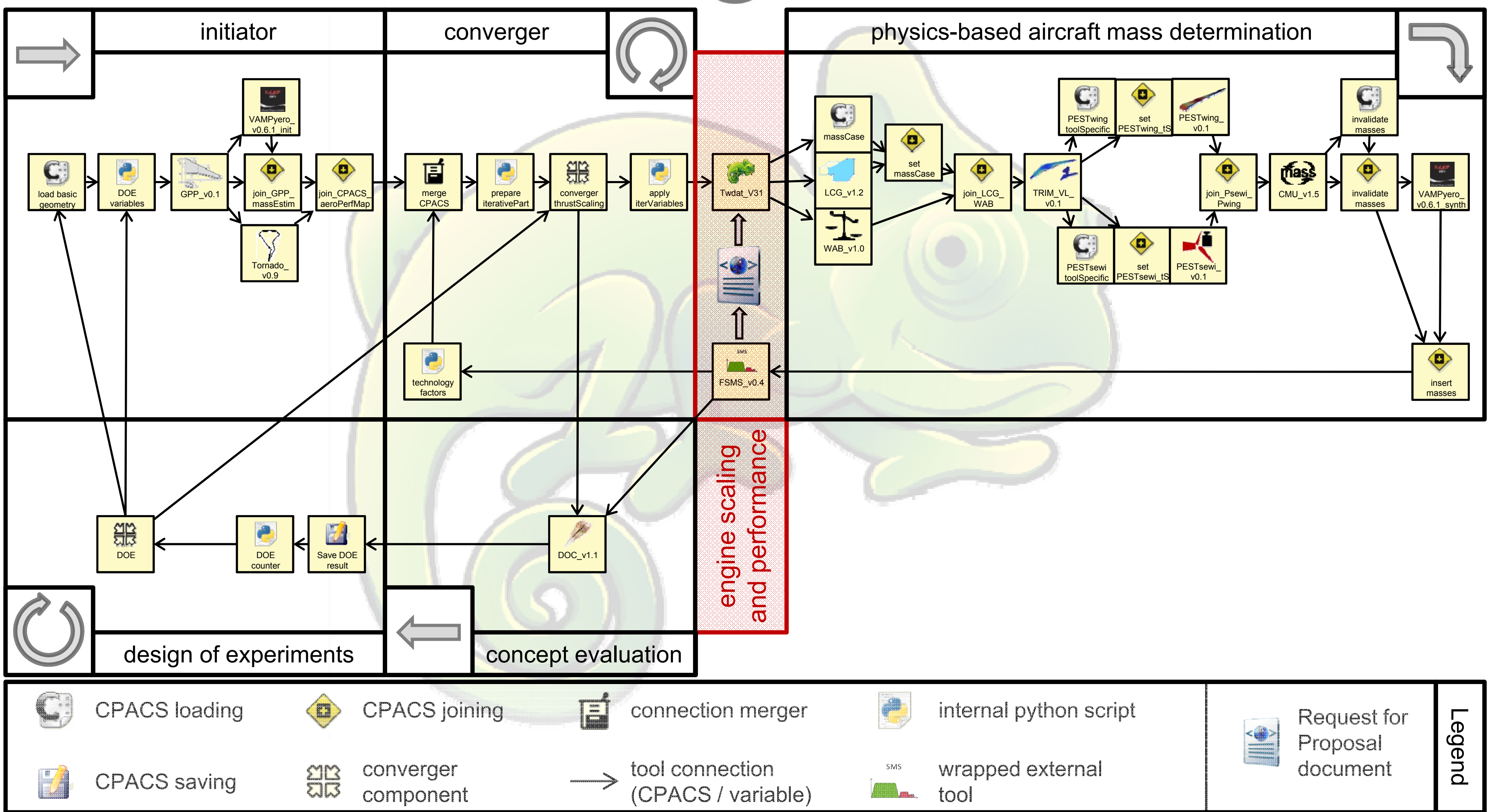
1 connection in initialisation phase

i input connection in interative phase

f feedback connection in iterative phase

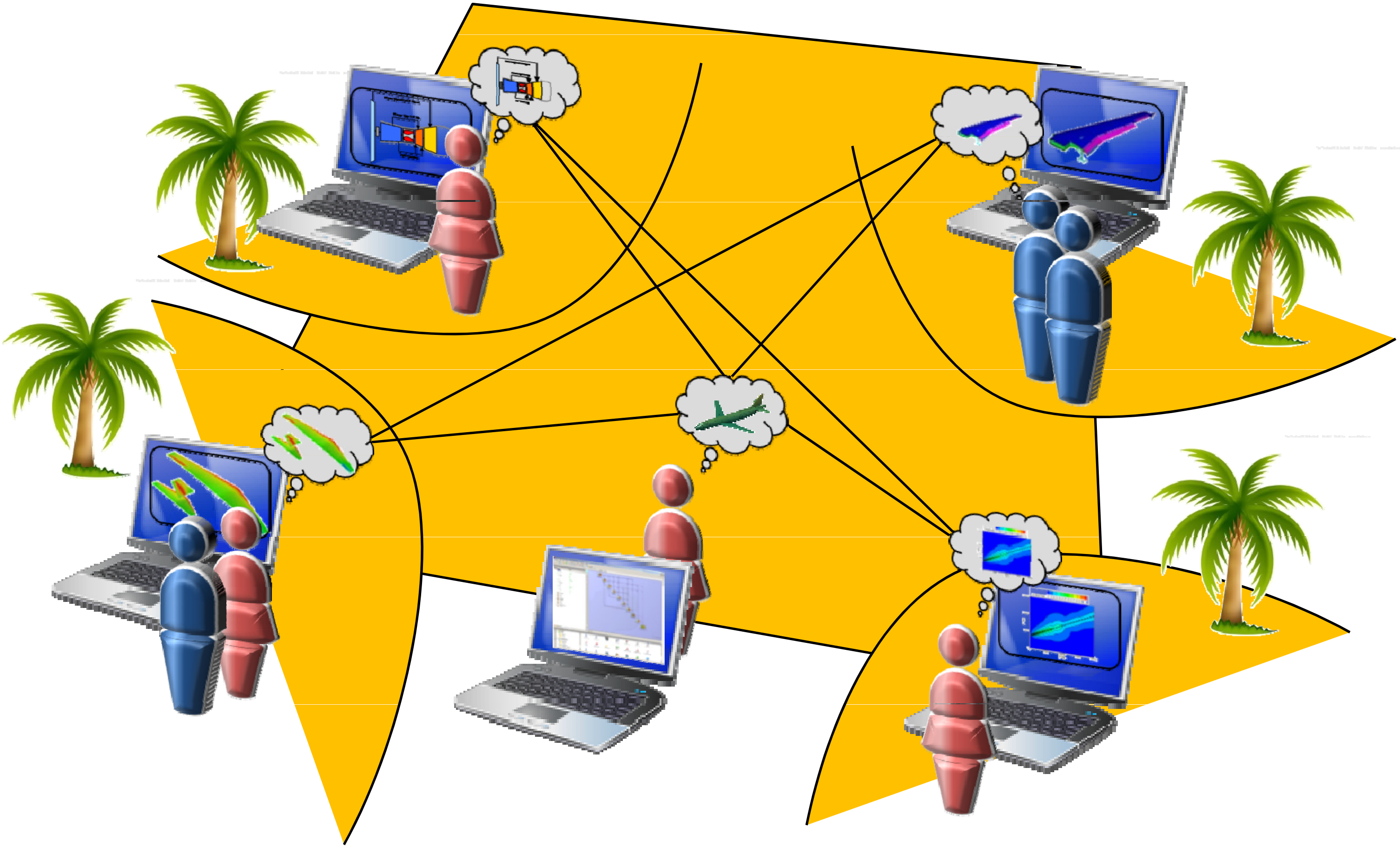
e connection in evaluation phase

Workflow in RCE for CPACS

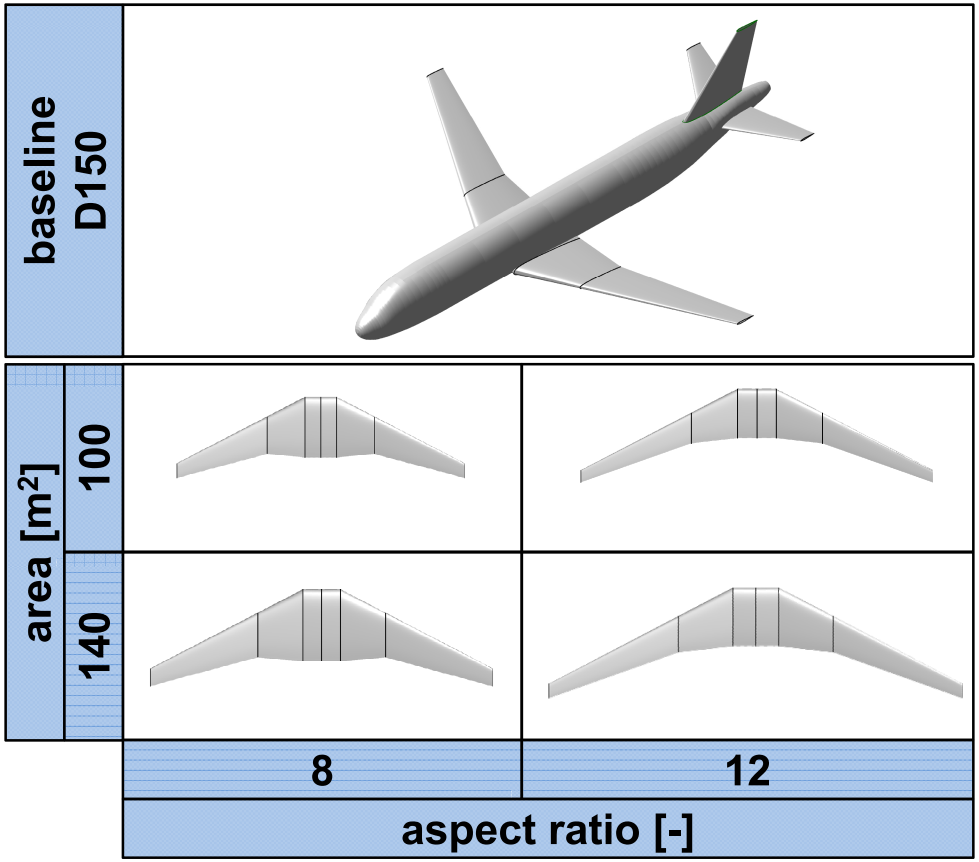


DLR

Design for collaboration

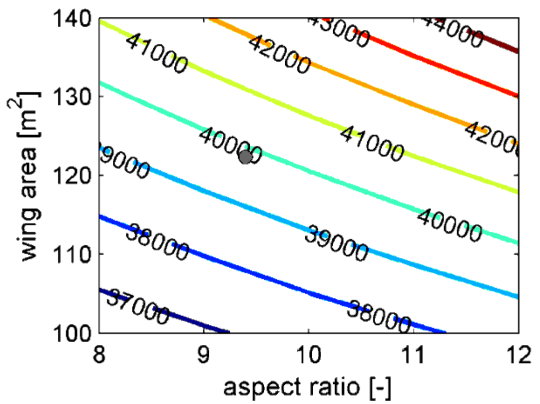


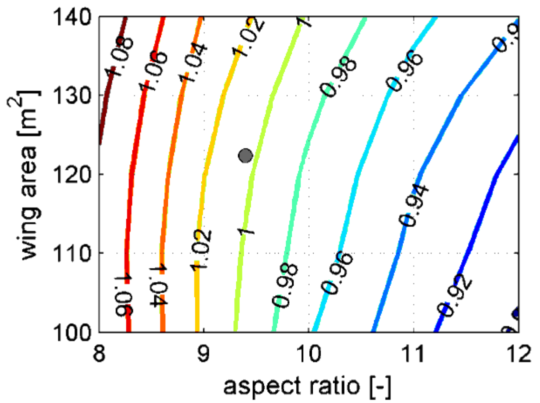
Aircraft parameter analysis



Transfer functions for interaction

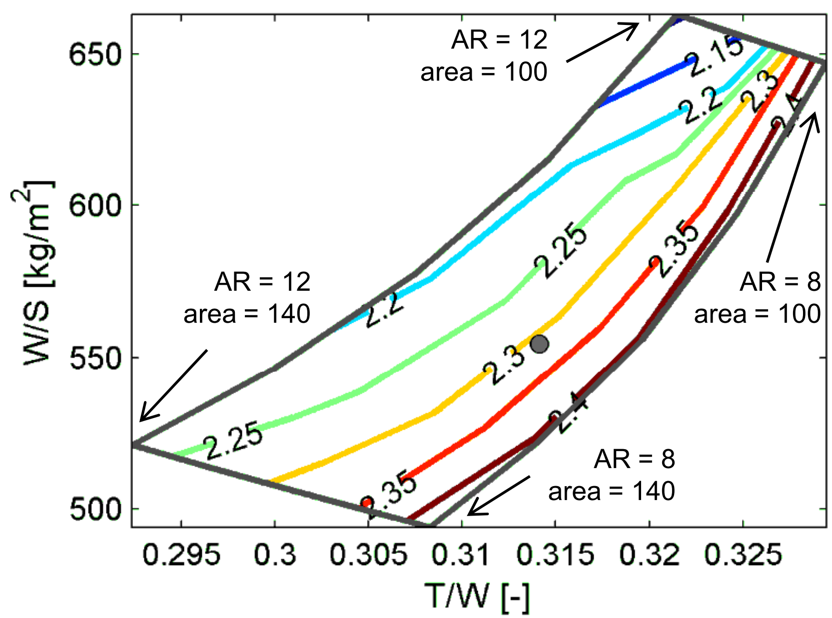
operating empty mass





engine scaling factor

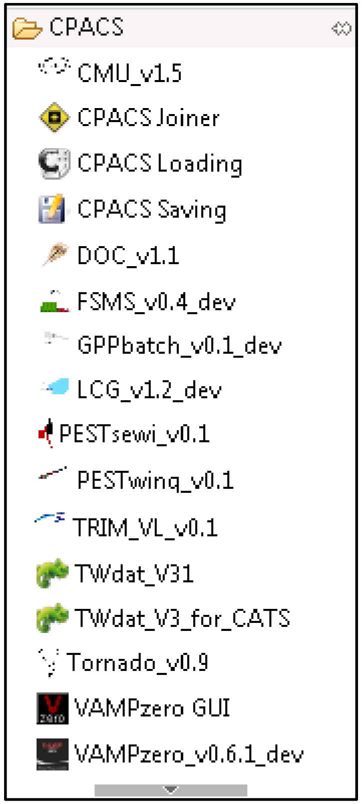
litres of fuel / 100 seat-km



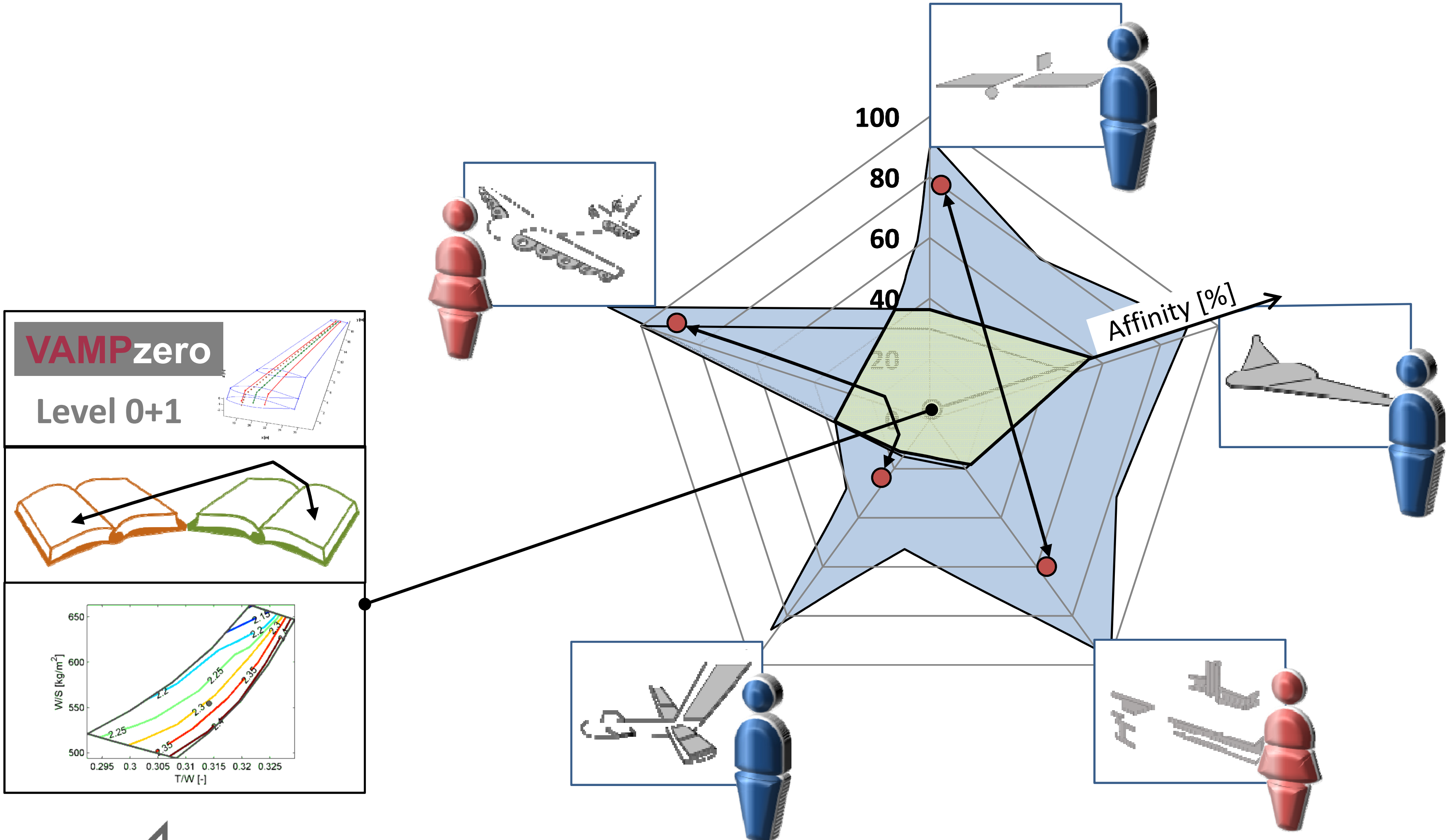
Conclusion

- Build up of low-level toolkit
- Initial application: combining a/c and engine predesign

- Modularly applicable components & attitude change
- Translate knowledge between team members having various backgrounds
- Clear and streamlined communication, combined implicit and explicit knowledge



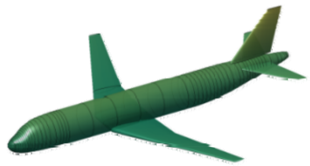
Conclusion

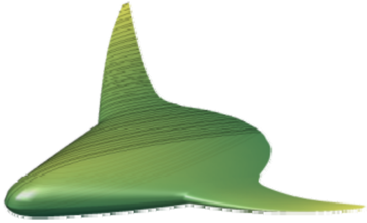


VAMPzero
Level 0+1
650
600
550
500
W/S [kg/m²]
0.295 0.3 0.305 0.31 0.315 0.32 0.325
T/W [-]
100
80
60
40
20
Affinity [%]

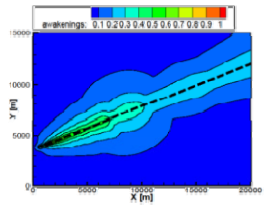
Outlook

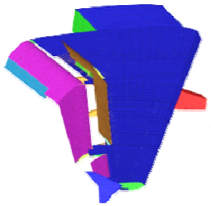
models

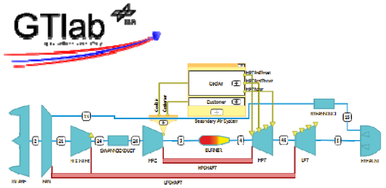




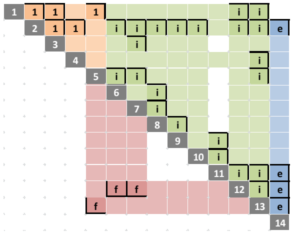
tools

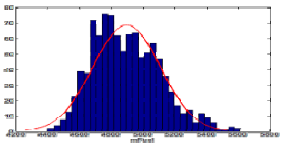




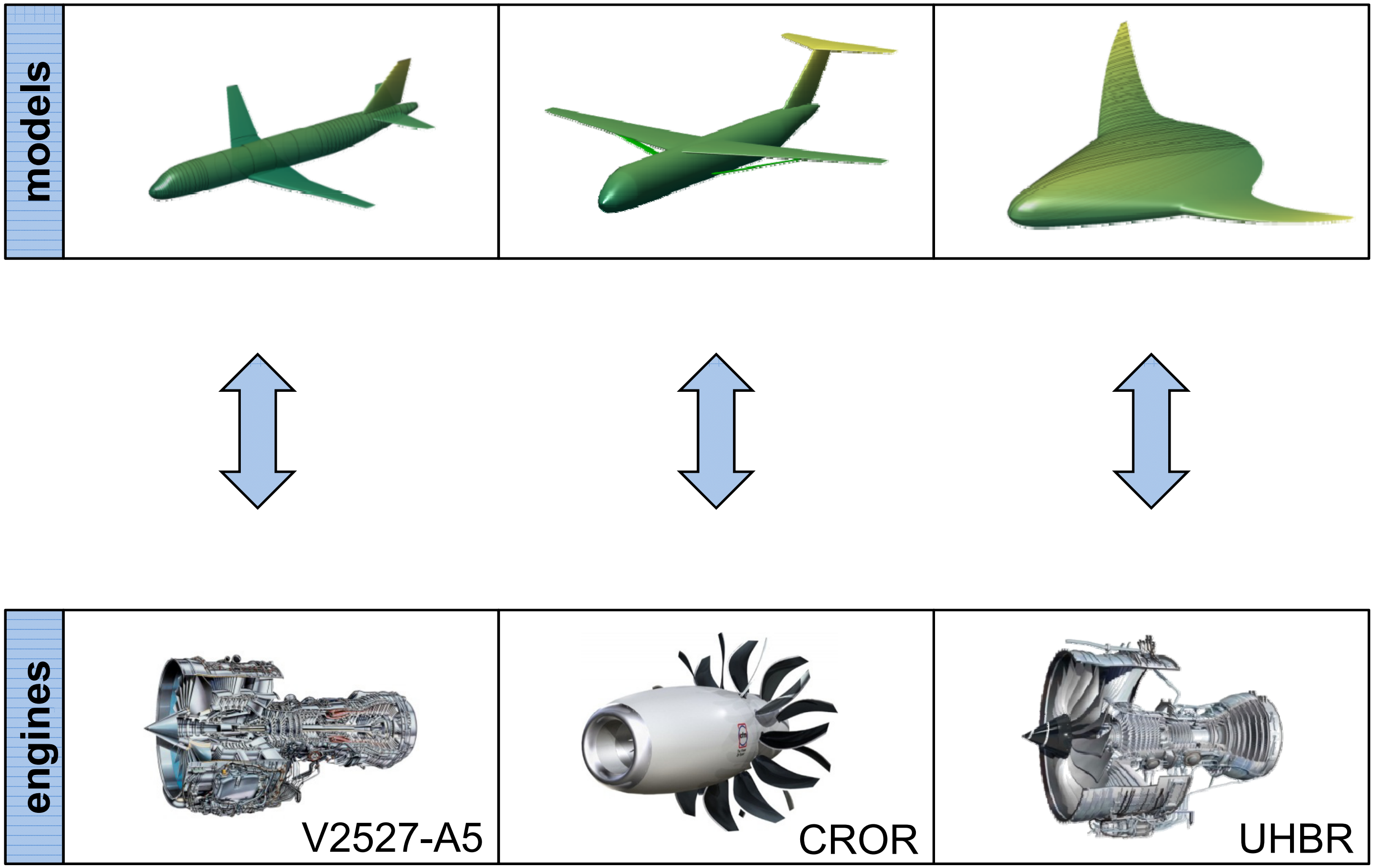


integration



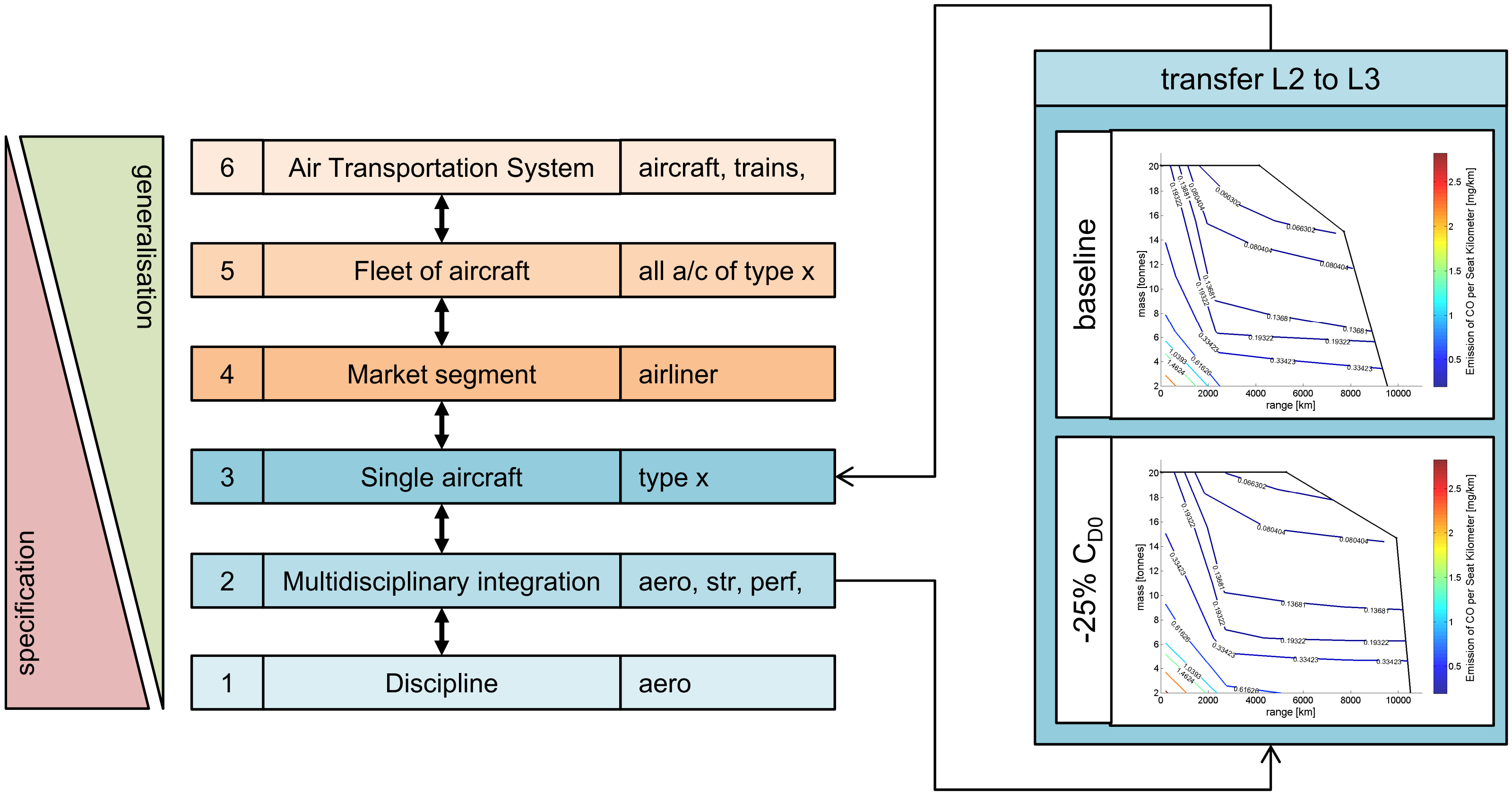


Outlook



source UHBR picture: theengineer.co.uk.

Design/Fidelity Level Transfer Functions



inspirational source: Hahn, “Providing quantifiable governance”, 2010

11th European Workshop on Aircraft Design Education, Linköping, 17.-19.09.2013

Integrated Aircraft Design Network

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546612

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FluMeS

Fluid and Mechatronic Systems

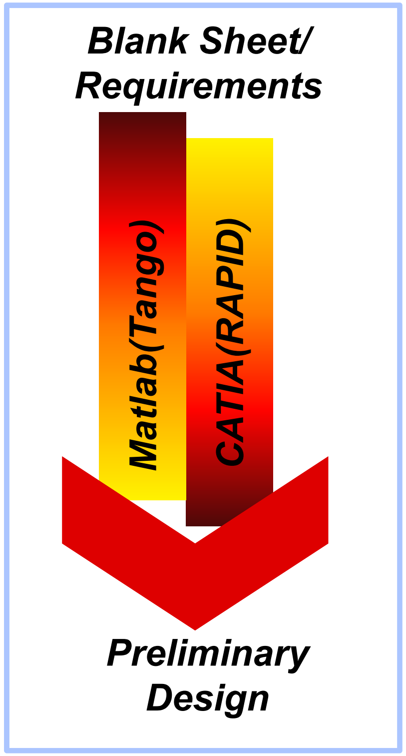
LINKÖPINGS UNIVERSITET

CONCEPT REALISATION LABORATORY

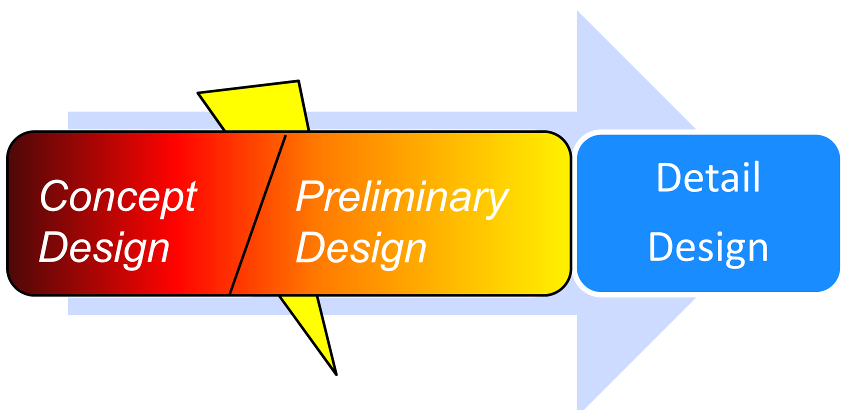
Agenda

- Aim
- Multidisciplinary Framework
- Aircraft Geometry Data Description
- Data Management
- XML Integration
    - RAPID XML
    - Tango XML
- Framework approach
- Implementation/Applications
- Conclusion
- Future Work

Aim



- *XML based multidisciplinary tool integration in a conceptual aircraft design framework.*
- ~~"One-tool"~~ or a "One-database" approach
- *Design Automation for fast realization of the concept*
- *To support **Conceptual** to **Preliminary** Aircraft Design*



Introduction

-Multidisciplinary Aircraft Conceptual Design Framework

- **Tango** - Data handling and tool integration, a/c sizing, mission calculation,aerodyn. calculations (e.g. Tornado), a/c systems definiton
- **RAPID** - Sizing, Geometry definition, Structure definition, Geometry for Aerodynamic and Structural analysis
- **Hopsan** - Performance, Stability and Control, Fault Analysis
- **Dymola** - Systems architecture, power analysis, Verification

Hopsan

Total System Simulation (mission)

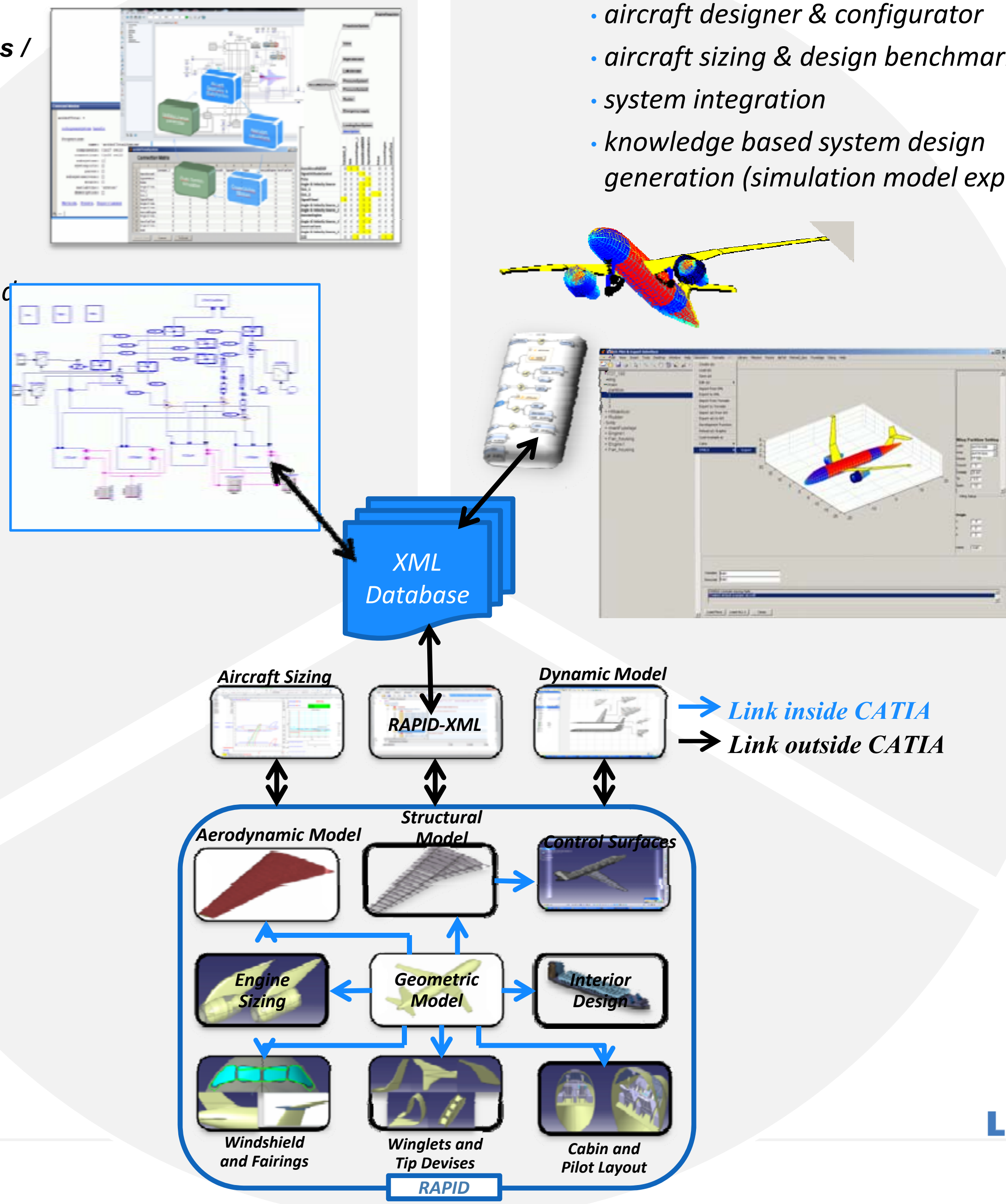
- **On-board power Systems / Subsystem simulation:**
  Hydraulic (Flight Control System)
  Fuel System, Electric System, etc.
- **Outcomes:**
  Performance, Stability and Control ,Fault Analysis

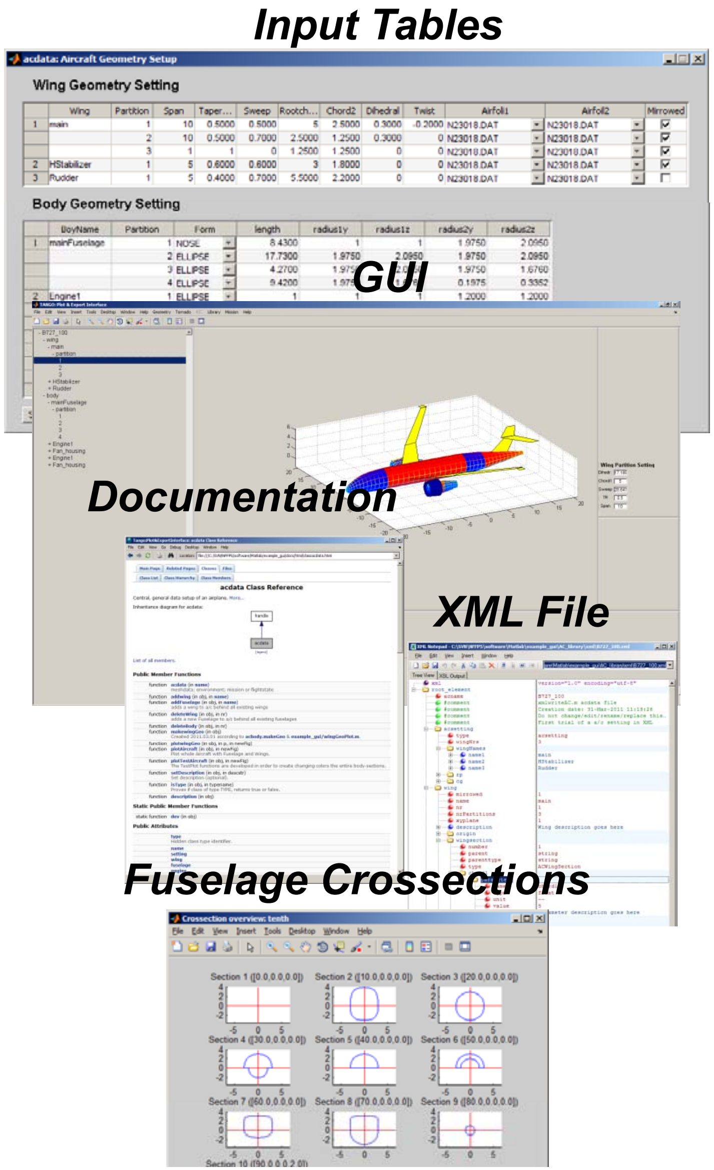
Dymola / Modelica usage of ModelicaXML

- **System Simulation:**
  ECS (Cooling , pressurization and Ventilation Systems)
  Thermal Management System
- **Outcomes:**
  Systems architecture / control modes, power analysis
  Verification

Tango (Matlab)

- *aircraft designer & configurator*
- *aircraft sizing & design benchmark*
- *system integration*
- *knowledge based system design generation (simulation model export)*





Tango

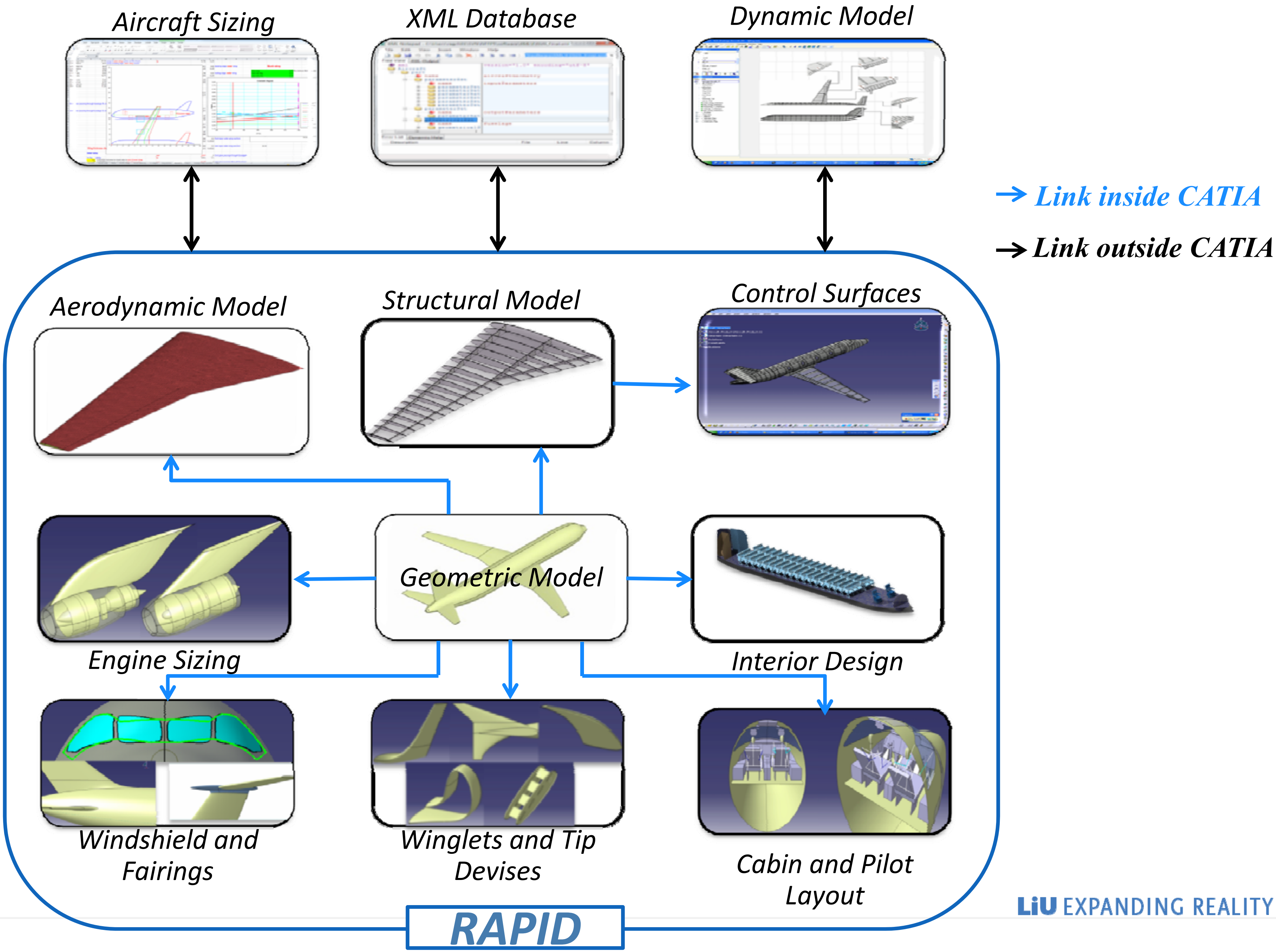
- A conceptual a/c design tool

Parametric a/c configurator including

- frameworks main GUI, data handling and tool integration
- Main topics:
  - a/c sizing
- a/c layout builder, including:
  - engine models
  - landing gear, control surfaces, control modes, etc…
- mission calculation
- aerodyn. calculations (e.g. Tornado)
- a/c systems definiton

Implementation:

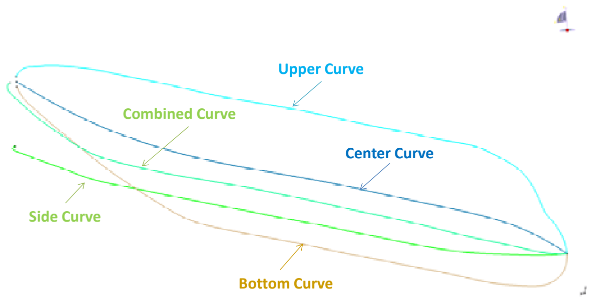
- object orientated class-based Matlab (prepared for C++ mitigation)
- separated GUI overlay

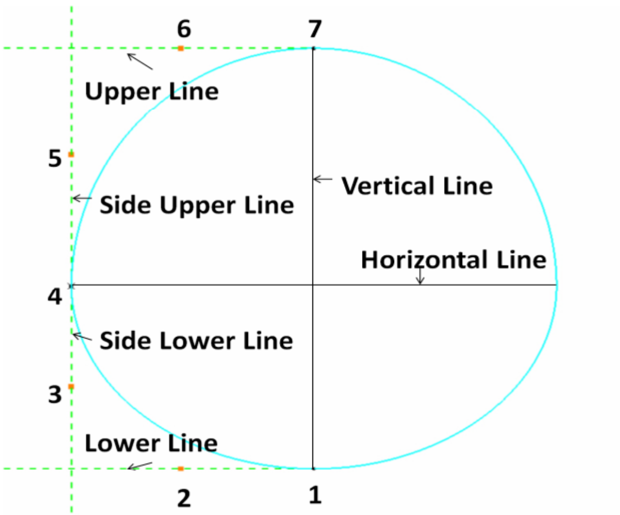


Aircraft Sizing
XML Database
Dynamic Model
Link inside CATIA
Link outside CATIA
Aerodynamic Model
Structural Model
Control Surfaces
Geometric Model
Engine Sizing
Interior Design
Windshield and Fairings
Winglets and Tip Devises
Cabin and Pilot Layout
RAPID

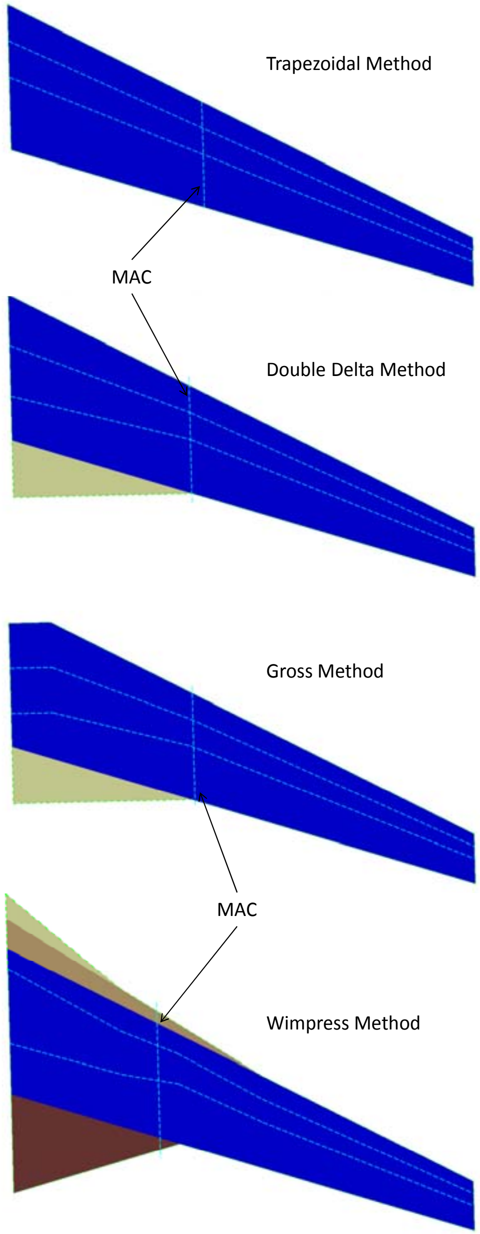
Aircraft Geometry Data Description

-Fuselage geometry description





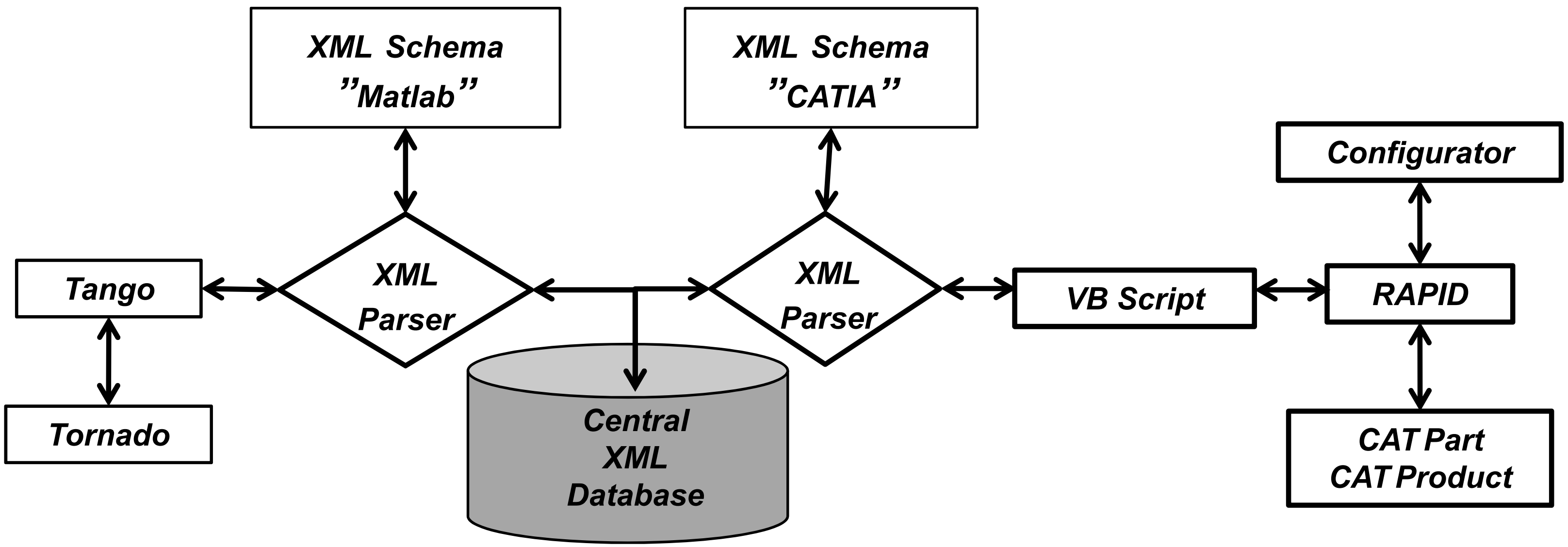
- Four Splines to create the foundation for the Fuselage
- Two 3rd order Bezier curves



Aircraft Geometry Data Description
- Wing Description

- Trapezoidal Method
- Double delta Method
- Gross Method
- Wimpress Method

Data Management



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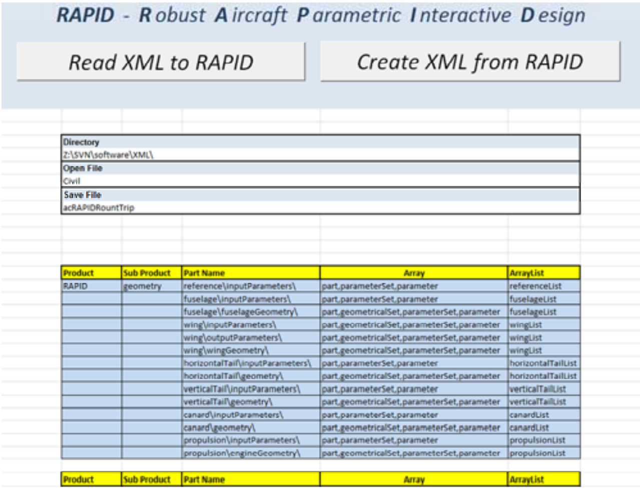


Product	Sub Product	Part Name	Array	ArrayList
RAPID	geometry	reference\inputParameters\	part,parameterSet,parameter	referenceList
		fuselage\inputParameters\	part,parameterSet,parameter	fuselageList
		fuselage\fuselageGeometry\	part,geometricalSet,parameterSet,parameter	fuselageList
		wing\inputParameters\	part,geometricalSet,parameterSet,parameter	wingList
		wing\outputParameters\	part,geometricalSet,parameterSet,parameter	wingList
		wing\wingGeometry\	part,geometricalSet,parameterSet,parameter	wingList
		horizontalTail\inputParameters\	part,parameterSet,parameter	horizontalTailList
		horizontalTail\geometry\	part,geometricalSet,parameterSet,parameter	horizontalTailList
		verticalTail\inputParameters\	part,parameterSet,parameter	verticalTailList
		verticalTail\geometry\	part,geometricalSet,parameterSet,parameter	verticalTailList
		canard\inputParameters\	part,parameterSet,parameter	canardList
		canard\geometry\	part,geometricalSet,parameterSet,parameter	canardList
		propulsion\inputParameters\	part,parameterSet,parameter	propulsionList
		propulsion\engineGeometry\	part,geometricalSet,parameterSet,parameter	propulsionList

Product	Sub Product	Part Name	Array	ArrayList

XML Integration

- *RAPID XML Export*

- Configuration of Parameter and Geometric sets through Excel

  Example: “fuselage\inputParameters\” & “fuselage\instantiatedGeometry\”

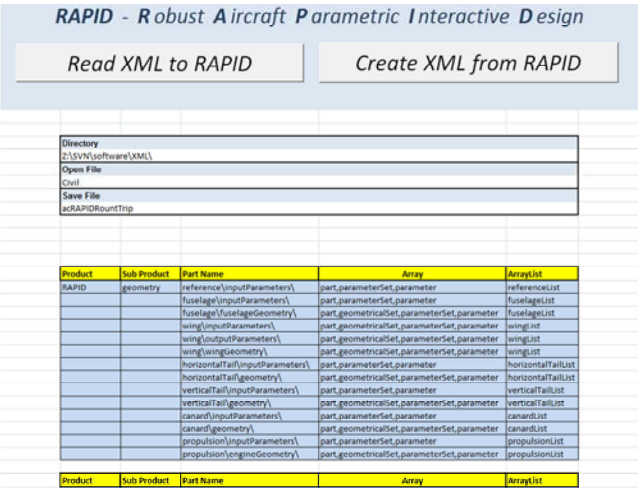
- Value Parsing
- Writing into XML using DOM Object
- Spline from CATIA to XML

  Example: “fuselage\exchangeTest”

- Finally the XML DOM object is written to XML

XML Integration

- *RAPID XML Import*


RAPID - Robust Aircraft Parametric Interactive Design

Read XML to RAPID | Create XML from RAPID

Directory
Z:\SVN\software\XML\
Open File
Civil
Save File
acRAPIDRountTrip

Product	Sub Product	Part Name	Array	ArrayList
RAPID	geometry	reference\inputParameters\	part,parameterSet,parameter	referenceList
		fuselage\inputParameters\	part,parameterSet,parameter	fuselageList
		fuselage\fuselageGeometry\	part,geometricalSet,parameterSet,parameter	fuselageList
		wing\inputParameters\	part,geometricalSet,parameterSet,parameter	wingList
		wing\outputParameters\	part,geometricalSet,parameterSet,parameter	wingList
		wing\wingGeometry\	part,geometricalSet,parameterSet,parameter	wingList
		horizontalTail\inputParameters\	part,parameterSet,parameter	horizontalTailList
		horizontalTail\geometry\	part,geometricalSet,parameterSet,parameter	horizontalTailList
		verticalTail\inputParameters\	part,parameterSet,parameter	verticalTailList
		verticalTail\geometry\	part,geometricalSet,parameterSet,parameter	verticalTailList
		canard\inputParameters\	part,parameterSet,parameter	canardList
		canard\geometry\	part,geometricalSet,parameterSet,parameter	canardList
		propulsion\inputParameters\	part,parameterSet,parameter	propulsionList
		propulsion\engineGeometry\	part,geometricalSet,parameterSet,parameter	propulsionList

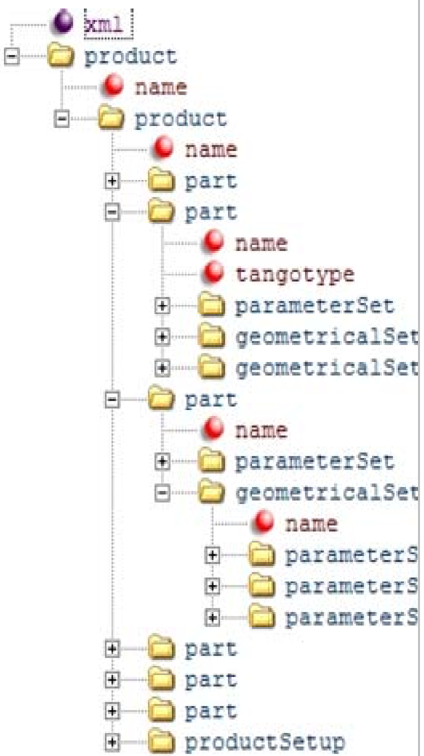
Product	Sub Product	Part Name	Array	ArrayList

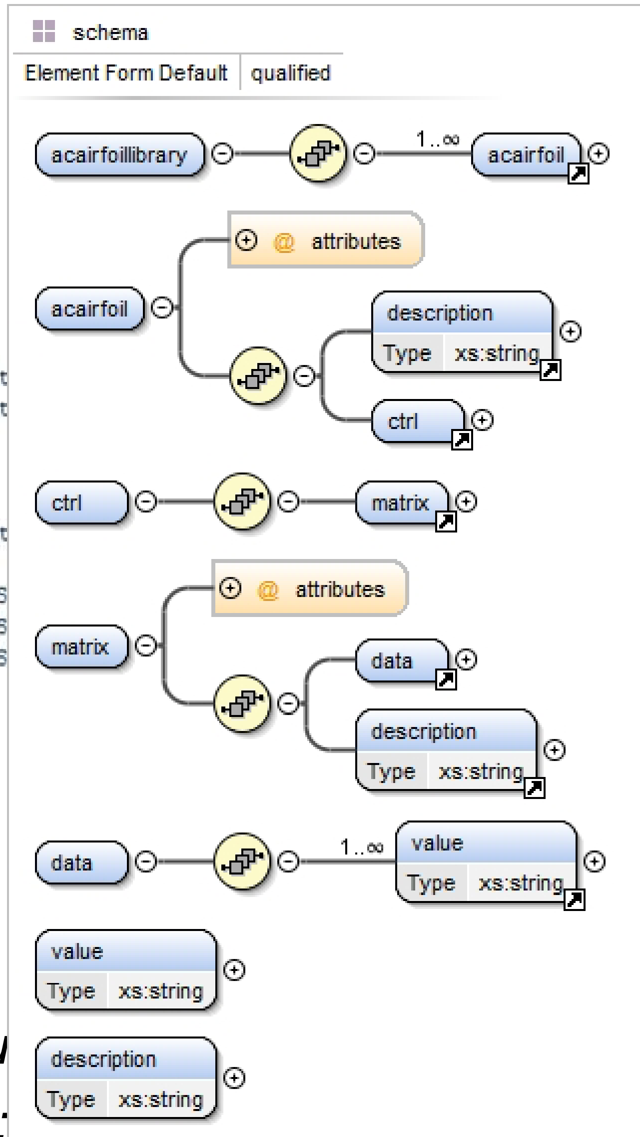
- Parsing the XML using DOM object
- Recursive Function to get child nodes
- Constructing the Parameter Strings to be updated
- Spline from XML to CATIA
- Updating CATIA

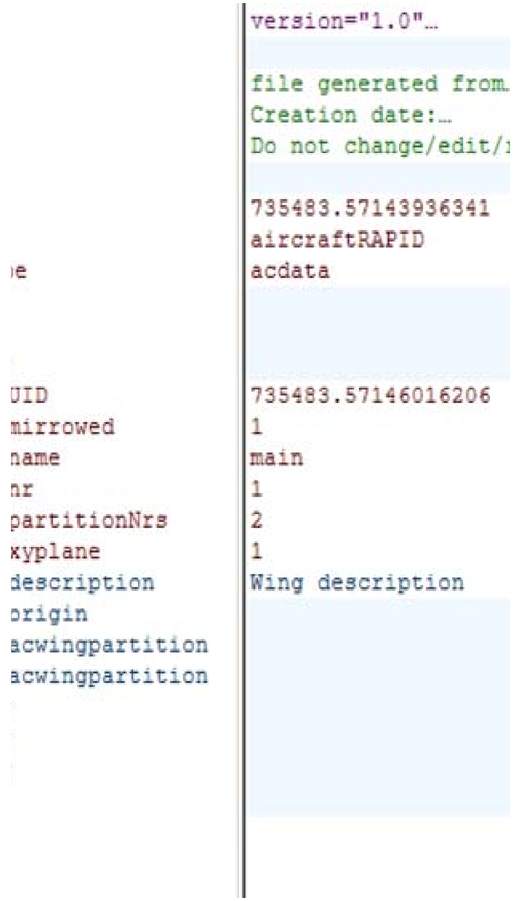
XML Integration

- *Tango XML*

- Tango makes usage of the underlying Java DOM application classes in Matlab that serves for the XML data handling.
- Class-related XML parsing functionalities allows for greater flexibility and fast replacement or appending of new classes.
- The basic classes are product–geometry related arranged (e.g., wing and underlying wing partition class)
- Higher level classes are product-functional (system) related (e.g., fuel system, primary flight control system).





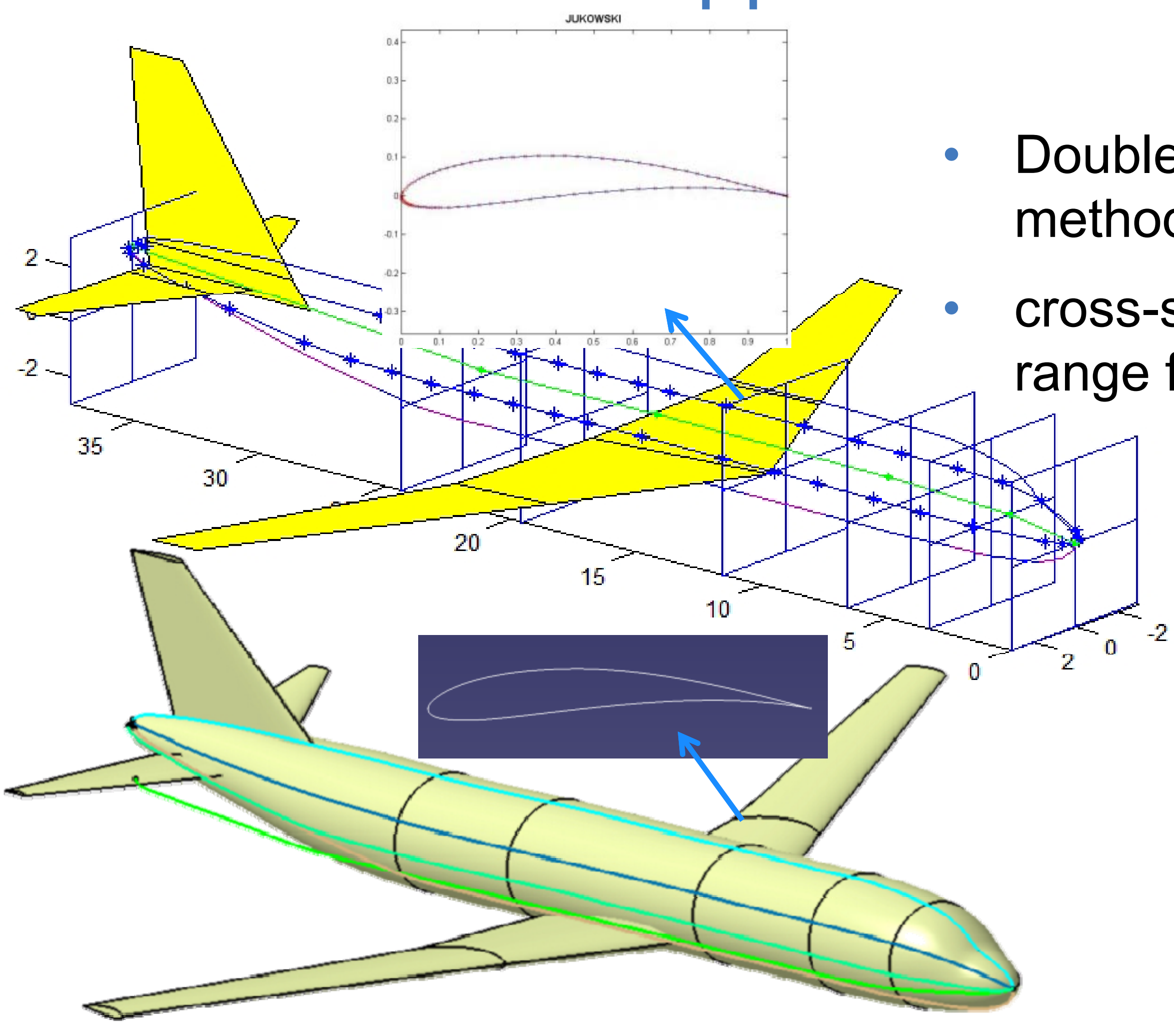


Data Stru… tools needs

Left Side:… Tango XML

XML Schema

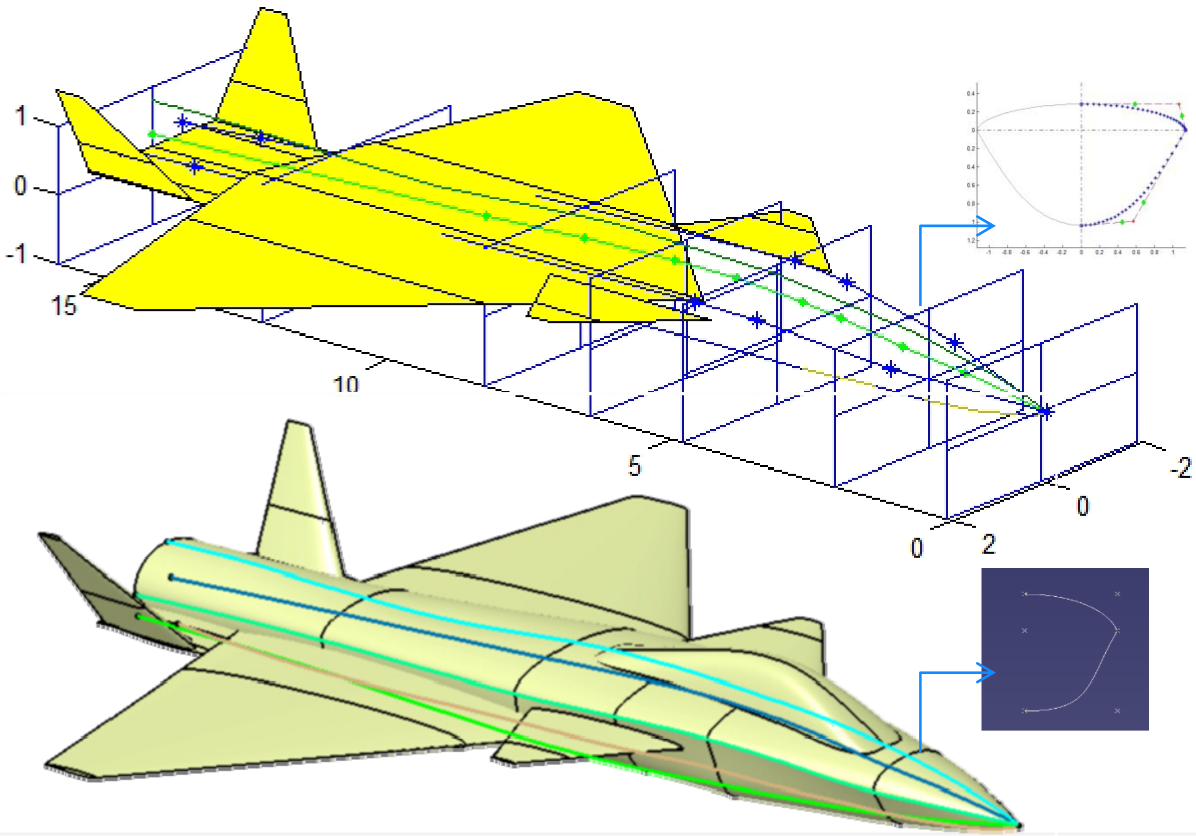
Application Example 1



- Double delta reference method
- cross-sections of the fuselage range from a circle to ellipse

Application Example 2

- Same data Structure as E.g.1
- Canard is added



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Conclusions

- Multidisciplinary conceptual aircraft design analysis based on a central parametric XML database.
- This database -containing all project related data- is intended to grow simultaneously with the refined specification of the airplane
- The unified geometry makes meshing easier and serves for no aperture for high fidelity CFD

THANK YOU

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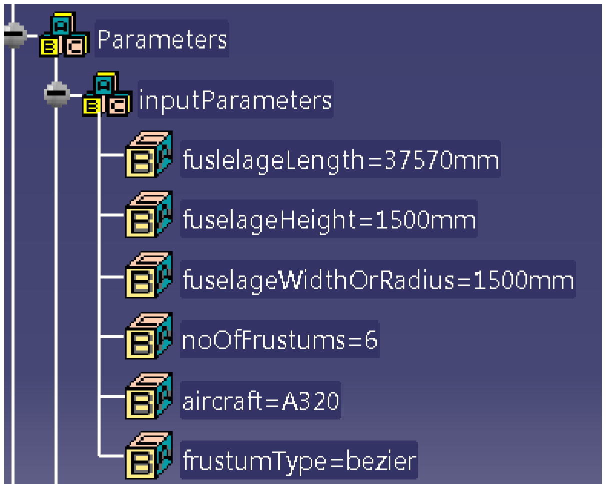
FluMeS
Fluid and Mechatronic Systems

LINKÖPINGS UNIVERSITET

CONCEPT REALISATION LABORATORY



Parameters
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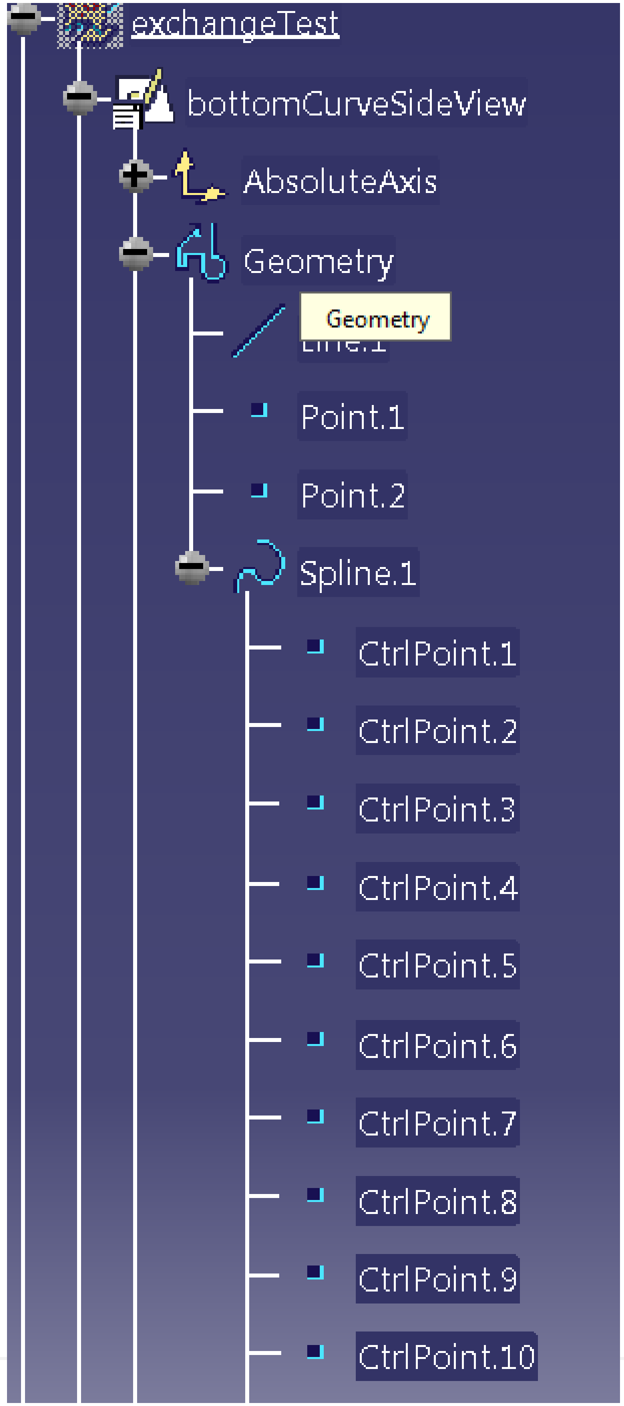
fuselageHeight=1500mm
fuselageWidthOrRadius=1500mm
noOfFrustums=6
aircraft=A320
frustumType=bezier



exchangeTest
bottomCurveSideView
AbsoluteAxis
Geometry
Geometry
Point.1
Point.2
Spline.1
CtrlPoint.1
CtrlPoint.2
CtrlPoint.3
CtrlPoint.4
CtrlPoint.5
CtrlPoint.6
CtrlPoint.7
CtrlPoint.8
CtrlPoint.9
CtrlPoint.10

4:th CEAS Air & Space Conference
FTF Congress: Flygteknik 2013

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546615

Preliminary Design for Flexible Aircraft in a Collaborative Environment

Pier Davide Ciampa, Björn Nagel

German Aerospace Center
Air Transportation Systems

Darwin Rajpal, Gianfranco La Rocca

TU Delft

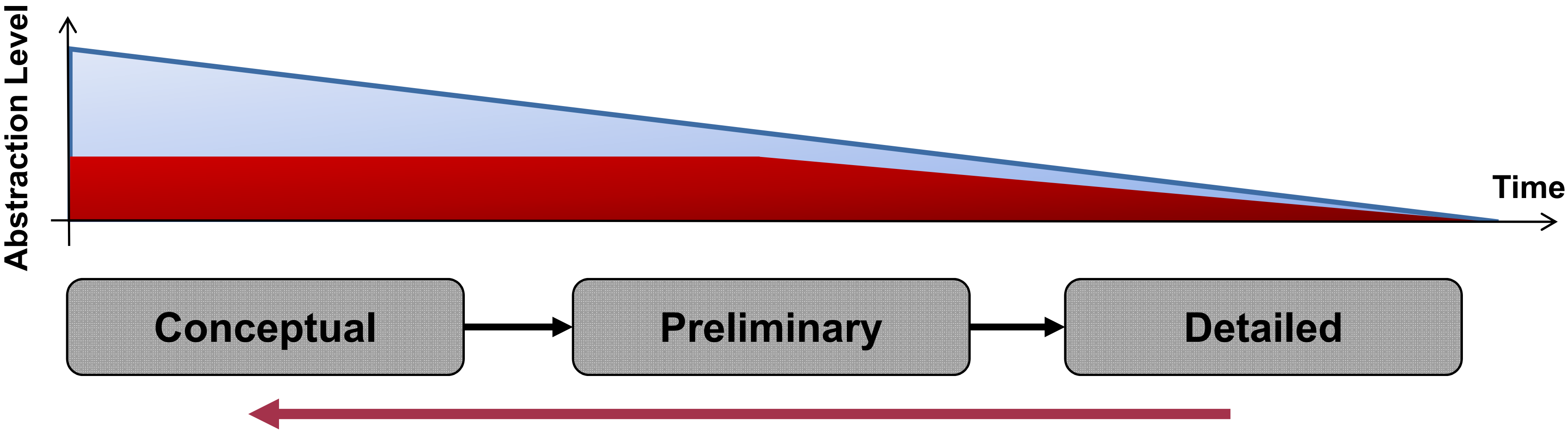
4th CEAS Air & Space Conference
16th-19th September 2013
Linköping

DLR

Outline

- Scope: Enhancing Overall Aircraft Design (OAD)
- Collaborative Design and Optimization Environment
    - DLR centralized data model and design framework
- Enabling physics based OAD
    - Design and disciplinary analysis modules integrated
    - OAD Workflow development
- Study Cases
    - Conventional aircraft
    - Boxwing configuration
- Conclusions and Outlook

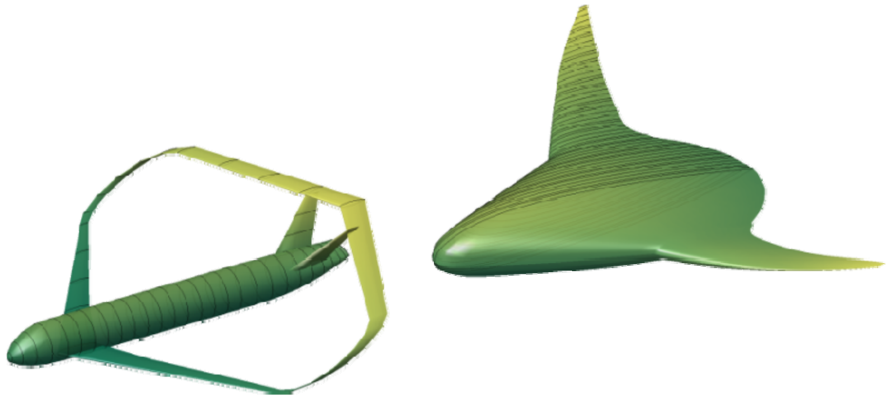
Overall Aircraft Design
Exploring novel design space



- Visions and Scenarios demand the extension of the current design space
  - No data/knowledge available at the early stage (no handbook methodologies)
  - But effective physics based model available to assess new Technologies

Shift to the early stages

Unconventional OAD in pre-design



Unconventional configurations:

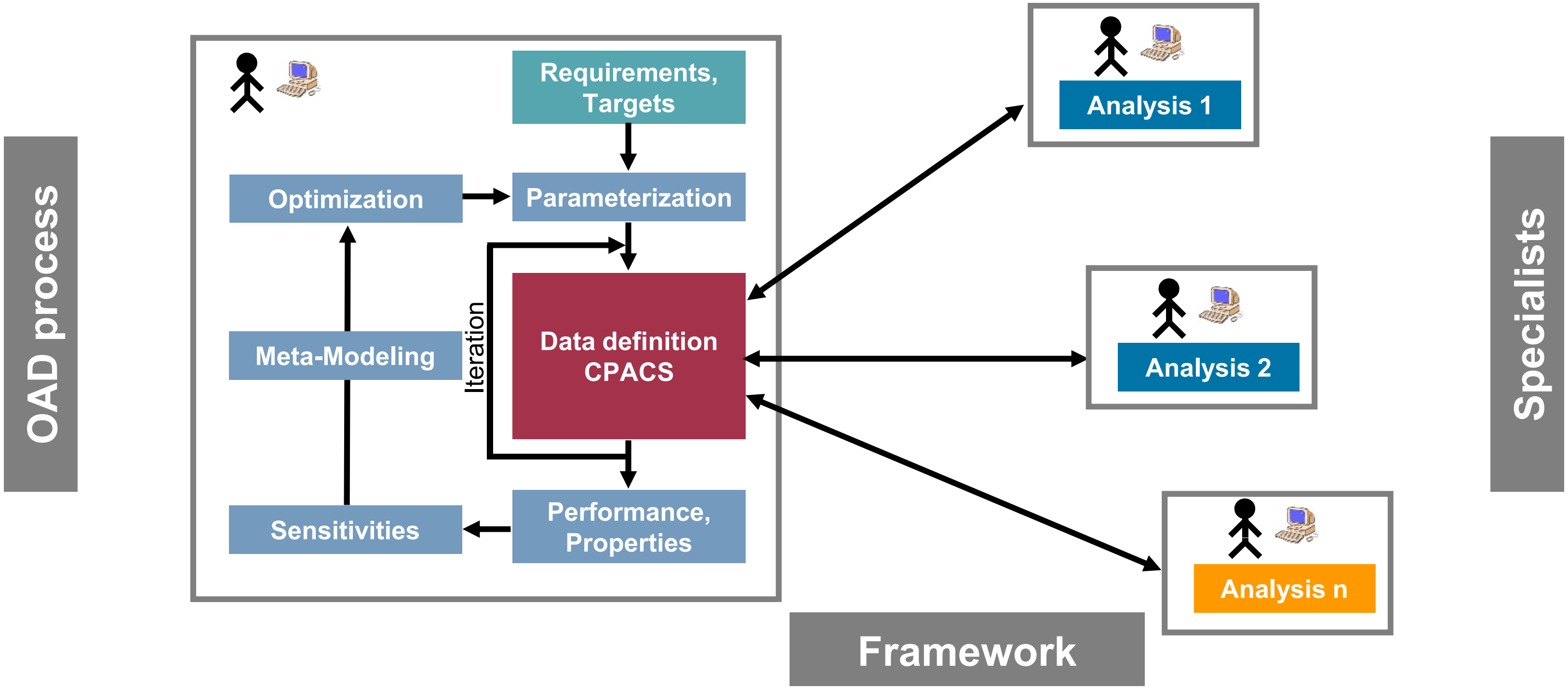
- Highly disciplinary coupled designs
- Unexpected behaviour
- MDO solution required

How to enable the pre-design of novel configurations?

Enhancing preliminary design requires:

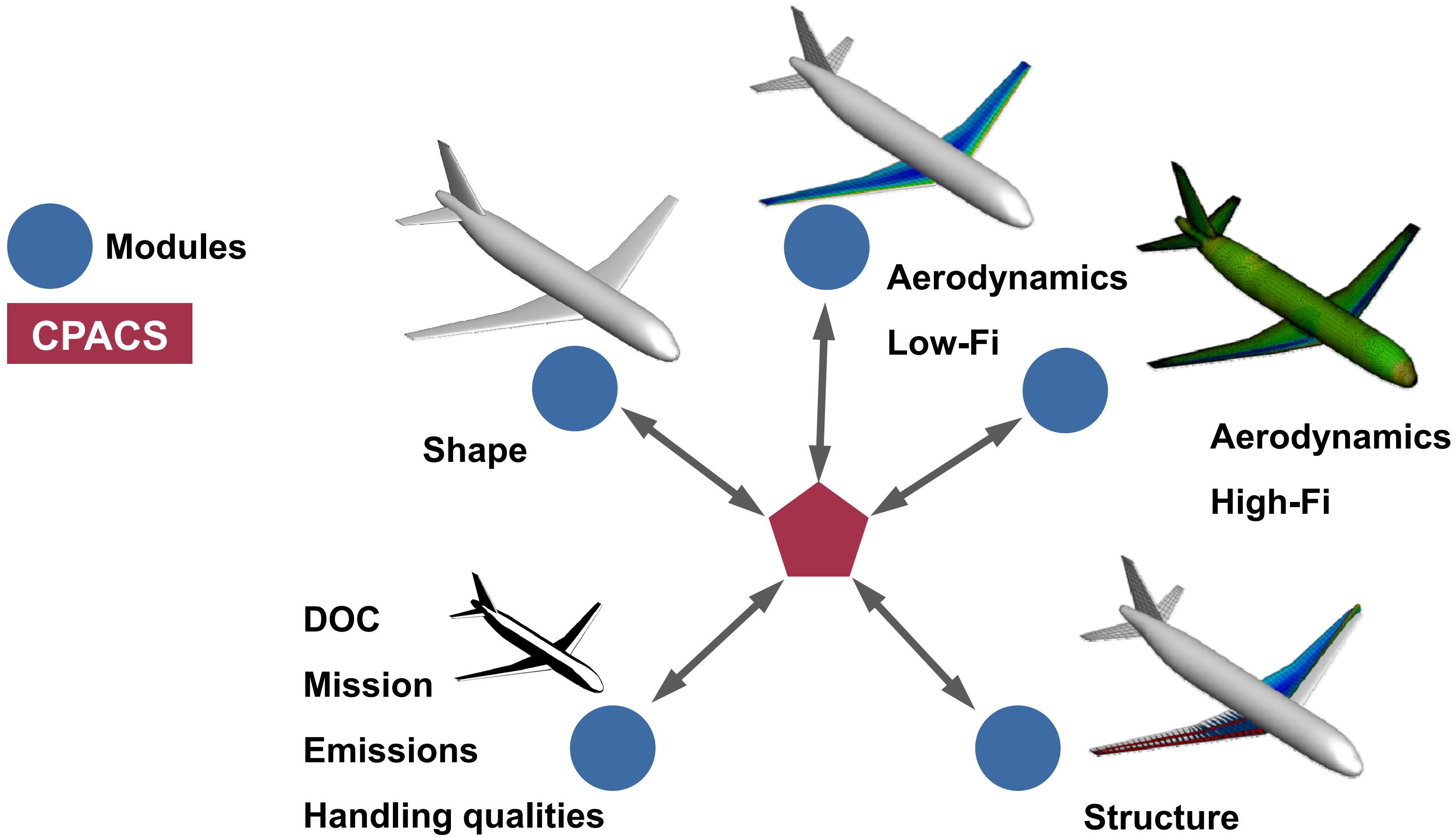
- Physics based analysis (many modules are already available)
- Collaborative design approach with specialists in OAD (Overall Aircraft Design)
- Automation of the design process, and cross-disciplinary management

Collaborative Design Environment



- Integration of modules developed by disciplinary specialists.
- A common namespace defined by DLR **CPACS** data format
- Design Framework for workflow orchestration
- Beyond tools: A system of distributed competencies.

CPACS
Common Parametric Aircraft Configuration Schema



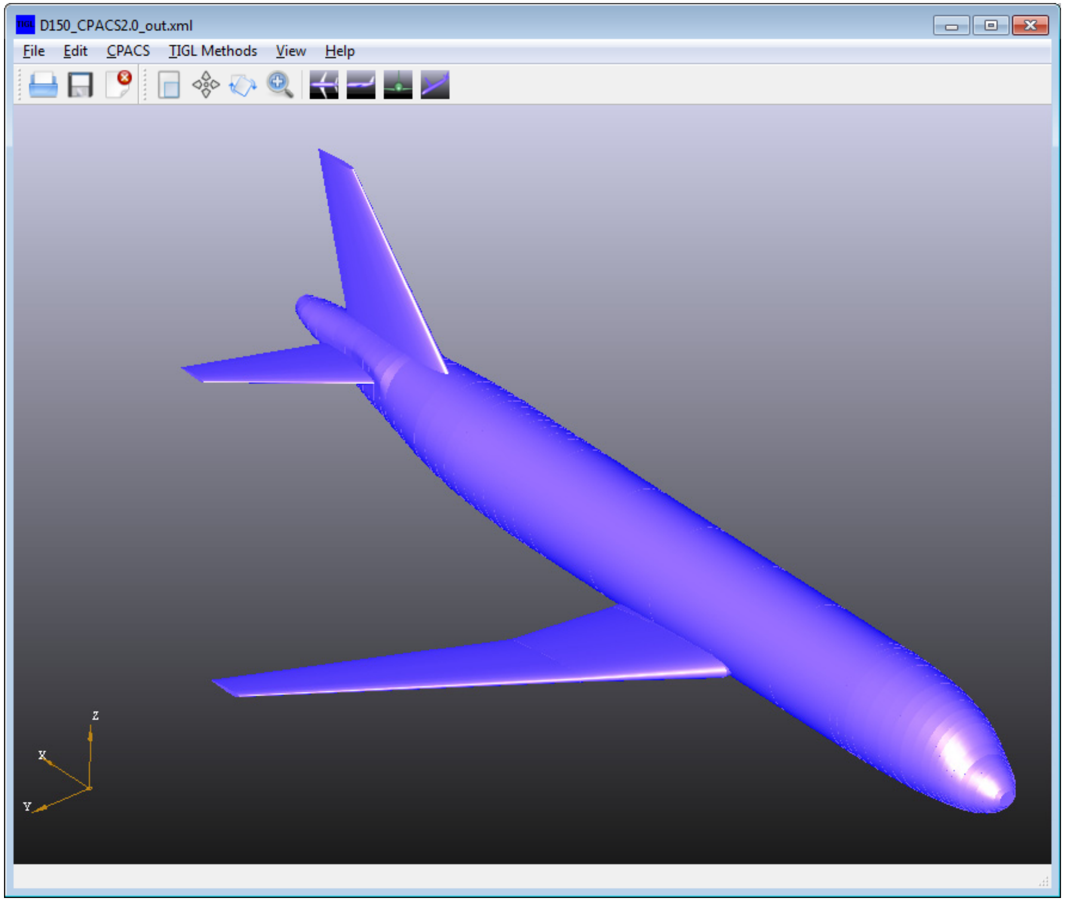
a CPACS file…

- **Hierarchical** schema definition (xml-structure data format)
- **Product** and **process** information
- Standard within DLR (since 2005)
- External Partners

- Multi-scale, containing data on:
  - Aerodynamics
  - Structures
  - Mission
  - Climate
  - Fleets

- Open source:

http://code.google.com/p/cpacs/

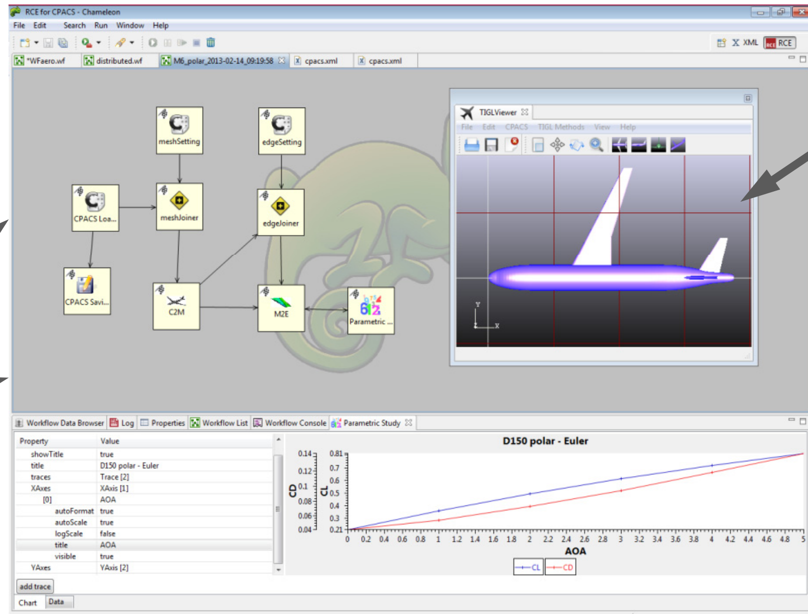


…the same CPACS file!

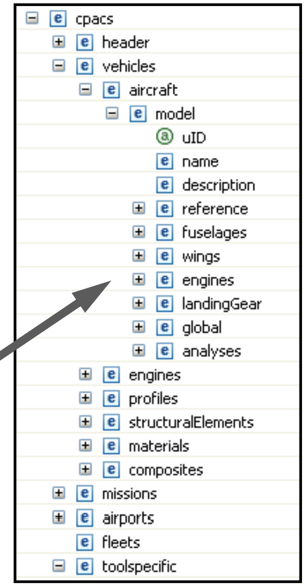
Design Framework RCE
Remote Component Environment

- Decentralized system
- Workflow development
- Distributed architecture
- DLR developed
- Open source

Tools remain on owners' servers. Exchange of input and output in CPACS format via the network.



CPACS

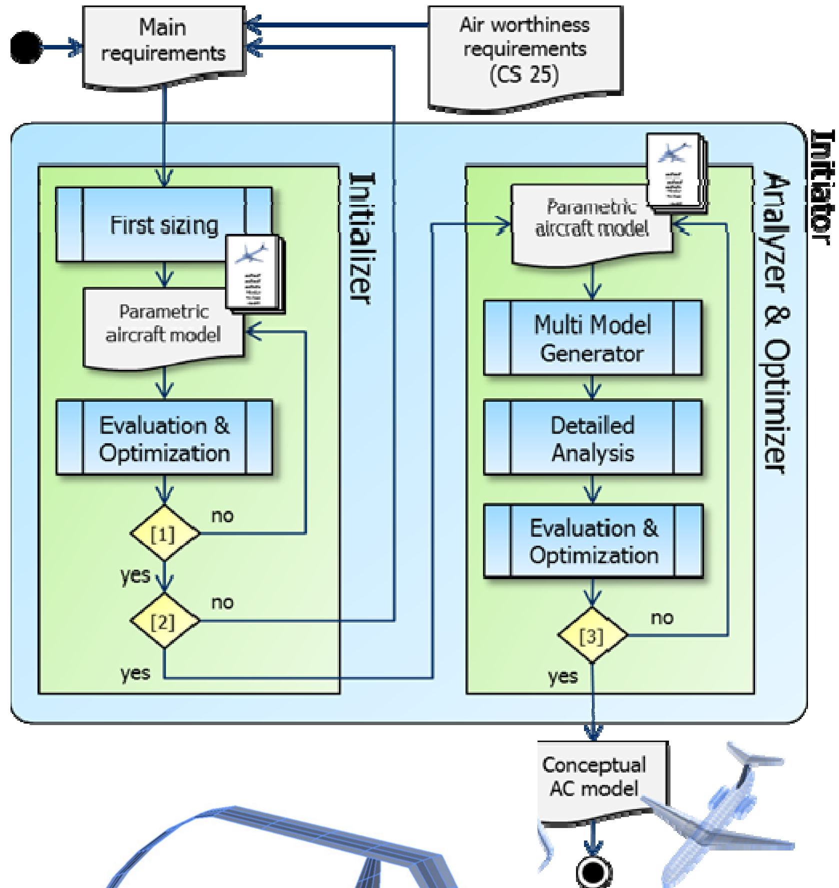


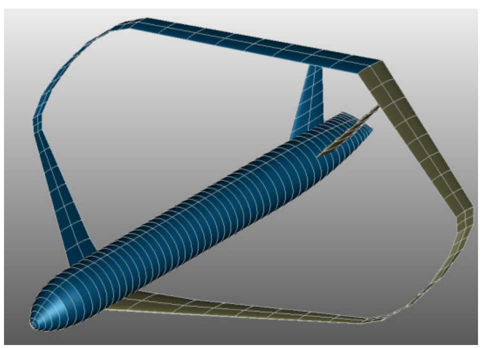
Modules

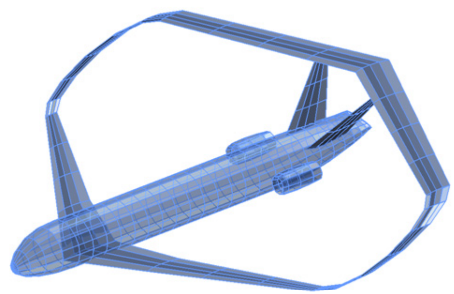
DLR

DEE Initiator
Conceptual OAD

- Conceptual design code
- Developed at TU Delft
- Conventional and Unconventional
- Consists of three separate modules-
  - Initializer
  - Analyzer
  - Optimizer
- CPACS compatible

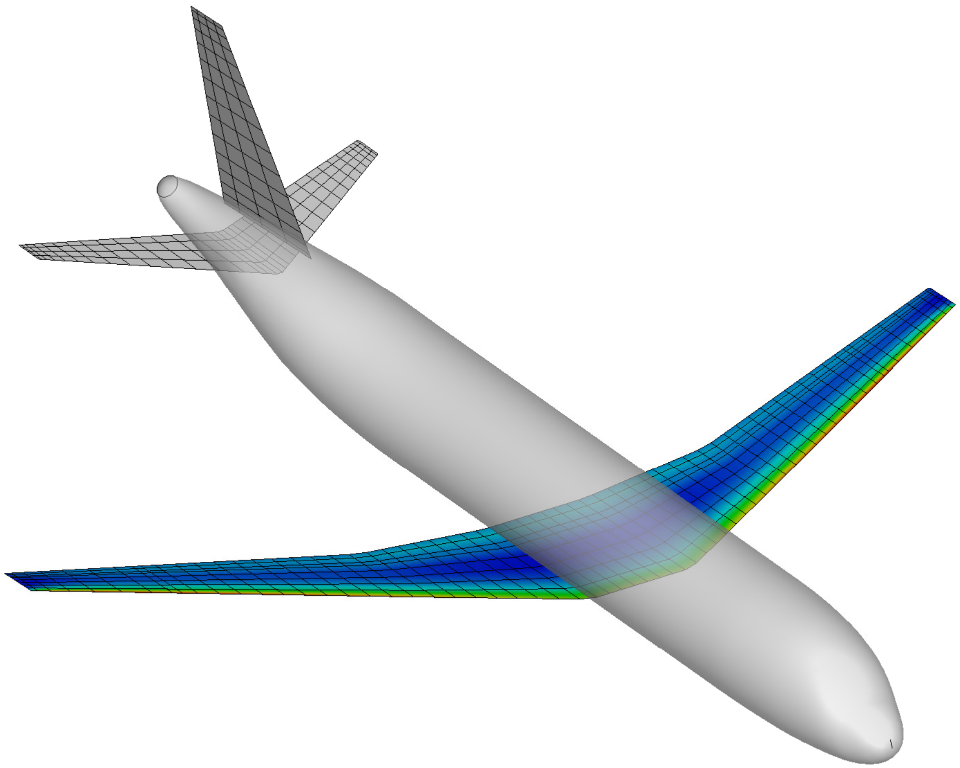


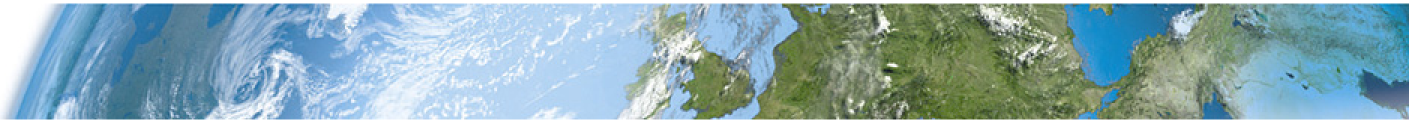




Aerodynamics Module
Aerodynamics Design

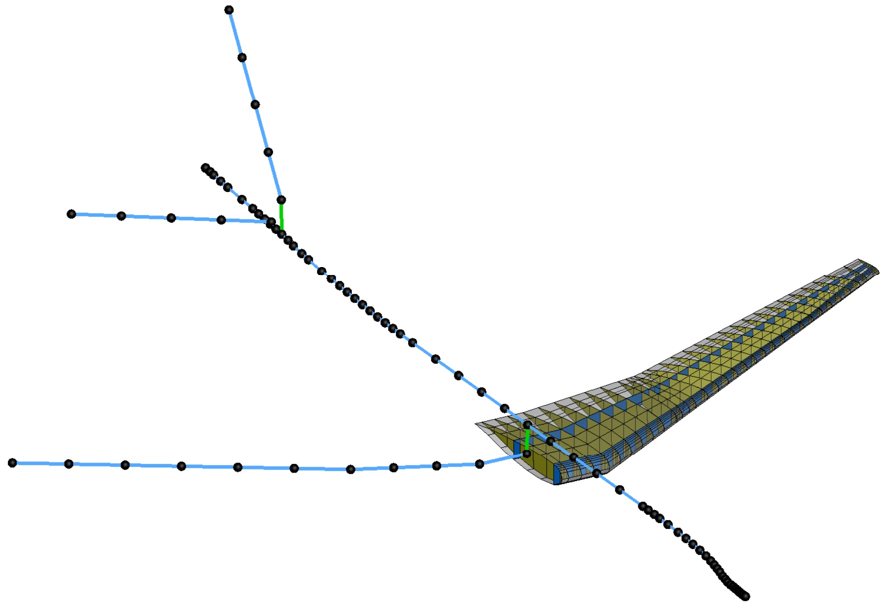
- Physics based aerodynamics module
- Automated generation lattice mesh for lifting surfaces
- AVL VLM solver for induced drag
- Additional components for estimation of wave and friction drag





Aeroelastic Engine
Structural Analysis

Automated Generation of FE models:
Multi-level approach:



Level-1

- FE beam formulation
- Distributed masses

Level-2

- FE shell formulation
- Hybrid Models

The module provides
- Internal static and dynamic FEA solver or exporting of macros for commercial FEA
- Sizing process for the primary structures

Aeroelastic Engine
FSI coupling

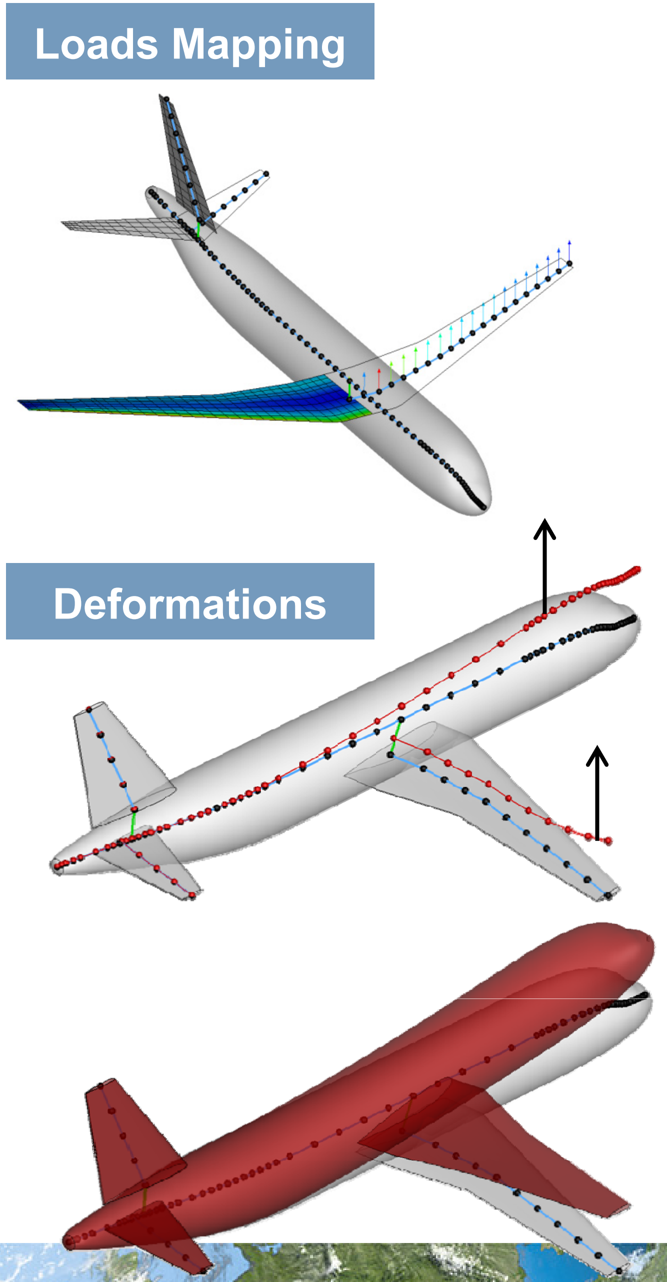
Collaborative design oriented:

- **Loosely coupled**

- Aerodynamics loads mapping (aero lattice → FE nodes)

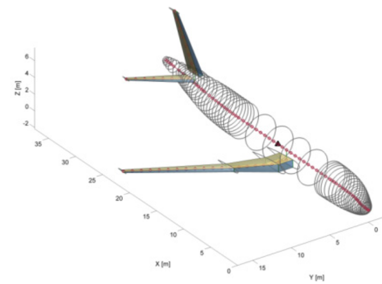
- Structural displacements deformations (FE nodes → aero lattice or geometry)

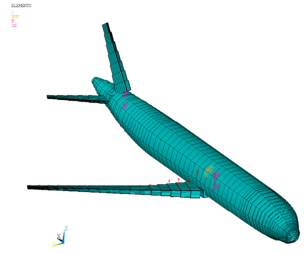
- Coupling kernel based on a modular set of interpolation schemas (e.g. RBF)



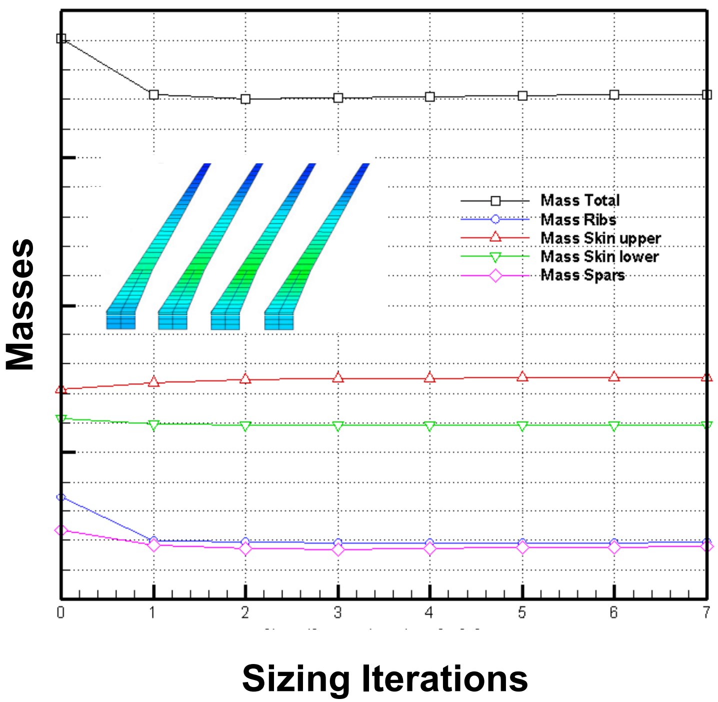
DLR

Disciplinary Analysis
Aero-Structural Sizing

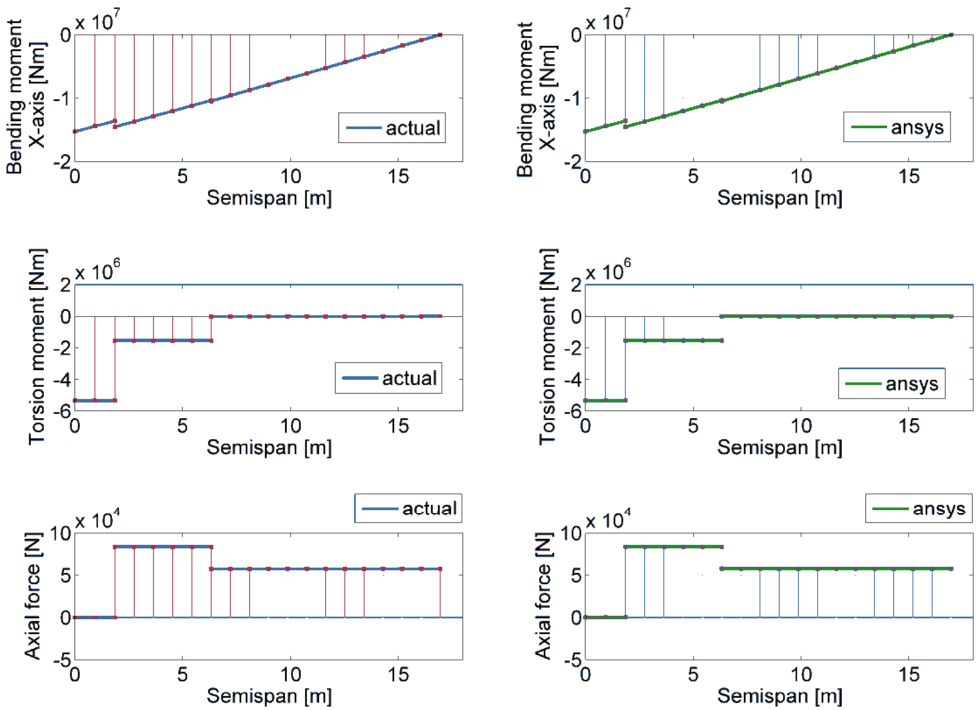




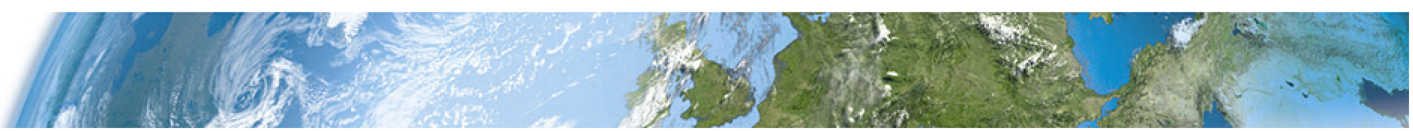
Iterative Sizing



Internal forces



DLR



Workflow Development
OAD process

3 phases workflow:

1) Initial Synthesis:
- Initialize the aircraft design
- Conceptual OAD tool

2) Physics based analysis:
- Aero-structural sizing loop
- Aircraft performance evaluation Rigid and Flexible (flexibility loop)

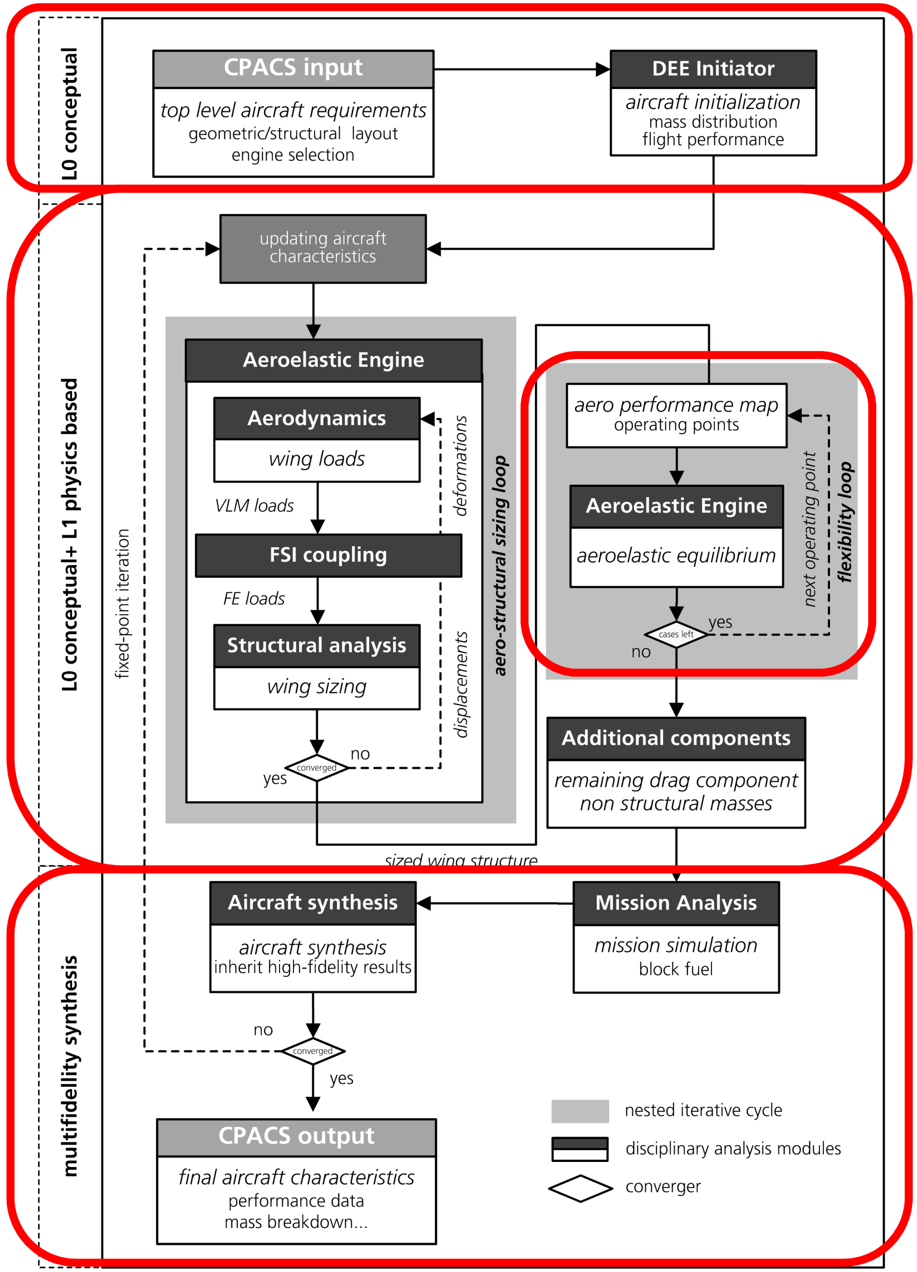
3) Multifidelity synthesis:
- Physics based values replace conceptual calculations
- New OAD synthesis

.

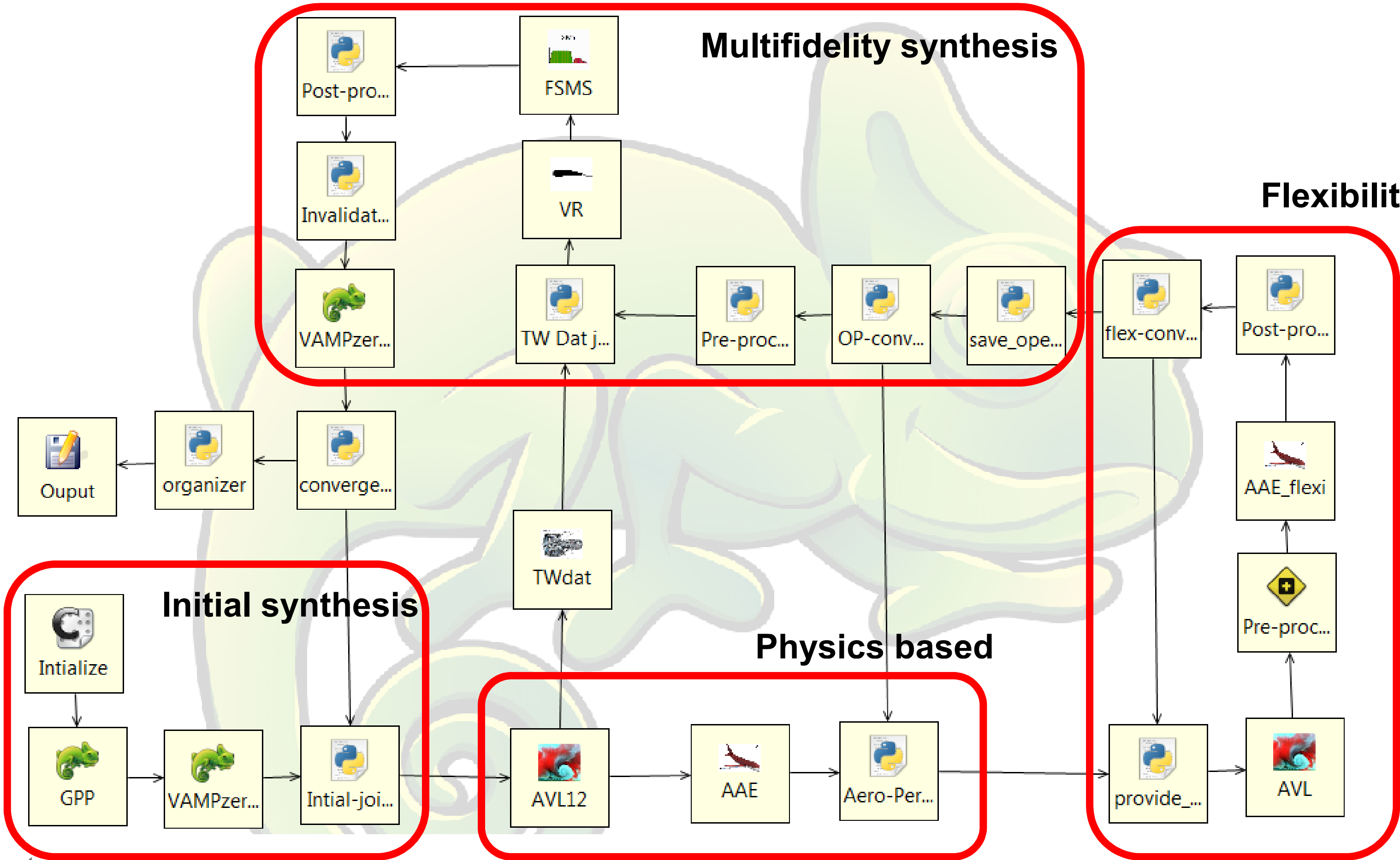
1)

2)

3)



Workflow Development
OAD process



Design Case I
Conventional configuration OAD

Test configuration:
- TLAR defined in a Design challenge launched in December 2012

TLAR	
Range (nm)	2000
Mach cruise	0.79
PAX	190

Aero-Structural analysis:
- 2.5g pull-up maneuver
- Static strength sizing
- Isotropic material
- Fixed structural layout
- Rigid / Flexible trim and performance

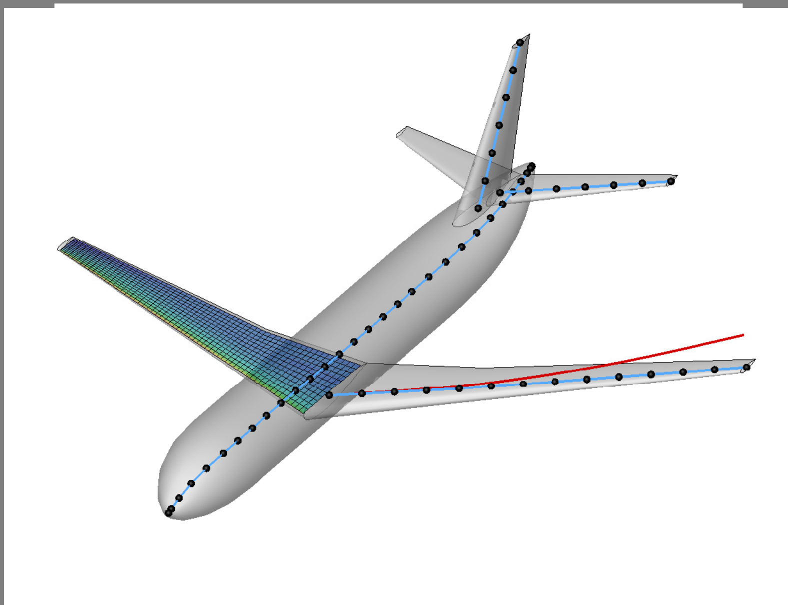
3 OAD design process modes:

L0 design process:
- Only conceptual aircraft design

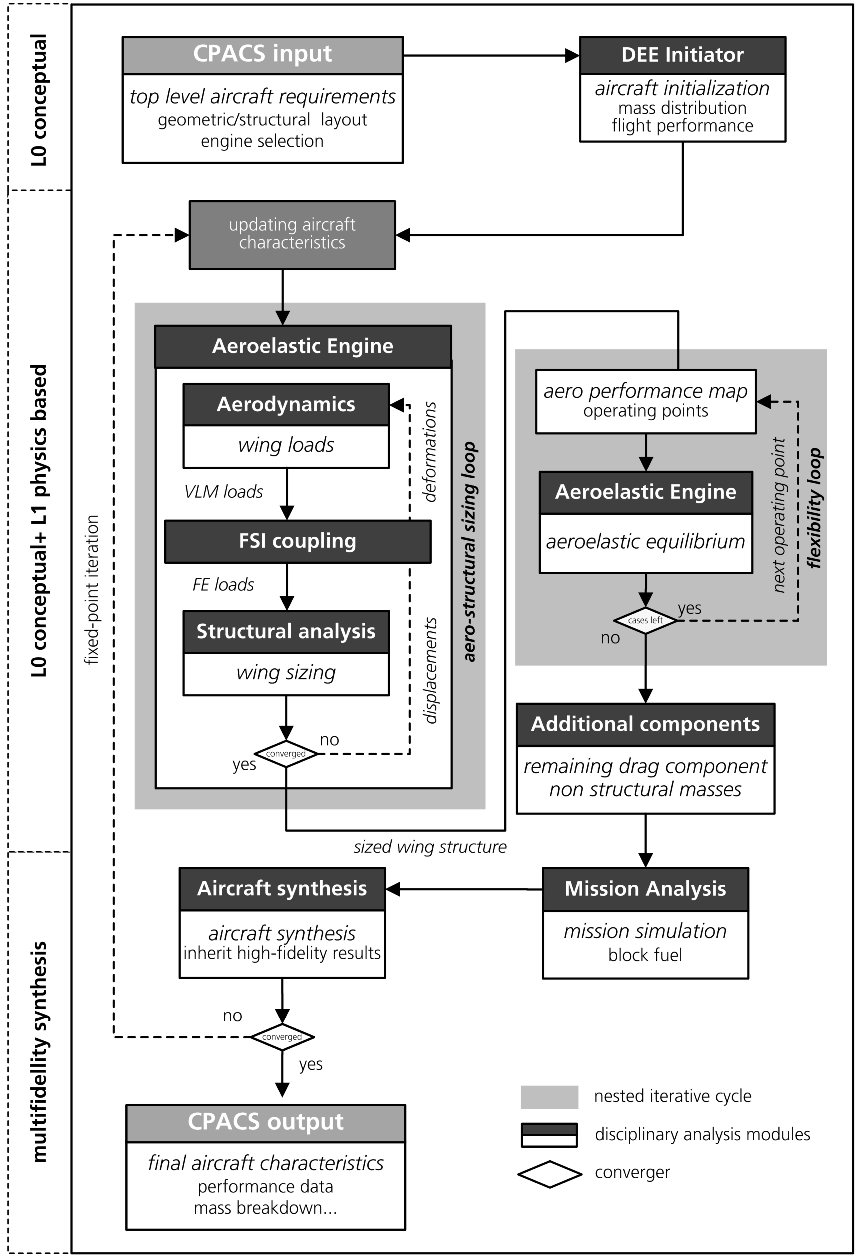
L1 Rigid design process:
- Conceptual and physics based design
- Aero-structural sizing, rigid performance

L1 Flexible design process:
- Conceptual and physics based design
- Including flexibility loop

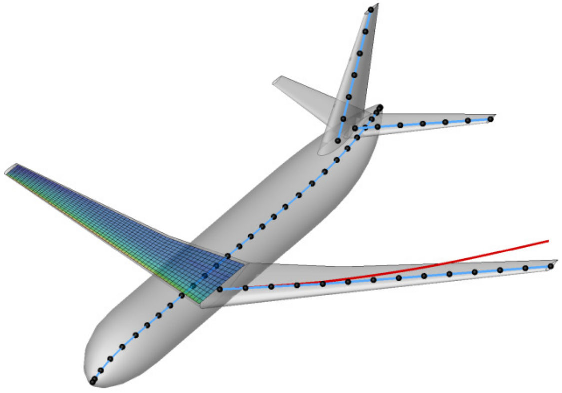
Design Case I
Conventional configuration



Flexible performance



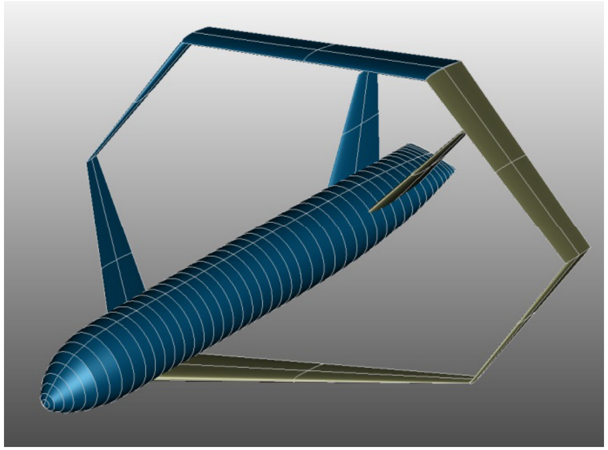
Design Case I
Results



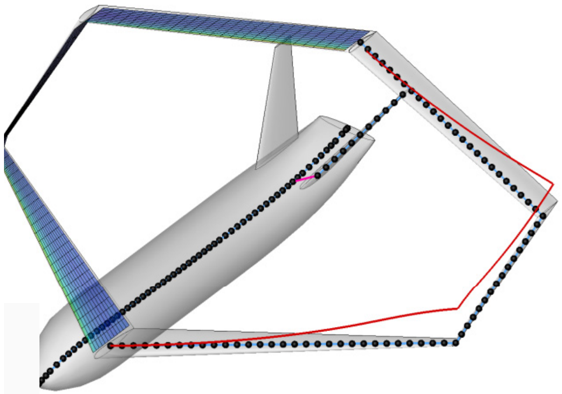
OAD	Conceptual L0
	Initial OAD
mTOM [kg]	83145.7
mFM [kg]	18947
OEM [kg]	45198

Design Case II
Results

- Unconventional boxwing OAD (ref. TLAR Pisa)
- Same approach conventional



OAD	Conceptual L0
	Initial
mTOM [kg]	245551
mFM [kg]	77474
OEM [kg]	126327



Conclusions and Outlook

- Collaborative design approach for aircraft in pre-design
    - Enabling physics based analysis
    - Focus on flexibility effects

- Integration of distributed physics based modules
    - Analysis starting from an initial OAD synthesis model
    - Disciplinary modules for aero-structural design and new synthesis
    - Flexibility loop influence

Design cases:
- Conventional aircraft behaves as expected
- Care has to be considered with the unconventional aircraft case

- Outlook:
    - Adopt the approach for design and optimization applications

Thank you for your interest!

Pier Davide Ciampa, Björn Nagel

German Aerospace Center
Air Transportation Systems

Darwin Rajpal, Gianfranco La Rocca

TU Delft

4th CEAS Air & Space Conference
16th-19th September 2013
Linköping

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Aerospace Engineering at TU Delft

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546616

G. La Rocca (TU Delft)

EWADE 2013

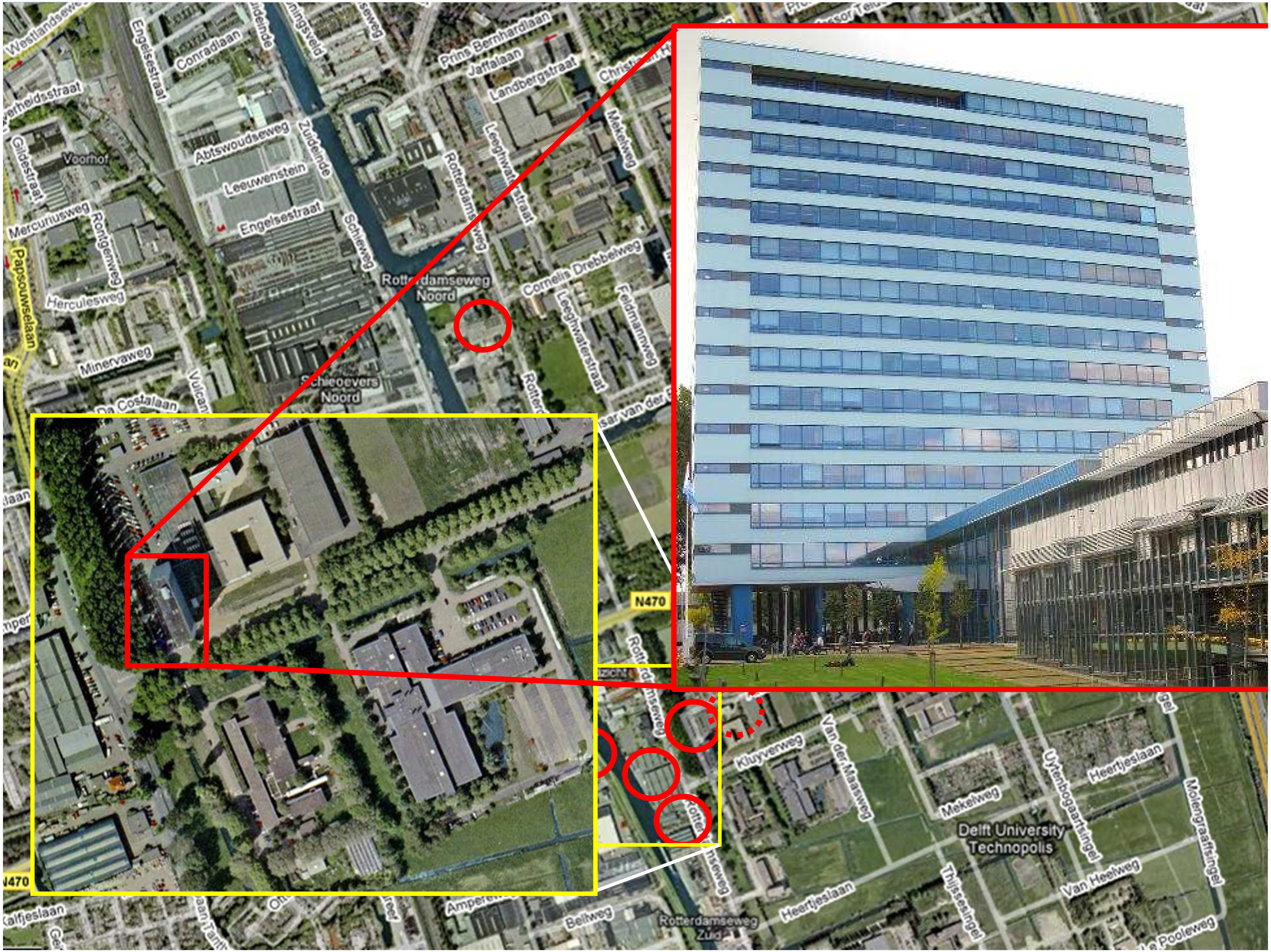
11th European Workshop on Aircraft Design Education
Linköping, Sweden

September 2013

TU Delft
Delft University of Technology

Challenge the future


Amsterdam
The Hague
Delft
Rotterdam



Westlandseweg
Engelsestraat
Conradlaan
Prins Bernhardlaan
Jaffalaan
Landbergstraat
Abtswoudseweg
Zuideinde
Leeuwenstein
Voorhof
Gildestraat
Mercuriusweg
Röntgenweg
Papsouwselaan
Herculesweg
Schieweg
Rotterdamseweg
Mekelweg
Leeghwaterstraat
Rotterdamseweg Noord
Cornelis Drebbelweg
Feldmannweg
Minervaweg
Schieoevers Noord
Da Costalaan
N470
Kluyverweg
Van der Maasweg
Heertjeslaan
Mekelweg
Uytenbogaartsingel
Molengraaffsingel
Delft University Technopolis
Van Heelweg
Thijsseweg
Bellweg
Rotterdamseweg Zuid

Aerospace Engineering

- 1842: TU Delft founded by King Willem II
- 1946: **Department** of Aeronautical Engineering founded by Prof. Van der Maas
- 1961: Start of Space technology
- 1975: **Faculty** of Aerospace Engineering

Aerospace Engineering

Complete

Research & education covering almost all areas of aerospace engineering, both with expertise and laboratory equipment

Largest aerospace engineering faculty in Western Europe

- International scientific reputation
- Unique facilities
- Large student body

Internationally oriented

- **Fully English taught programme**
- **34% International students**
- Member of IDEA League, PEGASUS university networks
- Bilateral international agreements
- Working in multinational research teams

Aerospace Engineering

Number of staff:

- 59 support staff
- 228 academic staff
- 100 Ph.D. students

Number of students:

- ±2000 students (BSc & MSc)
- ± 500 first year students

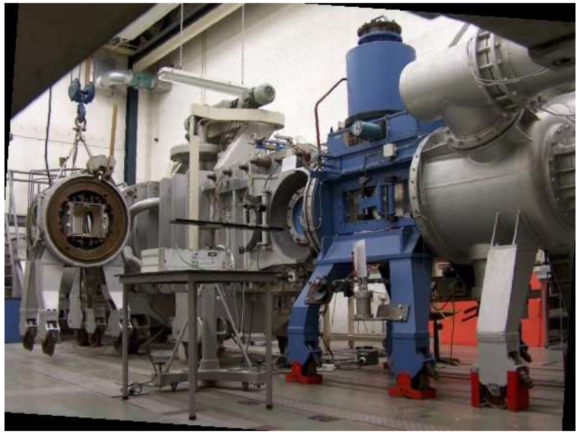
Funding:

- 22 M€ - Governmental funding
- 7 M€ - External funding

Aerospace Engineering facilities

Cessna Citation II jet aircraft
A flying laboratory for students to carry out experiments in the air space above and around Schiphol airport near Amsterdam

Wind Tunnels
Eight high-speed and low-speed wind tunnels to demonstrate aerodynamic theory.
From the subsonic at 35m/sec to the hypersonic at Mach 11.



Aerospace Engineering facilities

Structures and Material Lab
Five fatigue-testing machines, low-speed and high-speed impact testers, production equipment such as a filament winding machine, clean room for composite lamination, one autoclave. GLARE was born here!

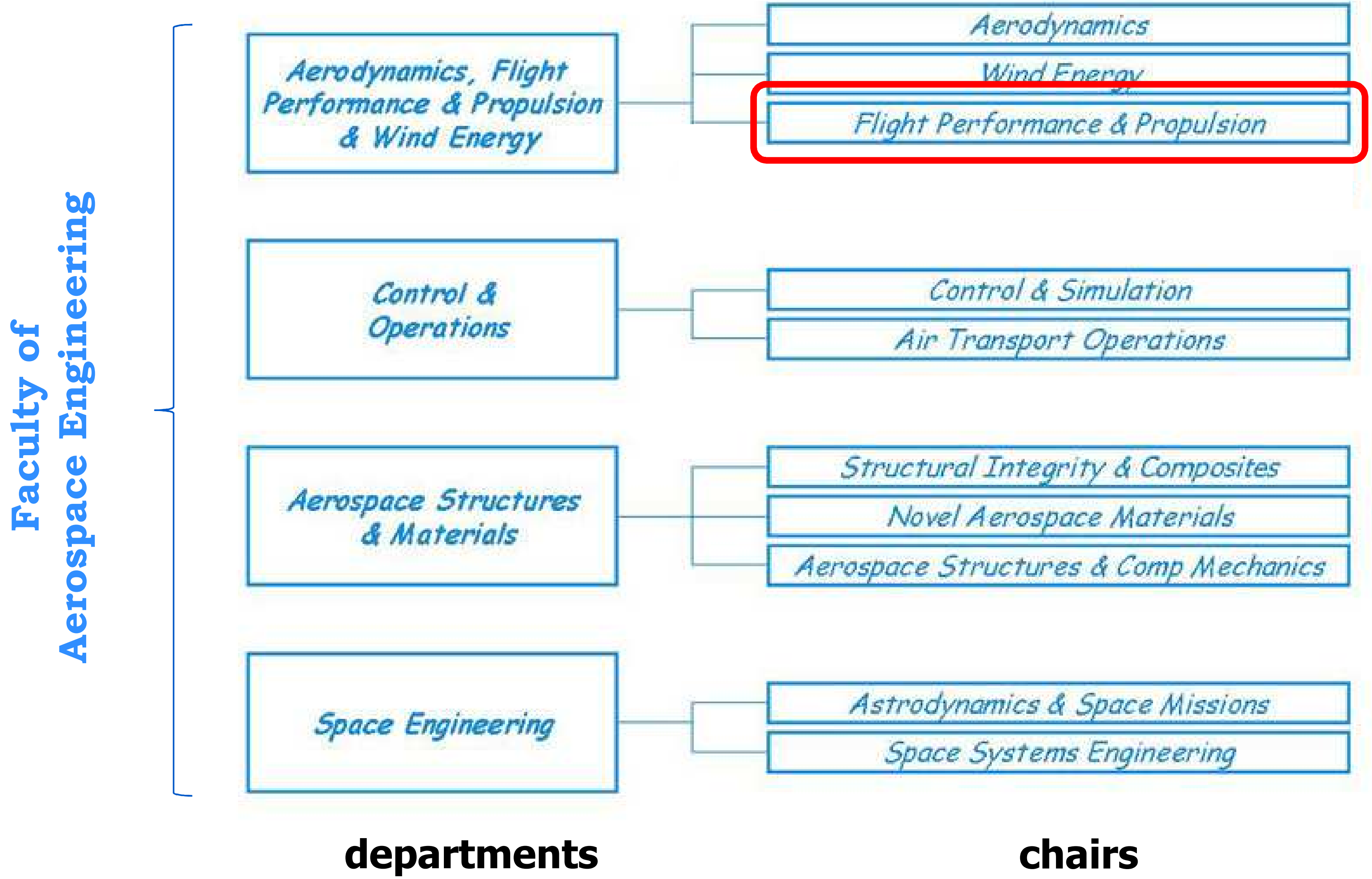
SIMONA
A super-simulator designed and built at TU Delft. It is used to study man-machine interaction and can simulate the motions of airplanes, helicopters, heavy and light vehicles, and Space Planes.

Aerospace Engineering facilities

The "Vliegtuighal"

The faculty hangar houses a collection of aircraft and spacecraft parts such as cockpits, wings, advanced sensors and rocket parts. It also has a helicopter, an F16, and a test model of Europe's largest satellite, ENVISAT.

Aerospace Engineering organization



FPP contribution to AE education*

Bachelor courses

1. Introduction to Aerospace Engineering (soon on Open Courseware)
2. Aerospace Design and Systems Engineering elements I – II
3. Systems Engineering and Aerospace Design
4. Flight Mechanics
5. Design Synthesis Exercises (a design assignment to be performed in 10 weeks in a group of 10)

Master courses

1. Advanced Aircraft Design I (on the aerodynamic design of transport aircraft)
2. Advanced Aircraft Design II (on the aerodynamic design and performance of combat aircraft)
3. Advanced Design Methods (on Multidisciplinary Design Optimization and Knowledge Based Engineering)

*Propulsion related courses not included here

Young aircraft designers

H.E.L.P.

1st prize AIAA student design competition 2013

Raphael Klein

- 27.1 m span
- 8.3 m booms
- 2,260 kg MTOW
- Cruise at 80,000 feet
- 20.2 hours endurance
- 182 kg payload
- MIL-B gusts specifications
- Taildragger configuration
- Jet powered
- Fits in a container

Tutors: R. Vos (TU Delft), R. Barret (KU)

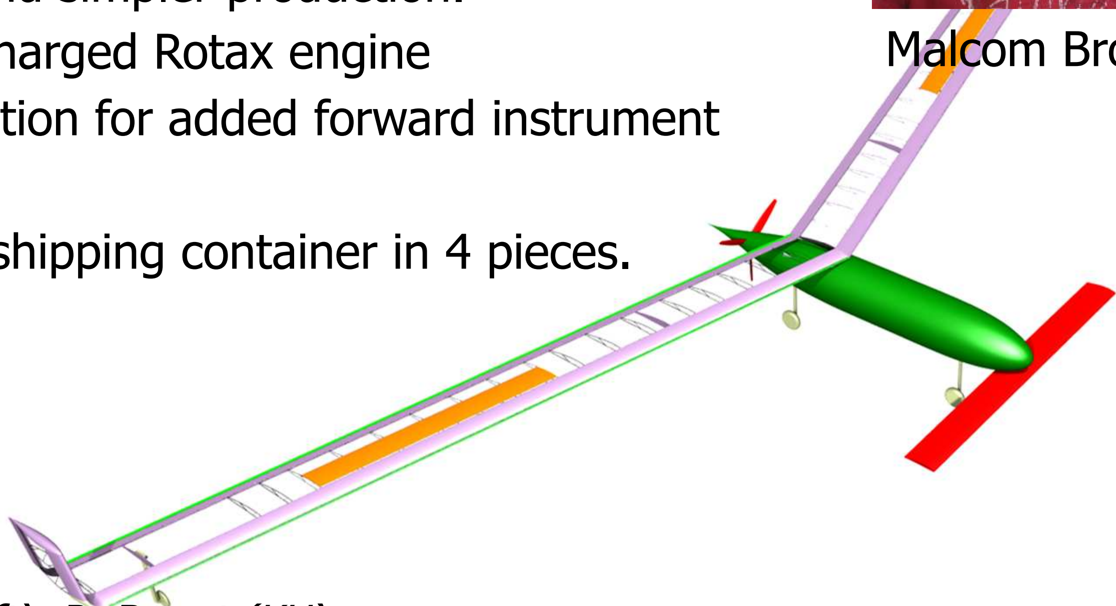
Young aircraft designers

Sky – I

3rd prize AIAA student design competition 2013

Malcom Brown

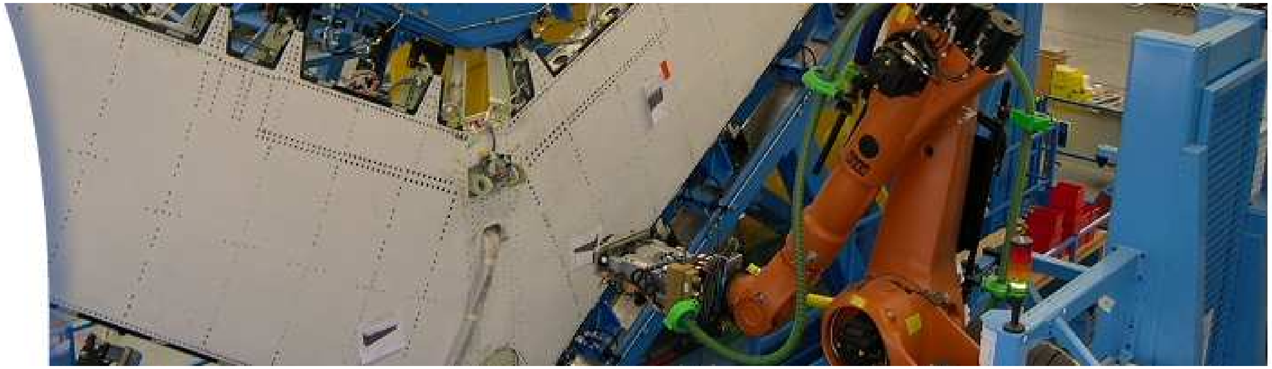
- All-lifting canard design.
- Low drag, large volume fuselage.
- Simple composite structure,
  allowing cheaper and simpler production.
- Multi-fueled turbocharged Rotax engine
  in pusher configuration for added forward instrument visibility.
- Transportable in 1 shipping container in 4 pieces.



Tutors: R. Vos (TU Delft), R. Barret (KU)

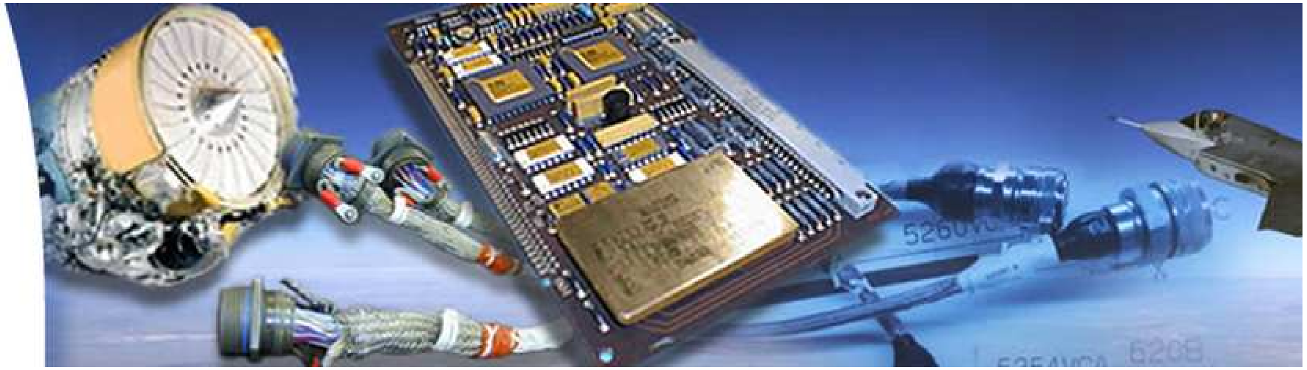
The aerospace industry

FOKKER
AEROSTRUCTURES



The aerospace industry

FOKKER
ELMO



The aerospace industry

German-Dutch Wind Tunnels

Delft

Delft

Not far from Delft

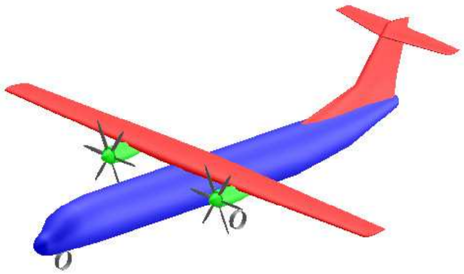
So, what about

EWADE 2015 – Delft?

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

OpenVSP-Connect – Visualize Your Aircraft Sizing Results with NASA's Vehicle Sketch Pad



Dieter Scholz — Hamburg University of Applied Sciences

Tahir Sousa — Hamburg University of Applied Sciences

http://ewade2013.AircraftDesign.org
http://dx.doi.org/10.5281/zenodo.546617
http://openVSP.ProfScholz.de

CEAS European Air & Space Conference 2013

Linköping, Sweden

16 to 19 September 2013

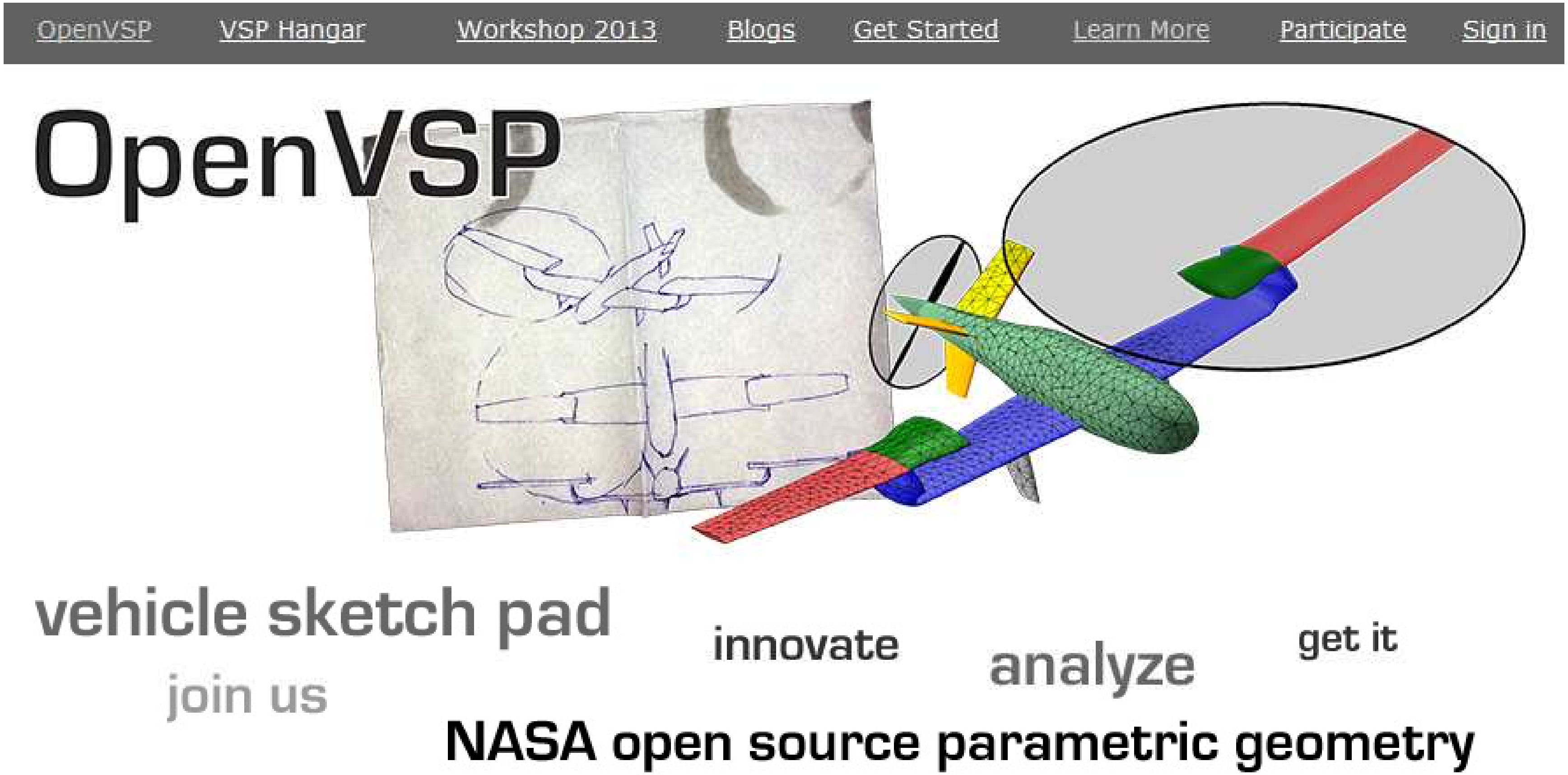
Abstract

A 3D visualization is missing for many aircraft preliminary sizing tools. NASA's Open Vehicle Sketch Pad (OpenVSP) is easy to use, but lacks an interface to input consistent aircraft data. Such an interface has been programmed and is called OpenVSP-Connect. Aircraft are sketched from about 50 parameters. If these are not known to the user, the interface calculates them as good as possible based on simple equations from aircraft design or statistics. Taken this to the extreme, a decent looking aircraft is drawn from as few as two or three input parameters.

Contents

Contents

OpenVSP



www.openVSP.org

OpenVSP

OpenVSP | VSP Hangar | Workshop 2013 | Blogs | Get Started | Learn More | Participate | Sign in

Download and Install

Getting started with VSP is easy. If you're on Windows or MacOS, visit the download page and pull down the latest version ready-to-go. If you're on Ubuntu, there are some installation instructions on the Wiki; installation on most other Linux distributions should be similar.

Tutorials

VSP is very easy to use. Most users get the hang of it after just a few minutes. If you're looking for more help, there are some tutorial videos and a downloadable manual which help you get started in VSP.

VSP Hangar

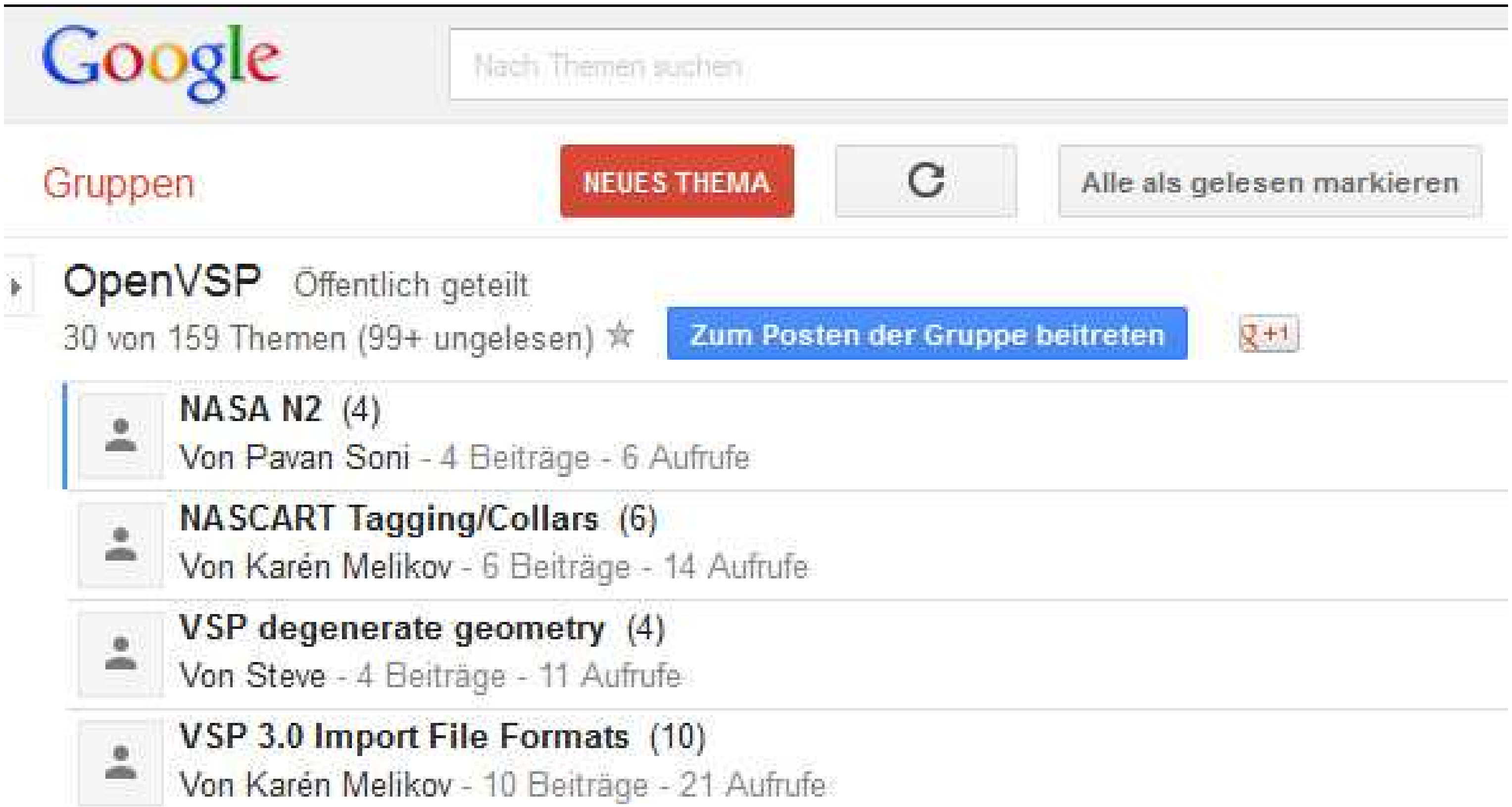
The VSP Hangar is a database of community contributed example models. Check it out for a starting point or just for inspiration. Once you've completed your first model, show it off by contributing it to the hangar.

OpenVSP

User Manual

81 pages

OpenVSP



OpenVSP Google Group

OpenVSP

Login

OpenVSP

Recent changes Media Manager Sitemap

Trace: · workshop2013 · workshop2012 · papers · installation_on_ubuntu_11.10 · rasce · programs · **start**

start

OpenVSP wiki

OpenVSP is a parametric aircraft geometry tool. OpenVSP allows the user to create a 3D model of an aircraft defined by common engineering parameters. This model can be processed into formats suitable for engineering analysis.

The predecessors to OpenVSP have been developed by J.R. Gloudemans and others for NASA since the early 1990's. On January 10 2012, OpenVSP was released as an open source project under the NASA Open Source Agreement (NOSA) version 1.3.

FAQ

Installation Instructions

Developer Instructions

API Use Cases

OpenVSP

Login

OpenVSP

Recent changes Media Manager Sitemap

Trace: · workshop2013 · workshop2012 · papers · installation_on_ubuntu_11.10 · rasce · programs · start · faq

faq

OpenVSP Frequently Asked Questions and Tips

Known Bugs and Workarounds

1. The airfoil picture covers the Wing editor on MacOS.
   - When using OpenVSPmac2.0.3 or earlier, the airfoil cross-section plot persists when you leave the Foil tab of the MS_Wing editor. This is a known bug. Until it is fixed, the workaround is pretty easy. Once you leave the Foil tab by selecting another tab in the MS_Wing editor, simply click on the component name in the Geom Browser (usually sitting just to the left of the MS_Wing editor). This will force a refresh of the MS_Wing editor window.

OpenVSP

Filter Results

Source Quality
- 5 - Completely Inaccurate (1)
- 1 - Definitive (1)
- 2 - Essentially Exact (3)
- 3 - Good (11)

Manufacturers
- (5)
- Bombardier (3)
- NASA (3)
- Boeing (2)
- MIT (1)
- McDonnell Douglas (1)
- Embraer (1)

Units
- feet (14)
- dimensionless (2)

Tags
- [x] transport (16)
- airplane (15)
- airliner (7)
- turboprop engine (3)
- twin-engine (3)
- blended wing body (2)
- lifting body (2)
- utility (1)

Filter Results

Name	Source Quality	Manufacturer	Model	Downloads	Comments	Date
IK-02	3			43	0	2013-02-24
IK-01	3			33	0	2013-02-24
LJJ-3X1	5		Jumbo Luxuryliner/ Cargo Transport	42	0	2013-01-31
DC-10	3	McDonnell Douglas	DC-10	99	0	2013-01-23
Bombardier Dash 8 Q400 clean w/o prop	2	Bombardier	Q400	144	0	2012-10-11
Bombardier Dash 8 Q400 clean w/o prop	2	Bombardier	Q400	70	0	2012-10-10
Bombardier Dash 8 Q400 clean	2	Bombardier	Q400	131	0	2012-10-04
ATR 42-600 Hybrid Electric	3		Hybrid ATR-42	119	0	2012-08-15
ATR 42-600	3	Embraer	ATR-42-600	129	0	2012-08-15

OpenVSP Hangar

OpenVSP

OpenVSP | VSP Hangar | Advanced Search | Upload | Help | Sign in

Boeing 787-300

OpenVSP Hangar

File ID#	61
Manufacuter	Boeing
Model	787-300
Units	Feet
Description	A general, non-exact Boeing 787-300 model
Source Quality	3 - The source material used to create this model was Good. This means good 3-view drawings were used to create the model.
Model Suitability	2 - Cartoon or Pretty Picture 2 - Weight and balance 2 - OML for wetted areas/drag buildup 2 - Check internal layout/volume 2 - Structures 2 - Build a display model 3 - Accurate OML for detailed aerodynamic analysis or CFD
Tags	airplane , transport

left-click = rotate, middle-button/CTLR-left-click = pan, scroll/right-click/ALT-left-click = zoom

Download | Revisions (0)

OpenVSP

hangar.openvsp.org

OpenVSP Hangar

OpenVSP

Login

OpenVSP

Recent changes Media Manager Sitemap

Trace: • workshop2013 • workshop2012 • installation_on_ubuntu_11.10 • rasce • programs • start • faq • **papers**

papers

These publication lists are very incomplete. Please take no offense to omissions – please help out and add them.

Papers about VSP

- Chaput, A., Rizo-Patron, S., "Vehicle Sketch Pad Structural Analysis Module Enhancements for Wing Design", 50th AIAA Aerospace Sciences Meeting, Nashville, TN, 2012, AIAA-2012-546
- Hahn, A., "Application of Cart3D to Complex Propulsion-Airframe Integration with Vehicle Sketch Pad", 50th AIAA Aerospace Sciences Meeting, Nashville, TN, 2012, AIAA-2012-547

Contents

Three Approaches to Visualization with OpenVSP

Open Vehicle Sketch Pad Aircraft Modeling Strategies

Andrew S. Hahn [1]
NASA Langley Research Center, Hampton, VA, 23681

Geometric modeling of aircraft during the Conceptual design phase is very different from that needed for the Preliminary or Detailed design phases. The Conceptual design phase is characterized by the rapid, multi-disciplinary analysis of many design variables by a small engineering team. The designer must walk a line between fidelity and productivity,

...

American Institute of Aeronautics and Astronautics

Three Approaches to Visualization with OpenVSP

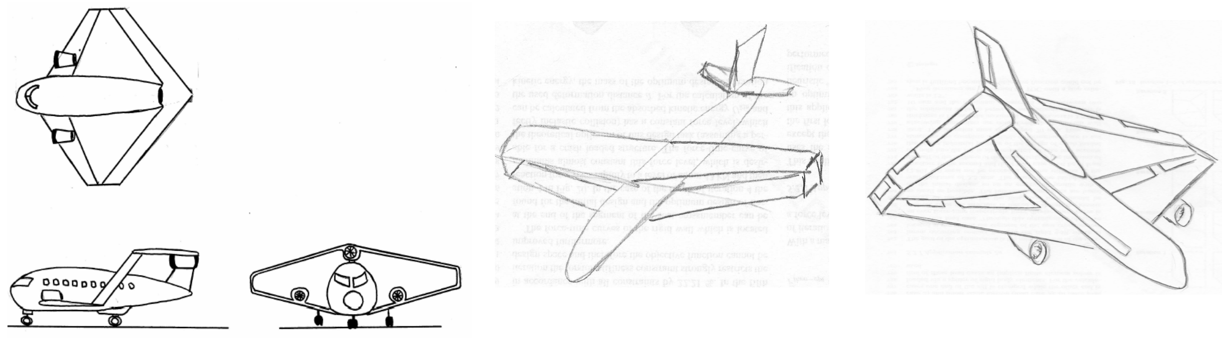
Hahn: There are **two basic kinds of models created in Open VSP**:

The **first approach** is the **“clean sheet” design** in which the **parameters are all chosen** by the designer using Open VSP. In this case, there is no other geometry and so this model is considered definitive.

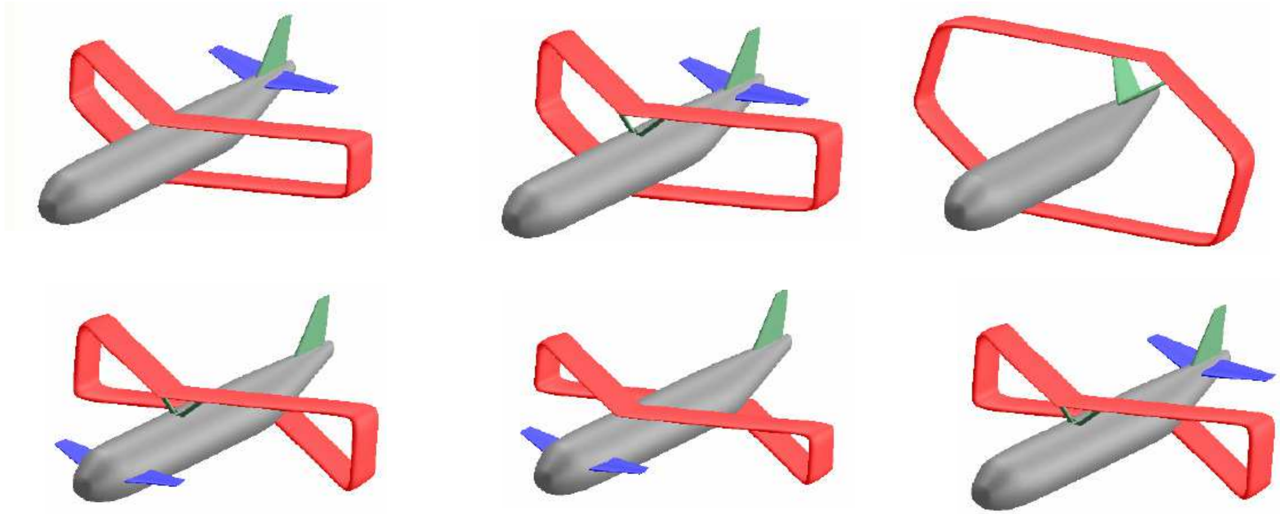
The **second approach** basic kind of model is the **“match” design**. … In this case, there is some other standard of comparison, be it a real aircraft or a geometry from a different modeler such as CAD. It takes significantly more effort to produce a model that is as good of a representation as possible. Usually, the only **geometric information available is limited tabular data and a three - view drawing**. There are different ways of building this kind of model, but the preferred way is to gather the most accurate information and then expend some effort to **derive the parameters that Open VSP needs** to create the model.

The first approach: „clean sheet“ design

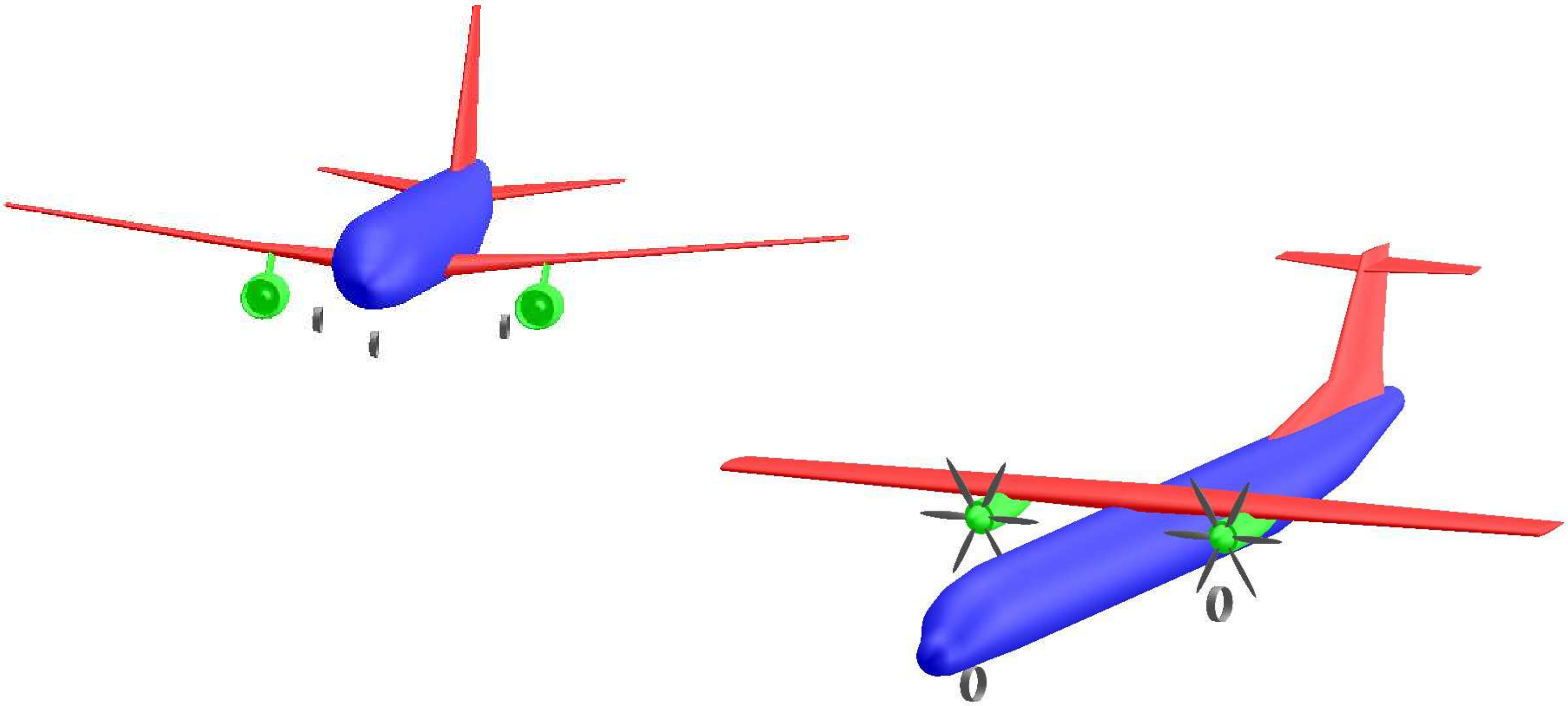
- **Hand Sketches**



- **Creative Methods**
  - **Brainstorming**
  - **Gallery Method**
  - **Visualization with OpenVSP**



The second approach: „match“ design

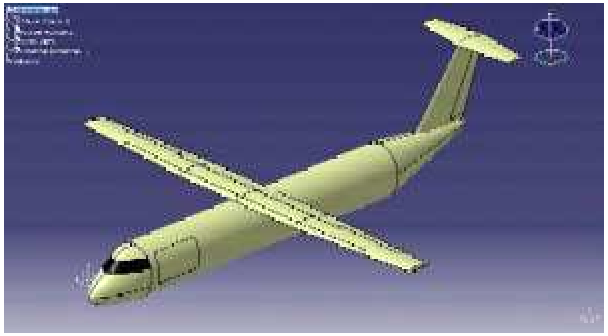


Three Approaches to Visualization with OpenVSP

The third approach: „calculated“ design

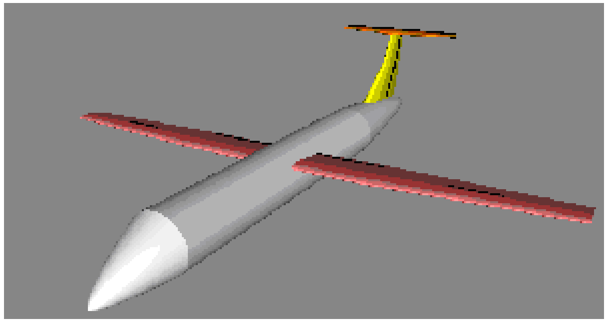
new

Simple Aircraft Sizing

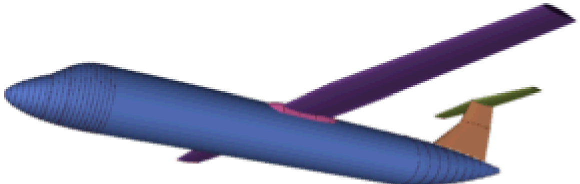


Parametric CATIA

OpenVSP



CEASIOM: AcBuilder



SUMO

Three Approaches to Visualization with OpenVSP


OpenVSP

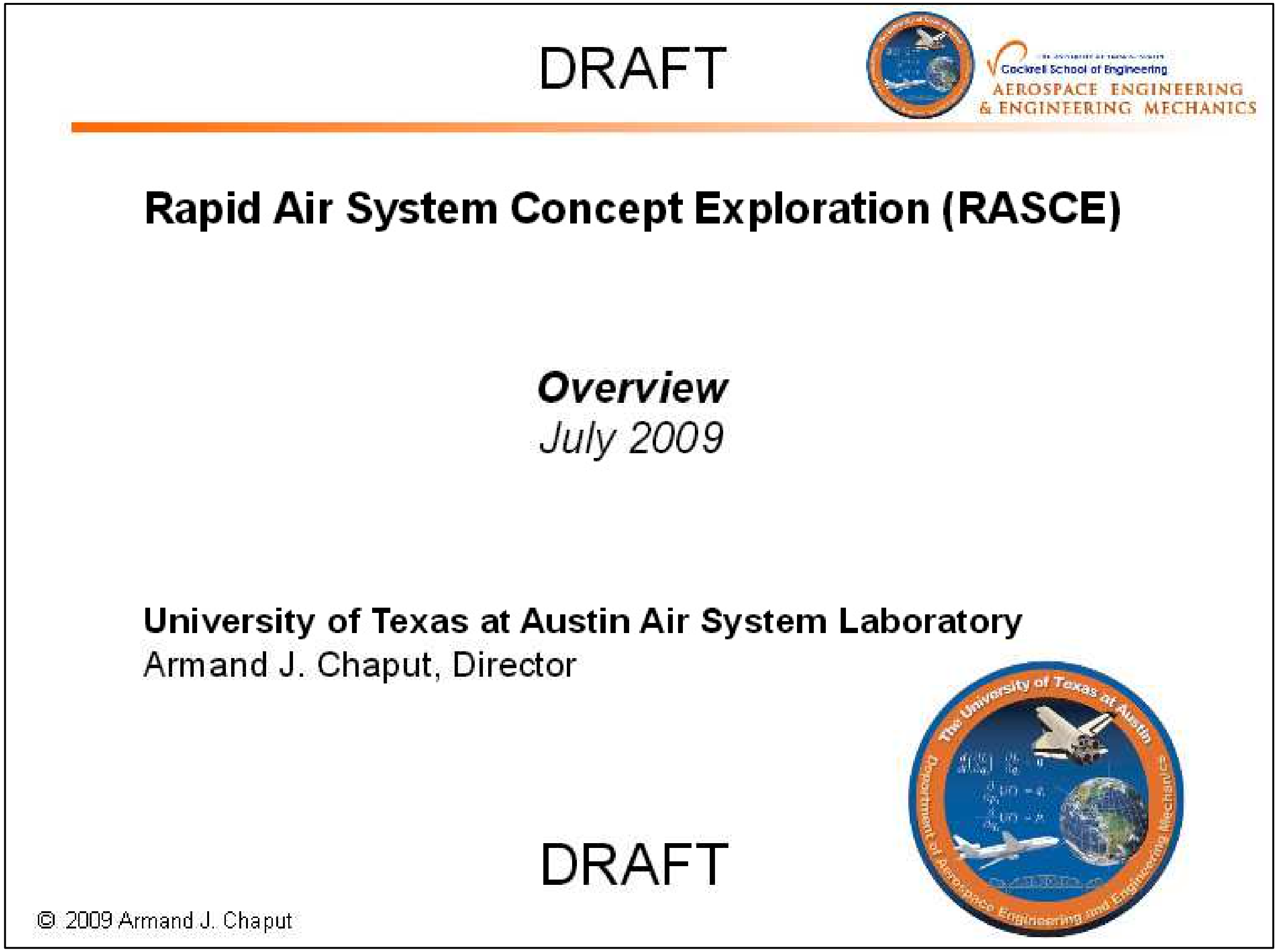
Trace: · workshop2013 · workshop2012 · papers · installation_on_ubuntu_11.10 · start · programs · rasce

RASCE

Rapid Air System Concept Exploration

RASCE is developed by Armand J. Chaput, and is distributed with the following license statement.

Three Approaches to Visualization with OpenVSP



See also: OpenVSP-Workshop 2012

Three Approaches to Visualization with OpenVSP

Summary

Cockrell School of Engineering
AEROSPACE ENGINEERING & ENGINEERING MECHANICS

RASCE - a physics-based, conceptual level, air system design and analysis M&S environment developed to provide students with hands-on experience in air system design including real world design drivers not typically taught

- *In continuous use since 2003 on student design projects*
- *Also applied to government and industry concept studies*

RASCE is particularly well suited for concept screening and quantitative design and technology trade studies

- *Configuration features and trade offs can be carefully and systematically controlled over a broad trade space*

RASCE runs in real time on a standard laptop

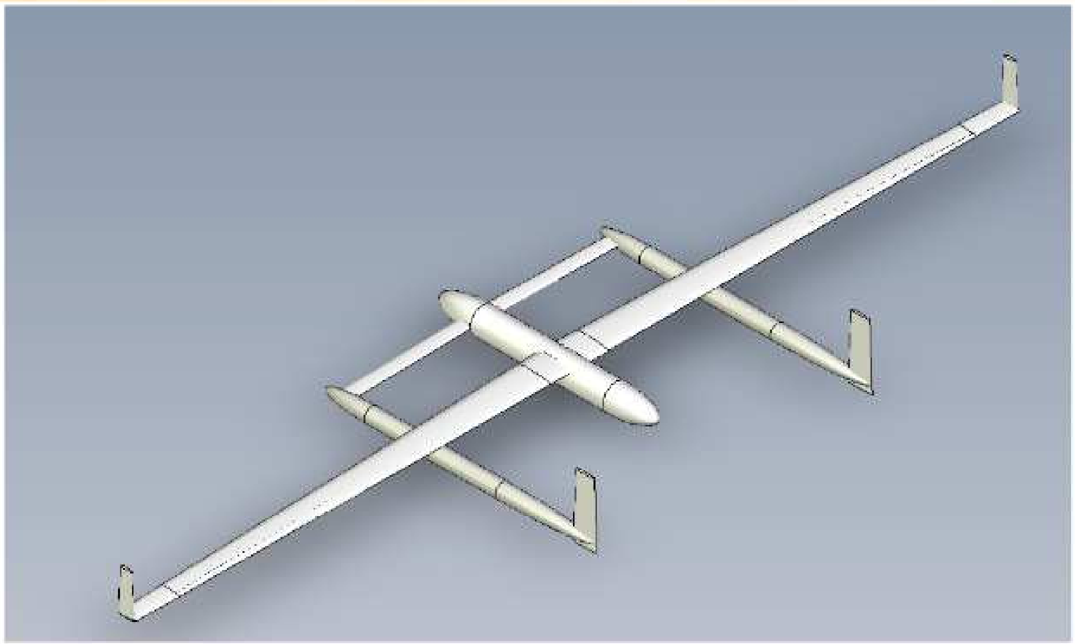
- *No laborious input data preparation and/or hand calculations*

Experienced users can go from initial concept to complete air system sized to standard mission rules in < 1 hour

Three Approaches to Visualization with OpenVSP

**3D model output
rendered by SolidWorks**

Cockrell School of Engineering
AEROSPACE ENGINEERING
& ENGINEERING MECHANICS



3D Rendering of Aircraft Configuration Designs

James R. Carlson[1]
University of Texas, Austin, Texas, 78712

Contents

OpenVSP-Connect

OpenVSP-Connect

Connect YOUR Aircraft Design Tool with Vehicle Sketch Pad from NASA

OpenVSP-Connect is primarily intended as an interface tool between ANY aircraft design tool and Open Vehicle Sketch Pad (openVSP) from NASA.
OpenVSP-Connect needs OpenVSP for the display of the aircraft. You can download OpenVSP for free:
http://www.openVSP.org
In the order of 50 core parameters of the aircraft are used to calculate the input parameters required by OpenVSP to sketch a passenger aircraft.
For each parameter a proposed value is given and automatically applied as long as the user does not specify his/her own value.
By using all default values, the program works in "automatic mode": Based on just two input values "Cruise Mach number" and "Number of passengers" an aircraft can be sketched automatically based on passenger aircraft statistics.

For further information, documentation please refer to:
http://OpenVSP-Connect.ProfScholz.de

OpenVSP-Connect is a project by Aircraft Design and Systems Group (AERO) at Hamburg University of Applied Sciences (HAW Hamburg).

GPLv3 Free Software

OpenVSP-Connect

OpenVSP-Connect is primarily intended as an **interface tool between ANY aircraft design tool and** Open Vehicle Sketch Pad (**openVSP**) from NASA.

OpenVSP-Connect needs OpenVSP for the display of the aircraft. You can download OpenVSP for free: **http://www.openVSP.org**

In the order of 50 core parameters of the aircraft are used to calculate the input parameters required by OpenVSP to sketch a passenger aircraft.

For each parameter a proposed value is given and automatically applied as long as the user does not specify his/her own value.

By using all **default values**, the program works in **"automatic mode":** Ultimately, based on just three input values **"Number of passengers", "Range" and "Cruise Mach number"** an aircraft can be sketched automatically based on passenger aircraft statistics.

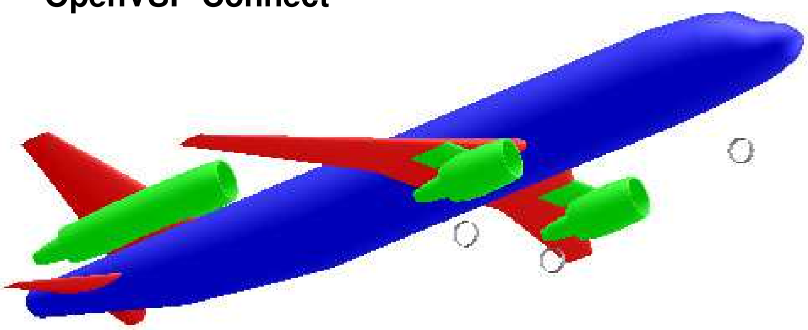
OpenVSP-Connect

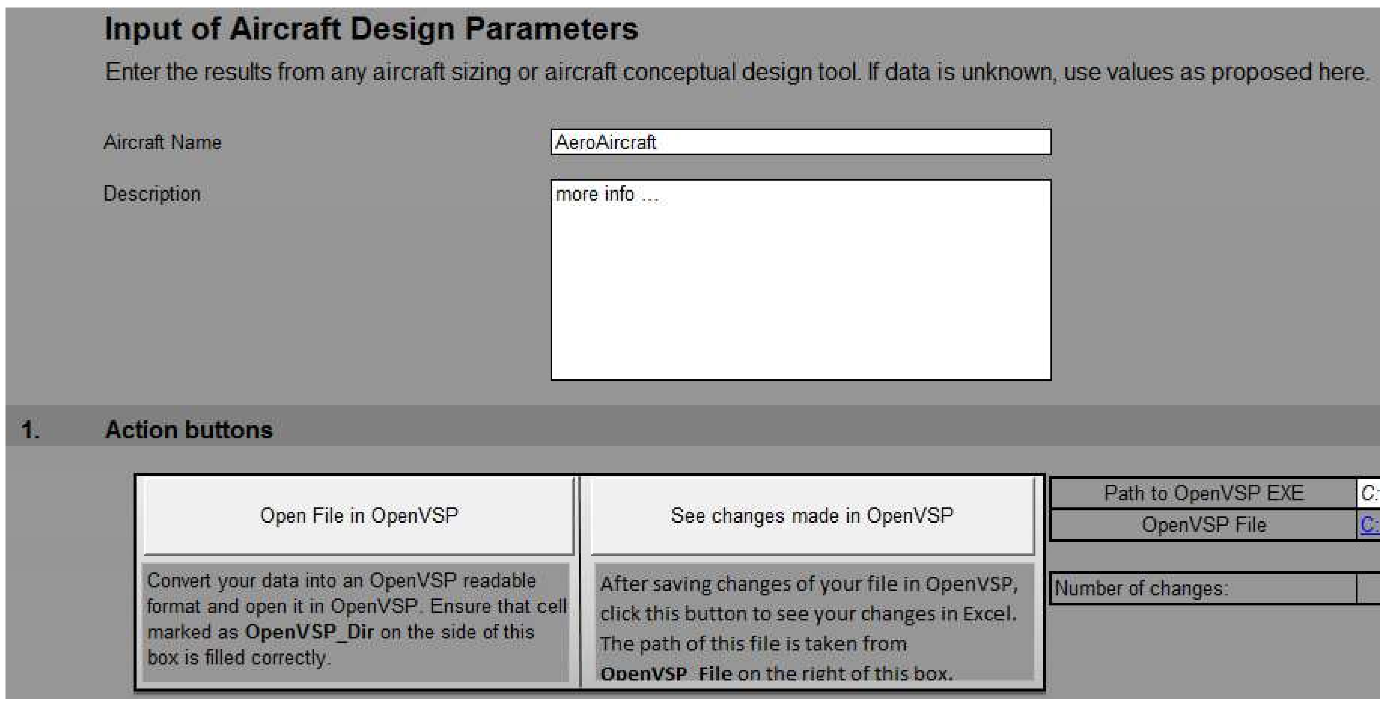
1	**Convert to OpenVSP XML**			
2	Convert data from Input-Tab to an OpenVSP XML file.			
3			**Visualization**	
4	**Parameter names**	**Parameter values**	**needed?**	**XML generated from OpenVSP Connect**
5				
6	**xml version**	"1.0"		<?xml version="1.0"?>
7	**Vsp_Geometry**			<Vsp_Geometry>
8	**Version**	3		<Version>3</Version>
9	**Name**	AeroAircraft		<Name>AeroAircraft</Name>
26	**VirtWindow_List**			<VirtWindow_List>
208	**Component_List**			<Component_List>
209	**Component**	HORIZONTAL TAIL	Yes	<Component>
339	**Component**	VERTICAL TAIL	Yes	<Component>
511	**Component**	WING	Yes	<Component>
512	**Type**	Mswing		<Type>Mswing</Type>
513	**General_Parms**			<General_Parms>
561	**Mswing_Parms**			<Mswing_Parms>
562	**Total_Area**	104,544832		<Total_Area>0.000.105</Total_Area>
563	**Total_Span**	33,728326		<Total_Span>0.000.034</Total_Span>
564	**Total_Proj_Span**	33,695906		<Total_Proj_Span>0.000.034</Total_Proj_S
565	**Avg_Chord**	3,528260		<Avg_Chord>0.000.004</Avg_Chord>
566	**Sweep_Off**	0,000000		<Sweep_Off>0.000.000</Sweep_Off>
567	**Deg_Per_Seg**	9		<Deg_Per_Seg>9</Deg_Per_Seg>
568	**Max_Num_Seg**	9		<Max_Num_Seg>9</Max_Num_Seg>
569	**Rel_Dihedral_Flag**	0		<Rel_Dihedral_Flag>0</Rel_Dihedral_Flag>
570	**Rel_Twist_Flag**	0		<Rel_Twist_Flag>0</Rel_Twist_Flag>
571	**Round_End_Cap_Flag**	Yes		<Round_End_Cap_Flag>1</Round_End_Ca
572	**/Mswing_Parms**			</Mswing_Parms>
573	**Airfoil_List**			<Airfoil_List>

OpenVSP-Connect

	A	B	C	D	E	F	G	H	I	J	K
42	4.	**Wing**									
43											
44		**Wing Type**	$Type_W$	Double-trapezoidal	[-]						
45		Total Area	S_W	120,000	[m²]						
46		Total Aspect ratio	A_W	9,480	[-]						
47							Total Span	b_W	33,728	[m]	
48		Outboard 25% Sweep	$\varphi_{25,W,o}$	21,881	[°]	<<<<<<	25% Wing sweep suggestion	$\varphi_{25,W,o}$	21,881	[°]	
49		Taper Ratio	λ_W	0,198	[-]	<<<<<<	Taper Ratio Suggestion	λ_W	0,198	[-]	
50							Root Chord	$c_{r,W}$	5,939	[m]	
51							Tip Chord	$c_{t,W}$	1,176	[m]	
52							Outboard Leading edge Sweep	$\varphi_{LE,W,o}$	24,334	[°]	
53							Outboard Trailing edge sweep	$\varphi_{TE,W,o}$	14,022	[m]	
54		Airfoil thickness ratio	(t/c)	0,116	[-]	<<<<<<	Thickness ratio	(t/c)	0,116	[-]	
55		X position of wing	$RelPos_{W,x}$	31,500	% of fuselage l	<<<<<<	X position of wing		31,500	% of fuselage length	
56		Z position of wing	$RelPos_{W,z}$	25,180	% of fuselage diameter						
57		Outboard dihedral angle	$\Gamma_{W,o}$	2,512	[°]	<<<<<<	Outboard dihedral angle	$\Gamma_{W,o}$	2,512	[°]	
58											
59		Edit this section									
60		Relative kink position	$\eta_{k,W}$	0,320	[-]	<<<<<<	Relative kink position	$\eta_{k,W}$	0,320	[-]	Relative kink constant
61		Inboard Leading edge Sweep	$\varphi_{LE,W,i}$	24,334	[°]	<<<<<<	Inboard Leading edge Sweep	$\varphi_{LE,W,i}$	24,334	[°]	
62		Inboard Trailing edge Sweep	$\varphi_{TE,W,i}$	0,000	[°]	<<<<<<	Inboard Trailing edge Sweep	$\varphi_{TE,W,i}$	0,000	[°]	
63		Inboard dihedral angle	$\Gamma_{W,i}$	2,512	[°]	<<<<<<	Inboard dihedral angle	$\Gamma_{W,i}$	2,512	[°]	
64											
65	5.	**Fuselage**									
66											
67		Fuselage diameter	d_F	3,950	[m]						
68		Fuselage length	L_F	35,827	[m]	<<<<<<	Fuselage length	L_F	35,827	[m]	Slenderness ratio
69		Nose length	$L_{nose,F}$	6,187	[m]	<<<<<<	Nose length	$L_{nose,F}$	6,187	[m]	
70		Cockpit length	$L_{cockpit,F}$	2,568	[m]	<<<<<<	Cockpit length	$L_{cockpit,F}$	2,568	[m]	Cockpit length constant
71		Fuselage aft length	$L_{aft,F}$	13,035	[m]	<<<<<<	Fuselage tail length	$L_{tail,F}$	13,035	[m]	Fuselage tailcone constant
72							Cylinder length	$L_{c,F}$	16,604	[m]	
73											
74	6.	**Horizontal Tail**									

OpenVSP-Connect





Summary

- OpenVSP-Connect is primarily intended as an **interface tool between ANY aircraft design tool and** Open Vehicle Sketch Pad (**openVSP**) from NASA.

- **For each parameter a proposed value is given and automatically applied as long as the user does not specify his/her own value.**

- By using all **default values**, the program works in **"automatic mode":** Ultimately, based on just three input values **"Number of passengers“, “Range” and "Cruise Mach number"** an aircraft can be sketched automatically based on passenger aircraft statistics.

OpenVSP-Connect – Visualize Your Aircraft Sizing Results with NASA's Vehicle Sketch Pad

http://OpenVSP.ProfScholz.de

EWADE 2013 Papers

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Table of Contents

PROCEEDINGS of the 4th CEAS Conference, Linköping, 2013
http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-99581

Integrated:
11th European Workshop on Aircraft Design Education
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Personal Jet
A student project

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Linköpings University, Sweden Affiliation 1, Country

Keywords: *Student project, demonstrator, aircraft design*

Abstract

The presented work considers designing, building and flight test of a demonstrator of a personal jet aircraft realized as a student project. The goal is to allow student to participate in an aircraft project from design to flight test in order to acquire aircraft design knowledge from theoretical and practical means. A first theoretical part consists of creating a sizing program for studying different concepts. Then the gathered knowledge will result in the realization of a flying demonstrator. This was realized during a student project over a 5 month period..

1 Background

Since the development of the BD5J, a kit plan, no personal jet has been available to the market. The possibilities for developing a new personal jet is studied, in order to reach a broader market an investigation on certifications regulation is performed. The project aim is to design a single seat sport jet aircraft based on a TJ100A turbine engine. To prove the design a radio controlled sub scale demonstrator will be built and flown, powered by a Funsonic FS70 jet engine.

2 Educational Challenge

Over the years there has been a dramatic reduction in ongoing aircraft projects. Today's aircraft design engineers are lucky if they will be involved in one or two complete projects during their entire careers. This is in sharp contrast to the "golden age", when an engineer was likely to be part of several projects during his career, see Table 1.

This situation creates an issue regarding the education of aircraft design engineers. When they start their professional life they will be assigned to an ongoing project and they may be involved in that for a long time before starting on a new project. The teaching approach as proposed by Linköping University is to allow future aircraft engineers to participate in a complete aircraft design project, from requirements to flight testing, as a preparation for their very first steps into industry.

The other major challenge in aerospace education is changing demands from the industry regarding the type of knowledge the yet to be engineers should be educated for. Most of university aerospace educations are focused on

Table 1 Aircraft project through an aerospace engineer's career [1]

Time Span	Aircraft projects
1950-1980	XP-5Y, A-2D, XC-120, F-4D, F-3H, B-52, A-3D, X-3, S-2F, X2, F-10F, F-2Y, F-100,B-57, F-102, R-3Y1, F-104, A-4D, B-66, F-11F, C-130, F-101, T-37, XFY, F-8U, F-6M, U-2, XY-3, F-105, X-13, C-133, F-107, B-58, F-106, F-5D, X-14, C-140, T-2, F-4, A-5, T-39, T-38, AQ-1, X-15, F-5A, X-1B...
1960-1990	A-6, SR-71, SC-4A, X-21, X-19, C-141, B-70, XC-142, F-111, A-7, OV-10, X-22, X-26B, X-5, X-24
1970-2000	F-14, S-8, YA-9, A-10, F-15, F-18, YF-17, B-1B, YC-15, YC-14, AV-8B, F/A-18
1980-2010	F-117, F-20, X-29, T-46, T-45, B-2, V-22
1990-2020	YF-22, YF-23, JSF, C-17
2000-2030	UCAV, B-3?...

developing students analytical skills and not as much to develop the synthesis capabilities nor the innovative perspective needed for aircraft design. Recent changes in educational perspective, such as the CDIO initiative[2], initiated by the Aerospace institute at MIT and tree Swedish universities, Linköping University being one among them, try to apply a more synthetical view on engineering education, by introducing small practical assignments into the regular courses. This approach is adopted in a larger scale for the aircraft design education at Linköping University, and was adopted before the creation of the CDIO initiative [2].

Nowadays team-work is increasingly important. Being able to present results and ideas in a selling manner is also an important skill, as well as to be able to convert ideas into something practical and useful. This is something which Universities seldom care much about, but that is certainly important, i.e. to bridge the cliff between the students mostly theoretical life into the more practical life in industry. One of the most important issues is to be able to gain a holistic viewpoint from the very start in working life, i.e. to possess a kind of "helicopter view" with regard to the product or project one is involved in. One way of preparing for that insight is to carry out projects like the aircraft design project at Linköping University.

3 Project Task

The project will be divided into the following phases:

- First phase: Concept generation and design competition
  - The group will be divided in teams and will compete for the best design
  - An advisory board will select 1 or 2 designs for further studies.
- Second phase: Conceptual and preliminary design
  - Further study of the selected designs
  - Sizing and performance calculations
  - CAD design
  - The advisory board will select one design for final development
- Third Phase: Detailed design and demonstrator development
  - Detailed studies of the final configuration.
  - Demonstrator development
  - Design
  - Manufacturing
  - Flight testing

3.1 Design specifications

The main characteristics are:

- Appealing design
- Good handling qualities
- Performance level similar to BD5J

Following must be included in the design of the fullscale and demonstrator must be represented in CATIA V5 R21

- Landing gear studies
  - retractable landing gear
  - steering on nose wheel
- Brakes
- Cockpit layout
  - Instrumentation and instrument panel
  - Adjustable pedals to accommodate different pilot sizes
  - all necessary information for the cockpit¨
  - Field of view for the pilot
- Mechanism for control surfaces/Flight control system
- Fuel system designed for advanced flight
- Engine installations
  - Duct design
  - Outlet design
- Emergency escape mechanism
- Electrical system Sizing for
  - Navigation light
  - ECU/engine start
  - Avionics

4 Certification and regulations

To be allowed to fly the airplane and make it profitable for production the airplane needs to be certified by competent authorities. Different certifications categories were studied, it appeared that the categories CS-VLA (Very Light Airplanes),
CS-LSA (Light Sport Airplanes) and Experimental could not be used for this project for different reasons. The CS-VLA is for non-aerobatic aircraft and the CS-LSA does not allow turbine engines, making both of these regulation categories unavailing. In addition, the experimental category is different in every country witch is not optimal for export possibilities.
The two remaining categories were CS-23 (Normal, Utility, Aerobatic, and Commuter Airplanes) [3]and FAR, another category for experimental aircraft. It was decided to use the CS-23 as certification basis for the aircraft, mainly because this category allows aerobatic and jet aircrafts and also commercial sales. Once the aircraft regulation category was decided, it was necessary to further study the associated regulation in order to extract the information needed and ensures that the aircraft is in accordance with the regulations.

5 Concept development

The conceptual phase started as a sketch exercise to present various ideas around a personal jet, examples of those sketch are illustrated in Fig. 1.

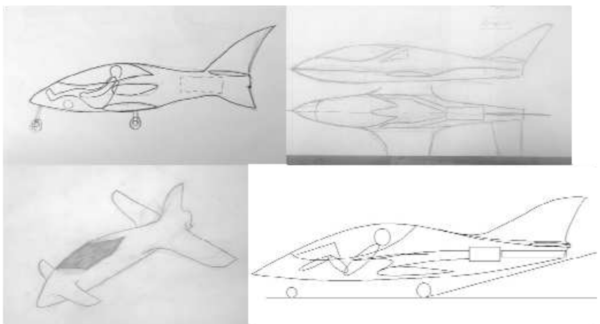
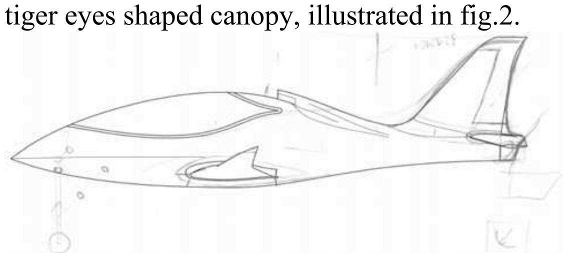


Fig. 1 Early concept sketches

Further discussion and development gave the airplanes more aggressive contours and keeping an aerodynamic shape. Inspiration from nature and animals gives a shark-shaped outlines and tiger eyes shaped canopy, illustrated in fig.2.



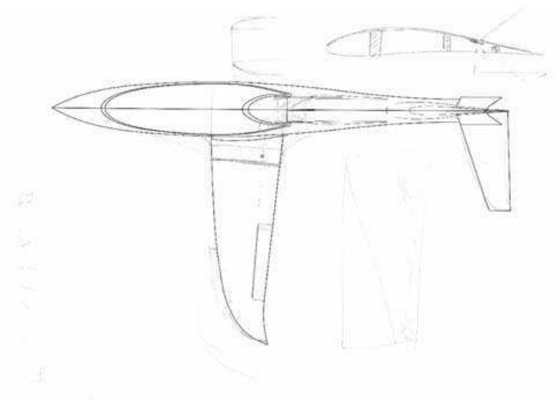


Fig. 2 Final Concept

5.1 Sizing

The sizing was performed around a given engine, the TJ100 from První brněnská strojírna Velká Bíteš. It is a single shaft, single stage radial compressor of about 20 kg's and has a static thrust of 1200N. The sizing program used is a Linköpings university in house sizing tool. The sizing tool was calibrated with the actual BD5J [4]. Weight factors were added in order to take into account composite usage instead of metal such as used in BD5J.

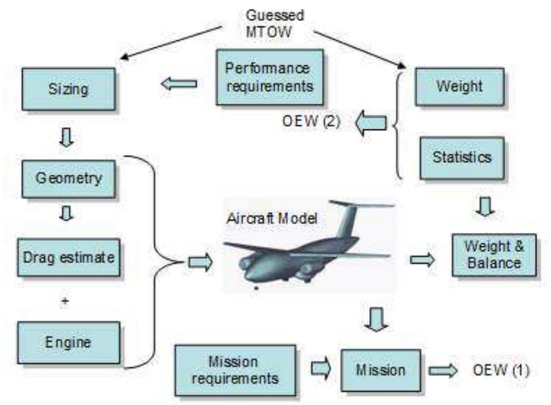
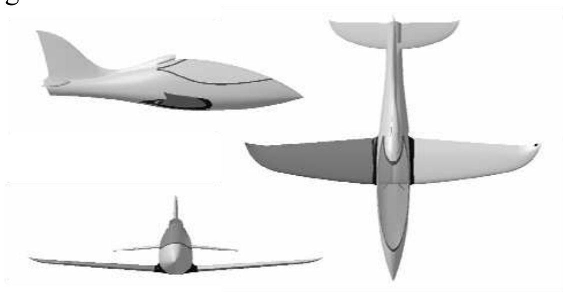


Fig. 3 sizing flow

The following characteristics were obtained from the sizing.

	MidJet	BD5J
MTOW [kg]	320	386
OEW [kg]	146	163
Vcruise [km/h]	437	386
Stall speed [km/h]	104	107
Wing loading [kg/m2]	100	137
Sref [m2]	3,2	2,8
Wing span [m]	5,2	4,36
Length [m]	4,8	3,6
Height [m]	1,46	1,68

The new design called MidJet is lighter than the original BD5J and has a lower wing loading. In order to improve handling characteristics the fuselage was stretched. The stretching of the fuselage provides a smother overall shape and gives a more modern look to it.



5.2 Engine specifications

The TJ100 is designed and manufactured by První brněnská strojírna Velká Bíteš. It is a single shaft, single stage radial compressor of about 20 kg's and has a static thrust of 1200N.

6 Preliminary design

6.1 Landing gear

A study on a retractable landing gear was performed, see Fig. 4. The landing gear has a classic nose configuration with a steerable nose wheel and hydraulic brakes on the main landing gear. The tires have a diameter of 220 mm. Retraction is performed by a mechanical system of rods and levers controlled by the force of the pilot’s hand motion. The weight distribution is 92% for the main landing gear and 8% for the nose wheel.

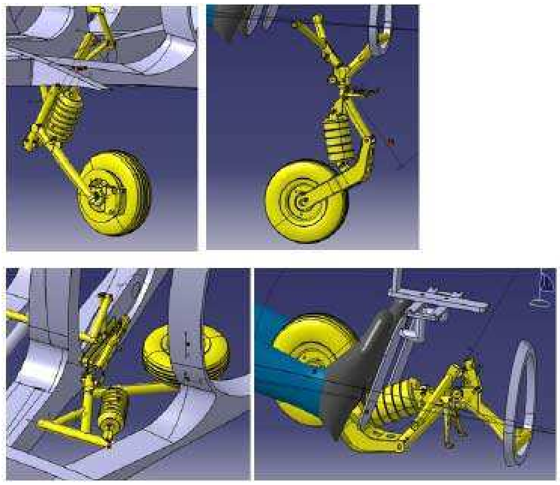


Fig. 4 Landing gear

6.2 Flight control system

In order to move the control surfaces, a linkage between the stick and pedals and the surface is required. A lot of research was done on the design of the stick. The challenge was to make a mechanism that allows the transfer a lateral and rotational movement at the same time, while being compact and robust.
The pedals are moving the rudder in the vertical tail as well as the nose wheel while it is extended.
Since the landing gear takes up a lot of space it was decided to have a lever on the stick for activating the brakes rather than toe brakes. The joint for the pedals which is usually placed underneath the pilots feet had to be repositioned to be able to fit the nose wheel.
The restrained space and rather complex routing for rods leads to a fly-by-wire system. The intention was to keep the wire as straight as possible to avoid friction between the pulleys and the wires. This was limited by the many components that had to be avoided between the stick and the control surfaces such as the fuel tank, the seat, the duct, the landing gear and the different frames.

6.3 Structure

The first thing that was considered when designing the structure was to think "composite". Then, since the fuselage and the wings are built using sandwich technique, there is neither need for stringers or longerons in the fuselage nor multiple ribs in the wings. The skin shell is stiff by itself for the fuselage but needs some reinforcements for the wings, horizontal and vertical stabilizer since they are thin parts and large bending moments are involved.

6.3.1 Fuselage design

The fuselage needed numerous frames to attach the internal components of the aircraft and this also offers more torsional stiffness (for loads that come from the vertical stabilizer), illustrated in Fig.5. The frames, regarding their location, are made with different thickness. The thin ones are used for carrying components such as engine, fuel tank or rudder pedals. Two big frames are used for the front (main) and rear spar of the wing. The main spar can then cross through the frame and therefore be very stiff. The two main frames were extended to carry the loads from the landing gear. The last spars in the rear part of the aircraft are realizing two functions: carrying the exhaust pipe and also acting as a spar for the vertical stabilizer and bring bending stiffness.

6.3.2 Wing design

Since the wing is mostly constructed from carbon fibre, there is no need for multiple ribs to support the skin. This skin links the main and rear spar and allows to form a "wing box" design and then creates something very stiff in a torsional and bending point of view. First, two ribs are needed: one at the root and one at the tip, illustrated in Fig.5. They enable to carry the hinge rod around which will swivel the flaps and ailerons. Between those two components (not on Catia) it is also required to have a hinge attached on the rear spar because of the aerodynamic forces that will tend to bend the hinge rod.
The main spar is made of two parts that are bolted together and on the frame. It was placed at the chord-wise thickest part so the web could be made as high as possible. The way of splitting the spar was to proceed with a shallow

angle (as done on some gliders) to avoid sharp corners that could generate structural problems. Therefore, the two parts bolted together that are crossing through the fuselage and allow a large bending and shear stiffness. The rear spar cannot cross the fuselage since there is the landing gear. Therefore, it is attached to a frame without going through it.

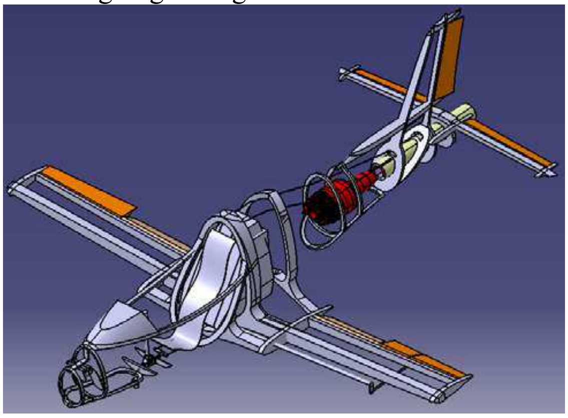


Fig. 5 Structure layout

7 Demonstrator

The scale of the demonstrator was determined by sizing down the full scaled aircraft to fit a engine (and its nozzle) that was already chosen, called FS70 made by the company Fun Sonic. The scale of the demonstrator was then set to 1:2,8. To get the center of gravity at the desired position the components had to be placed in a good way, the lightweight of the main component and the lack of "pilot" inside the demonstrator forced to use ballast in the nose in order to have a balanced aircraft.

The fuselage consists of three parts. The main and biggest part of fuselage is made out of composite sandwich with two millimeters foam core and glass fibre cloth, structure is showed in Fig.6 and molding of the fuselage is seen in Fig.7. The wings are attached wings to this part as well as the horizontal tail and the part of the inlet made out of glass fibre. On this part is glued third part of the fuselage - top part of the inlet made out of plastic on 3D-printer, see Fig.9.

Fig. 6 Structure layout of demonstrator

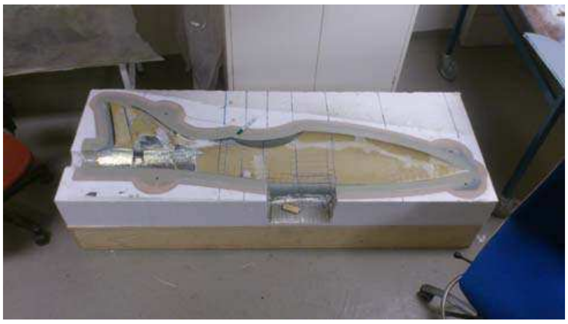


Fig. 7 Molding of the fuselage

Further stiffening of the fuselage is not required, so the structure inside is focused mainly on holding components. The front part of the structure is the frame and floor for attaching nose landing gear, batteries and extra weight for keeping center of gravity at the right place. Behind the nose landing gear there is space where regulators and remote control receiver will be attached. The wing will be attached on floor which is held by two frames from each side. The wing itself is attached to the floor by four screws. This part of the fuselage also holds the fuel tank, hopper tank and floor where the engine is attached. After the engine follows exhaust pipe that is held by four frames, where second frame is reinforced and used also as a vertical tail beam. The third frame is used to hold rudder hinges.

Fig. 8 Molding of the wing

The wing is made from composite structure and is undivided, see Fig.8. The wing attachment is done via 4 bolts, going into the fuselage wing attachment floor, made as a plywood sandwich. The bending moment is transferred by the main spar, specially by flanges of the main spar. Shear stress is transferred in the web of the main spar and finally the torsion moment is taken by the skin.

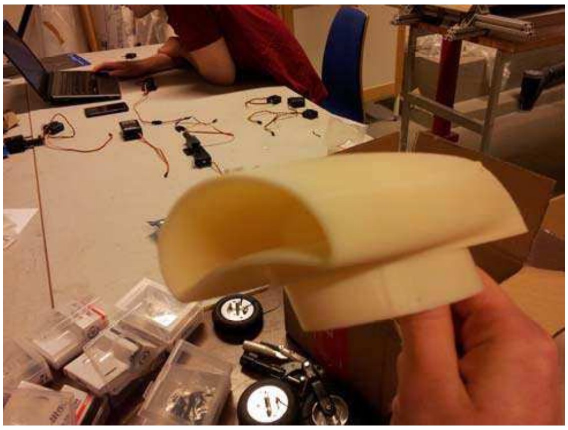
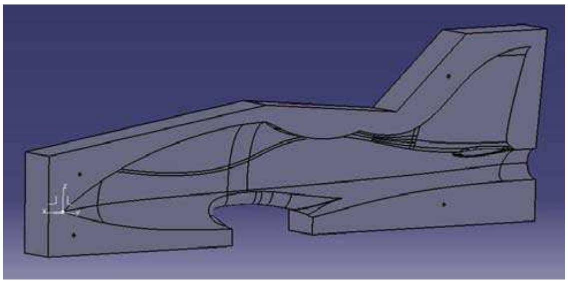


Fig. 9 3D printed inlet



8 Conclusion

Realization of a student project is a dual challenge. Education and the success of the project. The goal in this case is to give the student a broad understanding of the aeronautical challenges and the interaction between disciplines. The usage of a flight demonstrator, an advanced RC model is sufficient to allow students to acquires a sense for the challenges while applying there theoretical skills. The manufacturing phase remind the students that manufacturing is time consuming and that system installation is a large part of the finalization of aircraft project prior to flight testing. This makes this kind of project very suitable for education of broad aeronautical engineers.

Fig. 10 Artistic illustration of the MidJet

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FTF Congress: Flygteknik 2013

Open Access Publishing in Aerospace – Opportunities and Pitfalls

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Keywords: *aerospace, paper, journal, publisher, open access*

Abstract

The first Open Access (OA) peer reviewed online journals in aerospace were all established after 2007. Still today more and more OA aerospace journals get started. Many publishers are located in less developed countries. The benefits of OA publishing are undisputed in the academic community, but there is disagreement if the new publishers can work to required standards. The current situation is evaluated based on an Internet review. OA journals in aerospace are listed with their major characteristics. Well known OA publishers charge high publication fees, whereas less known OA publishers tend to charge relatively low fees. All publishers need to be carefully checked for their level of rigor in peer review and their offered service in the scholarly publication process. Authors should evaluate OA journals and publishers against provided lists of criteria before submitting their work.

1 Introduction

1.1 Objective

Intension is to explain the background and to systematically present possibilities for researchers in aerospace to have their work published on the Internet so that it can be read without access fees by anybody. Such Open Access (OA) publishing is growing at fast pace. Many models of OA exist and will be presented and discussed to enable subsequent application to OA publishing in aerospace.

Fig 1: Open Access Logos [2], [14]

1.2 Definition of Basic Terms

This contribution is about publishing an academic paper in contrast to publishing an academic books or a thesis. Several terms are defined in this context.

Open Access (OA) means "to provide the public with unrestricted, free access to scholarly research – much of which is publicly funded. Making the research publicly available to everyone – free of charge and without most copyright and licensing restrictions". [1] The Budapest Open Access Initiative [1] recommends establishing the "goal of achieving Open Access as the default method for distributing new peer-reviewed research". Open Access Initiatives are often marked with a logo as presented in Fig 1.

Publishing means "the activity of making information available" [3] and includes everything from development to distribution (e.g. in paper, online or both in parallel), including e.g. copy-editing, graphic design, production, and marketing.

Academic Publishing (of scholarly journals) is peer reviewed publishing. [4] An academic publisher has to be able to manage the peer review process and will index his journals.

Publication has two meanings [5]:
(a) *legal meaning*: anything that is made public,
(b) *scientific meaning*: only what is meeting the quality standards and acceptance for publication by a peer reviewed journal or peer reviewed proceedings. Journals will only accept submitted papers not having been published before (according to scientific meaning b).

2 Self-Archiving

Self-archiving is a possibility to make research results public on the Internet independent of a publisher. Self-archiving is sometimes also called *Green OA* and means "to deposit a digital document in a publicly accessible website" [6]. Self-archiving does not include anything else as to make the content available online. It is done for the purpose of maximizing the paper's accessibility, usage and citation impact. [7] The paper can be uploaded

- to the *website of the researcher*,
- to the *website of an organization*, or better
- to a *repository* [8].

Self-archiving is done in parallel to traditional academic publishing. A publisher with established reputation is used for providing the peer review process. The paper is made public in a print journal (with limited visibility). The author uses the possibilities granted by the rules of the publisher for self-archiving and enhanced visibility.

Possibilities for self-archiving granted by the publisher depending on **what** is allowed to go online [9]:

- *Green OA*
  - preprint (paper before the review process)
  - postprint (paper after the review process) or publisher-generated PDF file
- *Blue OA*
  - postprint (after review process) or publisher-generated PDF
- *Yellow OA*
  - preprint (before review process)
- *White OA*
  - Archiving not formally supported by the publisher.

Possibilities for self-archiving granted by the publisher depending on **when** it is allowed to go online:

- *instant self-archiving*: no time delay required
- *delayed self-archiving* (Delayed OA). Typical required elapsed times between journal publication and self-archiving are 6, 12 or even 24 month.

Repository is a systematic online collection of digital documents with "all stages of research from pre-refereed preprint, through successive revisions, till the refereed postprint" [10] and if (in rare cases) allowed for upload also with publisher-generated PDF files.

Eprints are either preprints or postprints.

3 OA Conference Publications

An Open Access conference publication is a publication based on a conference presentation or poster. The conference offers

- a peer-review process for the papers and
- to publish the papers online after the conference without access restrictions.

One example of such a conference in aerospace is the "Congress of the International Council of the Aeronautical Sciences" (ICAS) [11] offering paper review and uploading. However, most aerospace conferences seem not to fulfill both criteria. In that case, it is possible to go to a suitable journal after the conference for publication. The journal (OA journal or classic journal) will accept the proposed paper, because – so far without a review process or without wider dissemination – the paper is not considered a scientific publication yet. Conference publications are not further considered here.

4 Business Models

Business models have been established for OA and for traditional journals and their publishers:

- **OA journals** [12], [13], [2]:
  - *subsidized* (paid by: academic institution or learned society; eventual in most cases by the government)
  - *authors charged* (paid by: authors or their funding agencies; eventual in most cases by the government)
  - *institutional membership* (institutions pay a flat rate for a certain volume of publications of their members)
  - *advertisement on website*
- **Traditional journals**:
  - *subscription-based* (paid by libraries, eventual by the government)
  - *pay per view* (paid by readers for download of a single paper)
  - *Hybrid OA* (paid by author for the benefit that readers do not need to pay per view for his/her paper)
  - *advertisement in journal.*

OA and traditional journals tend to combine some or all of the listed options in their category to maximize revenues.

OA means **free access for the reader** to the papers, but the authors may need to pay instead. The subsequent classification looks at different **author payment models** depending also on the amount of delay (embargo) requested by the publisher [14]:

- Free OA (no payments by authors)
- Gold OA (*moderate payments* by authors)
- Hybrid OA (often *expensive payments* by authors)
- Delayed OA (embargo period, often no payments by authors)

Moderate payments: normally around 1000 €, but vary from 500 € to 2500 €.
Expensive payments: around 3000 $.
Linköping University says: "Virtually all the major subscription-based publishers offer a scheme whereby you can pay them $3000 (or thereabout) to make your article freely available in their otherwise subscription-based operation. As an author, you often receive an offer for this service just after your paper has been accepted for publication. We strongly do not recommend this option." [15]

5 Open Access Spectrum

The Open Access Spectrum [16] has been defined by the organizations SPARC [17], PLOS [18] and OASPA [19] to answer the question "How open is it?" (see logo in Fig. 3 and definitions in Fig 4). Together they point out: "Open Access is a means of disseminating scholarly research that breaks from the traditional subscription model of academic publishing. It has the potential to greatly accelerate the pace of scientific discovery, encourage innovation, and enrich education by reducing barriers to access. Open Access shifts the costs of publishing so that readers, practitioners, and researchers obtain content at no cost. However, Open Access is not as simple as 'articles are free to all readers'. Open Access encompasses a range of components such as readership, reuse, copyright, posting, and machine readability. Within these areas, publishers and funding agencies have adopted many different policies, some of which are more open and some less open. In general, the more a journal's policies codify immediate availability and reuse with as few restrictions as possible, the more open it is. Journals can be more open or less open, but their degree of openness is intrinsically independent from their: Impact, prestige, quality of peer review, peer review methodology, sustainability, effect on tenure & promotion, article quality."

The Open Access Spectrum embraces six core components with their most open characteristics they are:

1. *Reader Rights*: Free readership rights to all articles immediately upon publication.
2. *Reuse Rights*: Creative Commons License CC BY (see Chapter 6).
3. *Copyrights*: Author holds copyright with no restrictions.
4. *Author Posting Rights*: Author may post any version to any repository or website.
5. *Automatic Posting*: Journals make articles automatically available in trusted third-party repositories (e.g. PubMed Central) immediate upon publication.

6. *Machine Readability*: Article full text, metadata, citations & data, including supplementary data, provided in community machine readable standard formats through a community standard API or protocol.

The first of these six open access components is at the heart of OA, but also the second component "reuse rights" is heavily demanded already in form of "CC BY".

6 Creative Commons License CC BY

Creative Commons [20] – in short CC – has evolved as the accepted free provider of reuse right licenses. The most liberal reuse license is CC BY (except from CC0). CC BY [21] stands for

"You are free:

- to Share – to copy, distribute and transmit the work,
- to Remix – to adapt the work,
- to make commercial use of the work.

Under the following conditions:

- Attribution – You must attribute the work in the manner specified by the author or licensor (but not in any way that suggests that they endorse you or your use of the work)"

Its logo is given in Fig 2.

Fig 2: Creative Commons CC BY logos [22]

Research funders like RCUK [23] demand CC BY. If they have paid the research, they should have the right to dictate that everyone should ultimately benefit from it. Organizations of librarian like SPARC-Europe [24] strongly support CC BY. They have an interest to foster the widest possible information exchange. The Directory of Open Access Journals (DOAJ) [25] inspires the use [26]. Objection could come from those authors who have written their paper in their own time and have paid publication fees from their own pocket and do not want to see others to commercially exploit their work. Creative Commons offers for them e.g. CC BY-NC [27] and CC BY-NC-SA [28], but these licenses are not considered a "Free Culture License".

7 Current Debate

Without doubt, a paradigm shift in the business model of academic publishing (see Chapter 4) got started in the US [29], in Europe [30] and beyond. That ultimately means that not all of the traditional publishers may survive, if they can not quickly enough adapt. On the other hand the "gold rush" in starting new OA journals has not always brought quality. Sound and established processes have yet to be found by the newcomers. Repositories are increasing at a rapid rate [8]. For this reason at the heart of the debate [31], [32] is the fear of traditional publishers to loose market share and profit.

The open access newcomers are under heavy observation. Two possibilities exist:

- **To black-list** journals and publishers who do not perform up to established standards. "Beall's List of Predatory Publishers 2013" [33] is the current prominent blacklist with 242 OA publishers and 126 OA journals listed. A less prominent black list is [34] with only 7 OA journals listed (but also linking to [33]).
- **To white-list** journals and publishers who have undergone a minimum check by a respected organization and are listed with this organization. If an open access journal or publisher is listed in the Directory of Open Access Journals (DOAJ) [25] it is a first good sign. DOAJ lists currently almost 10000 OA journals. If the publisher is listed as a member of Open Access Scholarly Publishers Association (OASPA) [19] it has undergone an even more detailed check. OASPA lists currently (only) about 40 OA professional publishing organizations.

8 Pros and Cons of Blacklisting versus Whitelisting Publishers and Journals

The pros and cons of blacklisting and whitelisting have been discussed in [35].

"Beall says ... he is sceptical about whether a white list would be able to keep up with the surge of new publishers, and believes that his blacklist provides more immediate warning" [35].

" 'One of the major weaknesses of Jeffrey Beall's methodology is that he does not typically engage in direct communication with the journals that he has classified as predatory,' says Paul Peters, chief strategy officer at Hindawi Publishing Corporation, based in Cairo, and president of the Open Access Scholarly Publishers Association (OASPA), based in The Hague, the Netherlands. A set of Hindawi's journals appeared on a version of Beall's list because he had concerns about their editorial process, but has since been removed. 'I reanalysed it and determined that it did not belong on the list,' he [Beall] says." [35]

" 'Some [publishers] are embarrassingly ... amateurish, but predatory is a term that, I think, implies intent to deceive,' says Jan Velterop, a former science publisher at Nature Publishing Group" "Damage could be done if 'a damning verdict is given to otherwise honest, though perhaps amateurish, attempts to enter the publishing market', he says." [35]

"Publishers in developing countries and emerging economies are at particular risk of being unfairly tarred by Beall's brush, critics say. Many open-access publishers are springing up in India and China, for example, where swelling researcher ranks are creating large publishing markets." [35]

" 'It is important that criteria for evaluating publishers and journals do not discriminate [against] publishers and journals from other parts of the world,' says Lars Bjørnshauge, managing director of the Directory of Open Access Journals (DOAJ), based in Copenhagen, which lists open-access journals that have been reviewed for quality. 'New publishing outfits may legitimately use aggressive marketing tactics to recruit authors, and they may have yet to polish their websites, editorial boards and peer-review procedures.' " [35]

"Bjørnshauge feels that the entire problem needs to be kept in perspective. He estimates that questionable publishing probably accounts for fewer than 1 % of all author-pays, open-access papers – a proportion far lower than Beall's estimate of 5 ... 10 %. Instead of relying on blacklists, Bjørnshauge argues, open-access associations such as the DOAJ and the OASPA should adopt more responsibility for policing publishers. He says that they should lay out a set of criteria that publishers and journals must comply with to win a place on a 'white list' indicating that they are trustworthy." [35]

9 Criteria for OA Publishers and Journals

9.1 Criteria of the Directory of Open Access Journals (DOAJ)

To be (white) listed as journal on DOAJ, criteria as follows have to be met [25] (summary):

- Open Access Journal: We define open access journals as journals that use a funding model that does not charge readers or their institutions for access. From the BOAI definition of "open access", we support the rights of users to "read, download, copy, distribute, print, search, or link to the full texts of these articles" as mandatory for a journal to be included in the directory.
- Registration: Free user registration online is acceptable.
- Open Access without delay (e.g. no embargo period).
- Research Journal: Journals that report primary results of research or overviews of research results to a scholarly community.
- Periodical: A serial appearing, or intending to appear, indefinitely at regular intervals and generally more frequently than annually, each issue of which is numbered or dated consecutively and normally contains separate articles, stories, or other writings. The journal should have an ISSN (International Standard Serial Number). Online journals should have an eISSN.
- Content: a substantive part of the journal should consist of research papers. All content should be available in full text.
- Quality: For a journal to be included it should exercise quality control on submitted papers through an editor, editorial board and/or a peer-review system. Describe the process on the web site.
- Metadata: Journal owners are encouraged to supply article metadata.

- Necessary information: The journal's aims and scope, presentation of the editorial board, author guidelines, description of the quality control system and information about Open Access, information about the specific journal should be available on its own URL.
- Commercials: If for financial reasons it is necessary to have commercials on the journal's web site make sure the commercial is not in any way offensive or includes information that could decrease the credibility of the journal. Please note that blinking and/or moving objects can distract a reader.
- Transparency: Be as transparent as possible when presenting your editorial board. Provide:
  - a contact address for the journal,
  - the affiliation of the editorial board members,
  - the contact addresses to the editorial board members,
  - add a link to the web site where the specific editorial board member is presented by his or her employing institution.
- Author guidelines: Provide
  - information on journal charges, handling fees, publication fees with the amount clearly stated,
  - a CC-license for the journal papers; the SPARC Europe Seal is given for a journal with CC BY and provision of metadata,
  - information about copyright – please note the importance of informing authors about whether the journal will be the copyright holder after publication of an article or if the copyright remains with the author(s),
  - description of how to submit an article,
  - a detailed style guide.

9.2 Criteria of the Open Access Scholarly Publishers Association (OASPA)

To be (white) listed as publisher with the OASPA, criteria as follows have to be met [19] (summary):

- The publisher's website demonstrates that care has been taken to ensure high standards of presentation.
- Published articles can be read without the requirement for registration of any kind.
- Full contact information is visible on the website and includes a business address.
- Clear and detailed Instructions for Authors are present and easily located from the homepage. The guidelines include details of the Open Access policy for this publication.
- All articles shall be subjected to some form of peer-based review process. This process and policies related to peer-review shall be clearly outlined on the journal or publisher web site.
- Journals shall have editorial boards or other governing bodies of sufficient size to support the journal, whose members are recognized experts in the field(s) that constitute the scope of the publication.
- Any fees for publishing in the journal are clearly displayed. If there are no charges to authors this should also be highlighted.
- The journal website and published articles, including PDF, should clearly show the licensing policy of the journal. Ideally, the policy should be equivalent to CC BY (also CC BY-NC is acceptable).
- The publisher should not indulge in any practices or activities that could bring the Association or open access publishing into disrepute.
- Any direct marketing activities publishers engage in shall be appropriate and unobtrusive.
- Where appropriate, OASPA will request information about the legal status of the publishing organization, for example, whether it is a privately-owned or public company, a not-for-profit organization or a charity. OASPA will request company registration information.
- Demonstration of the following is also desirable: A&I services that index the journal(s), availability of DOIs for published content, COPE membership [36] and archiving policy.

9.3 Criteria of LiU Electronic Press for Evaluating a Journal

Before publishing it is important to determine whether a journal is serious or not writes Linköpings University Electronic Press [37]. It is important to check if a publication in the journal under investigation "counts" in an academic evaluation exercise in the author's home country. This includes checking the journal being appropriately indexed. The following criteria are worth checking in addition:

- Is the publisher a member of OASPA?
- Is the journal listed in the Director of Open Access Journals (DOAJ)?
- Who is on the editorial committee?
- Who produces the journal?
- Do they give clear contact information?
- Is there a clear and detailed description of the peer-review process?
- Is there regular publishing of articles, no periods of inactivity?
- Are articles found by Google, when searching by using their full titles?
- Is transfer of copyright required? (Should not be required)
- Is the right to parallel publishing (preferably with an embargo period of 6 months or less) retained? (Should be retained)
- Are DOIs (Digital Object Identifier) assigned to all articles?
- Do well established authors in the field publish in the journal?

Also [35] includes “A checklist to identify reputable publishers” which however does not give new criteria compared to the criteria listed so far. Also [35] sees DOAJ and OASPA as the two organizations that check OA journals respectively OA publishers.

9.4 Criteria to Put a Publisher on Beall's Black List

There are many things a publisher can do wrong. Accordingly, Beall's “Criteria for Determining Predatory Open-Access Publishers” [38] is quite long and will not be reproduced here in full. Some (interesting) criteria not mentioned before are selected to illustrate the pitfalls that publishers and authors should watch out for:

1. The publisher depends on author fees as the sole and only means of operation with no alternative, long-term business plan for sustaining the journal through augmented income sources.
2. The publisher provides insufficient information or hides information about author fees, offering to publish an author's paper and later sending a previously-undisclosed invoice.
3. The publisher sends spam requests for peer reviews to scholars unqualified to review submitted manuscripts.
4. The publisher dedicates insufficient resources to preventing and eliminating author misconduct, to the extent that the journal or journals suffer from repeated cases of plagiarism, self-plagiarism, image manipulation, and the like.
5. The publisher asks the corresponding author for suggested reviewers and the publisher subsequently uses the suggested reviewers without sufficiently vetting their qualifications or authenticity.
6. Operate in a Western country chiefly for the purpose of functioning as a vanity press for scholars in a developing country.
7. Do minimal or no copyediting.
8. Have a “contact us” page that only includes a web form, and the publisher hides or does not reveal its location.

“The following practices are considered to be reflective of poor journal standards ..., while they do not equal predatory criteria” [38]:

9. The publisher copies “authors guidelines” verbatim (or with minor editing) from other publishers.
10. The publisher lists insufficient contact information, including contact information that does not clearly state the headquarters location or misrepresents the headquarters location (e.g., through the use of addresses that are actually mail drops).
11. The publisher publishes journals that are excessively broad (e.g., Journal of Education) in order to attract more articles and gain more revenue from author fees.

12. The publisher requires transfer of copyright and retains copyright on journal content. Or the publisher requires the copyright transfer upon submission of manuscript.
13. The publisher has poorly maintained websites, including dead links, prominent misspellings and grammatical errors on the website.
14. The publisher engages in excessive use of spam email to solicit manuscripts or editorial board memberships.
15. The publishers' officers use email addresses that end in .gmail.com, yahoo.com some other free email supplier.
16. The publisher includes links to legitimate conferences and associations on its main website, as if to borrow from other organizations' legitimacy, and emblazon the new publisher with the others' legacy value.
17. The publisher displays prominent statements that promise rapid publication and/or unusually quick peer review.
18. The publisher uses text on the publisher's main page that describes the open access movement and then foists the publisher as if the publisher is active in fulfilling the movement's values and goals.
19. None of the members of a particular journal's editorial board have ever published an article in the journal.

These criteria should suffice to illustrate how publishers can fall in traps and should give an overview of how badly some publishers are organized apparently. However, it seems not clear how to apply some criteria in practice to black-list publishers:

1. Every publisher with a business model base only on author fees is black-listed? How to obtain the business plan from the publisher?
6. To distinguish between "Western country" and "developing country" is imprecise. What about Japan? The term "vanity press" seems to be used in a subjective way. Possible questions for a distinction could be based on: Is vanity press "self-publishing" in contrast to "self-archiving"? [5] Is vanity press defined as "without peer-review"? [10] Is vanity press based on "correlation between publishers' quality standards and the fees charge"? Will positive or negative correlation cause black-listing? [39]
7. Business models can vary, including extensive copyediting in the publication fee, charging for copyediting in addition, handing over this task to another company specialized it this field. Hence more details need to be included in a verdict on this point.
11. To establish broad-spectrum journals seems to be common accepted practice. PLOS ONE's publication criteria state "We welcome submissions in any discipline" [40]. Similarly, SAGE Open spans "the full extent of the social and behavioral sciences and the humanities" [41].
14. It is not defined what "spam emails" are. Commercial electronic mail messages are legal e.g. in the USA according to the CAN-SPAM Act of 2003 [42] if they observe unsubscribe, content and sending behavior compliance.
16. What may be allowed for a "white" publisher seems not to be allowed for a "black" publisher. A more precise statement would be: Including links to other organizations should (preferably) require that these organizations also link back to the publisher.
17. Ok, but some traditional publishers should be blamed for dragging on publication in a way that should not be tolerated.
18. Here the evaluation will be subjective.

Some criteria may show a "Western" bias:

10. A publisher showing its (say) Indian origin will be blamed for being Indian. An Indian publisher trying to hide its origin will be blamed for not being transparent. This is a catch-22.
12. Grammar and spelling: Only English language journals seem to be investigated. Journals published by employees with English not a native language are treated like journals published by native English employees. However, journals publishing in a language other than English do not run the danger of being blacklisted, they are not even considered.

15. This may be normal in "developing countries".

These *remarks do not attempt to be a full criticism* of [38], but may show how problematic it is to come to a verdict. It may be asked, if [38] has been applied only to publishers already in focus to produce Bell's list [33]. *Applying [38] also to established publishers* may reveal more candidates for the list. Applying [38] to Springer's "European Transport Research Review" would probably reveal "predatory behavior" according to criteria 2 (fees, see below). Yet Springer is not listed in [33]. The journal writes: "Manuscripts that are accepted for publication will be checked by our copyeditors for spelling and formal style. This may not be sufficient if English is not your native language and substantial editing would be required." [43] The journal links to an external service which is charging extra. Is this "predatory behavior" according to criteria 7 (minimal or no copyediting)?

After all, it is not made public how many and which of the criteria a black-listed publisher was found guilt of.

10 Review of Open Access Aerospace Journals

Listed are primarily journals that are only dedicated to aerospace. Given is the journal name and with web link to the journal. The publisher's origin is given according to the web page information and from the registration of the domain name. If the domain name information is hidden this is indicated ("hidden"). White or black listings are indicated of the publisher. If the publisher and the journal is listed on DOAJ three numbers are given (number of journals listed / number of articles listed / number of articles of the aerospace journal listed). If only one journal exists two numbers are given. Information is provided, if ISSNs are assigned for the journal, if DOIs are assigned to articles of the publisher, in which format the articles are presented, reuse and copyright details according to the publisher's information. Listed is further how many articles have been published in the journal and in how many databases the journal is indexed. Since all these journals are quite new, none has an impact factor. A subjective indication is given about the web page appearance with regards to clear design, structure and necessary information for an OA journal (according to Chapter 9).

International Journal of Aerospace Engineering
Hindawi Publishing Corporation
http://www.hindawi.com/journals/ijae
Origin: Egypt
Started: 2008
Fees: 600 USD
Publisher and journal white-listed:
DOAJ (SPARC Europe Seal) (405/73000/79), OASPA
Publisher black-listed: none
ISSN, eISSN, DOI, PDF, HTML, CC BY, copyright ret.
Articles: 84 (≈ 14 per year)
Indexed in databases/resources: 28
Editor-in-Chief: none
Members on Editorial Board: 75
Reviewers acknowledged: 340
Web page appearance: good

Open Aerospace Engineering Journal
Bentham open
http://www.benthamscience.com/open/toaej
Origin: USA / United Arab Emirates, ... / hidden
Started: 2010
Fees: 250 USD
White-listed: DOAJ (106/139/0)
Black-listed: Beall (no comments given),
Linköpings Universitet
ISSN, PDF, CC BY-NC, copyright retained
Articles: 20 (≈ 3 per year)
Editor-in-Chief: Dan Mateescu, Canada
Members on Editorial Board: 84
Web page appearance: "less convincing"

Journal of Aeronautics & Aerospace Engineering
OMICS Group
http://www.omicsgroup.org/journals/jaaehome.php
Origin: USA / India
Started: 2012
Fees: 919 USD
White-listed: DOAJ (1/207/0)
Black-listed: Beall (no comments given),
Linköpings Universitet
ISSN, HTML, PDF, Audio, CC BY, copyright retained
Articles: 21 (≈ 10 per year)
Indexed in databases/resources: 4
Editor-in-Chief: Prof. Raffaele Savino, Italy
Members on Editorial Board: 47
Web page appearance: "less convincing"

Frontiers in Aerospace Engineering (FAE)
Science and Engineering Publishing Company
Journal: http://www.fae-journal.org
Publisher: http://www.seipub.org
USA / China
Started: 2012
Fees: 0 USD (in 2013)
Publisher white-listed: none
Publisher black-listed: Beall (comments outdated)
ISSN, eISSN, PDF, CC BY-NC-ND, copyright ret.
Articles: 22 (≈ 22 per year)
Indexed in databases/resources: 15
Editor-in-Chief: Prof. Pizhong Qiao
Members on Editorial Board: 10
Web page appearance: good

Advances in Aerospace Science and Technology (AAST)
Scientific Research Publishing
http://www.scirp.org/journal/aast
USA (registration) / China (offices)
Started: 2013, Fees: 300 USD
Publisher white-listed:
DOAJ (127/19000/0), application: OASPA
Publisher black-listed: Beall (no comments given)
CC BY or CC BY-NC, copyright retained
Editor-in-Chief: Prof. Dieter Scholz, Germany
Members on Editorial Board: 10
STARTUP!

American Journal of Aerospace Engineering
Science Publishing Group (SciencePG)
http://www.sciencepublishinggroup.com/journal/news.aspx?journalid=309
Origin: USA / hidden
Started: 2012
Fees: 170 USD
White-listed: none
Black-listed: Beall (no comments given)
Editor-in-Chief: none
Members on Editorial Board: none
Web page appearance: good
STARTUP!

Journal of Aeronautical Engineering (JAeE)
Trans Stellar Journal Publication Research Consultancy
http://tjprc.org/journals.php?jtype=1&id=2
India
White-listed: none
Black-listed: Beall (no comments given)
STARTUP!

Not considered in full detail, because the scientific field is broader than "aerospace":

International Journal of Research in Aeronautical and Mechanical Engineering (IJRAME)
IJRAME Aero Team, Hyderabad
http://www.ijrame.com
(http://www.mlrinstitutions.ac.in/aeronautical-engineering.html)?
Origin: India / hidden
Started: 2013
Fees: 50 USD
Publisher white-listed:
DOAJ (SPARC Europe Seal) (1/17)
Publisher black-listed: none
eISSN, PDF, CC BY, copyright transferred
Articles: 17 (≈ 17 per year)
Editor-in-Chief: Mr. Mohammad Salahuddin (student?)
Members on Editorial Board: 2
Reviewers acknowledged: 8
Web page appearance: simple but ok

Journal of Mechanical, Aerospace and Industrial Engineering
Publisher: Scientific Journals International (SJI)
http://www.scientificjournals.org/Journals2011/j_of_mechanical1.htm
Origin: USA / hidden
Started: 2011
White-listed: none
Black-listed: Beall (no comments given),
Linköpings Universitet
Articles: 1 (≈ 1/2 per year)
Web page appearance: very confusing, little information

International Journal of Mechanical and Aerospace Engineering
World Academy of Science, Engineering and Technology
http://www.waset.org/journals/ijmae
Origin: USA / hidden
Started: 2012
White-listed: none
Black-listed: Beall (no comments given)
Articles: 79 (≈ 79 per year)
Web page appearance: very dubious, little information

On DOAJ there are also aerospace journals listed that are published by their own institution – probably more for own purposes then for international authors. All three journals do not charge fees, because they are sponsored by their founding institution (but note the Springer journal!):

INCAS Bulletin
National Institute for Aerospace Research (INCAS)
http://bulletin.incas.ro
Origin: Romania
Started: 2009
Fees: 0 USD (according to DOAJ), no information given on web page, response to email: **no fee**, international authors welcome
Publisher white-listed: DOAJ (1/277)

Journal of Aerospace Technology and Management
Institute of Aeronautics and Space
http://www.jatm.com.br
Origin: Brazil
Started: 2009
Fees: 0 USD (according to DOAJ), no information given on web page, not further checked
Publisher white-listed: DOAJ (1/97)

European Transport Research Review
Springer
http://www.springer.com/engineering/civil+engineering/journal/12544
for the
European Conference of Transport Research Institutes (ECTRI)
http://www.ectri.org
Origin: Germany
Started: 2009
Articles: 110 (≈ 28 per year)
Fees: 0 USD (according to – information delivered to – DOAJ), no information given on web page, response to email: **1250 EUR** (if not sponsored by ECTRI)
Publisher white-listed: DOAJ (1/0)

11 Conclusions

It makes sense for everyone that **OA is the way for the future** and to let everyone participate from the common knowledge. As long as the traditional publishers with their subscription-based business model dominate and control the market only **Green OA and self-archiving is possible**. **This however is not a final solution**. The rate with which self-archiving is done is only 20 % on a world average [45]. With full implementation of OA the rate would be 100 %.

Commercial OA Journals obviously **need to charge publication fees in some form** to be viable as an enterprise. Low cost publishing can be performed better in countries with low labor rates (Egypt, China, India), but errors occur caused by lack of experience of startup companies. Undoubtedly there are various difficulties in these countries to overcome, and off course financial pressure exists in these companies as in companies of other countries.

The *International Journal of Aerospace Engineering* by Hindawi Publishing Corporation is fully white-listed and not black-listed. No other commercial OA journal is without blemish. The startup standalone journal International Journal of Research in Aeronautical and Mechanical Engineering (IJRAME) from Hyderabad, India seems to be lucky not to have been spotted by any watchdog, but needs still to mature. Institutes working on limited public funding may not be capable of handling large numbers of manuscripts for free in the long run flowing in from all over the world.

To develop a journal that gets accepted and earns a reputation over time it seems to be advisable to meet all quality and publication standards and display them on the journals website in a way that the statements can be proven by the reader. Get the journal listed in DOAJ [25] with SPARC Europe Seal [24], [26] and in Sherpa RoMEO [46]. Publishers should become a member of OASPA [19] and COPE [36] following COPE guidelines and flowcharts. Editors should become members of e.g. the Council of Science Editors (CSE) [47] or the European Association of Science Editors (EASE) [48] and should follow their recommended and other accepted standards preferably the ISO [49] standards that should find world wide acceptance.

Beall's statement "... we recommend that researchers, scientists, and academics avoid doing business with these publishers and journals. Scholars should avoid sending article submissions to them, serving on their editorial boards or reviewing papers for them" **can be seen as libel** without prove (prove seems missing), can have immense consequences for the companies and can destroy them. This is probably what Beall intends. I can think of **two different approaches**:

1. Instead of seeking to have a few major commercial OA aerospace journals in the world, many organizations (universities, research establishments, societies) could handle smaller OA aerospace journals (like the INCAS Bulletin) based on basic and simple HTML or based on the Open Journal Systems (OJS), a journal management and publishing system serving more than 14000 journals around the world [50]. In this way fees could be kept low.
2. In the same way as companies like e.g. Airbus are cooperating with China [51], editors-in-chief can get active and can build quality into existing or startup journals from such countries. Publishers seem to have their

doors wide open for such co-operation and volunteer work. Also in this way fees could be kept relatively low.
Let every nation bring in their strength.

Let's not destroy, but rather let's work together in this world, share our knowledge and let's live in peace!

Fig 3: Logo of the Open Access Spectrum [16]

Access	Reader Rights	Reuse Rights	Copyrights	Author Posting Rights	Automatic Posting	Machine Readability	Access
OPEN ACCESS	Free readership rights to all articles immediately upon publication	Generous reuse & remixing rights (e.g., CC BY license)	Author holds copyright with no restrictions	Author may post any version to any repository or website	Journals make copies of articles automatically available in trusted third-party repositories (e.g., PubMed Central) immediately upon publication	Article full text, metadata, citations, & data, including supplementary data, provided in community machine-readable standard formats through a community standard API or protocol	OPEN ACCESS
	Free readership rights to all articles after an embargo of no more than 6 months	Reuse, remixing, & further building upon the work subject to certain restrictions & conditions (e.g., CC BY-NC & CC BY-SA licenses)	Author holds copyright, with some restrictions on author reuse of published version	Author may post final version of the peer-reviewed manuscript ("postprint") to any repository or website	Journals make copies of articles automatically available in trusted third-party repositories (e.g., PubMed Central) within 6 months	Article full text, metadata, citations, & data, including supplementary data, may be crawled or accessed through a community standard API or protocol	
	Free readership rights to all articles after an embargo greater than 6 months	Reuse (no remixing or further building upon the work) subject to certain restrictions and conditions (e.g., CC BY-ND license)	Publisher holds copyright, with some allowances for author and reader reuse of published version	Author may post final version of the peer-reviewed manuscript ("postprint") to certain repositories or websites	Journals make copies of articles automatically available in trusted third-party repositories (e.g., PubMed Central) within 12 months	Article full text, metadata, & citations may be crawled or accessed without special permission or registration	
	Free and immediate readership rights to some, but not all, articles (including "hybrid" models)	—	Publisher holds copyright, with some allowances for author reuse of published version	Author may post submitted version/draft of final work ("preprint") to certain repositories or websites	—	Article full text, metadata, & citations may be crawled or accessed with permission	
CLOSED ACCESS	Subscription, membership, pay-per-view, or other fees required to read all articles	No reuse rights beyond fair use/ limitations & exceptions to copyright (all rights reserved copyright) to read	Publisher holds copyright, with no author reuse of published version beyond fair use	Author may not deposit any versions to repositories or websites	No automatic posting in third-party repositories	Article full text & metadata not available in machine-readable format	CLOSED ACCESS

Fig 4: The Open Access Spectrum – A systematic way of showing the openness of a journal [16]

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[15] Linköpings Universitet: "Open Access", 2013-06-24. – URL: http://www.ep.liu.se/openaccess/
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Feasibility study of a nuclear powered blended wing body aircraft for the Cruiser/Feeder concept

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Keywords: *Cruiser/Feeder, blended wing body, nuclear propulsion, in-flight passenger exchange*

Abstract

This paper describes the conceptual study of a nuclear powered blended wing body aircraft for the cruiser/feeder concept. According to this radically new aviation paradigm, large transport aircraft (cruisers) carry passengers over long distances, while remaining airborne for very long periods. Smaller aircraft (feeders) take off from local airports, intercept the cruiser, dock and enable in-flight exchange of passengers and supplies. Preliminary studies indicated that cruiser concepts based on engines burning kerosene would be too heavy and feeders would need to operate also as tankers. Propelling the cruiser with a nuclear power source would yield very high efficiency parameters, even if the weight of the system would result higher due to the required reactor shielding. The blended wing body configuration was selected both for its potential advantages in terms of aerodynamic and structural efficiency, as well as for the use flexibility of its internal volume, necessary to integrate power plants and shielding, accommodate 1000 passengers and host the loading/unloading station for in-flight payload exchange. The daring nature of the proposed solution is compatible to the foreseen entry into service date, which is set for the last part of this century. The peculiar nature of the aircraft under consideration has required a somehow different conceptual design approach, than generally used for conventional passenger transport aircraft. Apart from the inherent complexity related to the design of such a novel and integrated configuration as a blended wing body, the typical design approach based on the use of simple performance equations and statistics to achieve a first estimation of the main weight contributors was of little use in this case. From one side, the fuel mass used to perform the mission is just negligible; from the other, a method was necessary to account for the weight of the radiation shielding, which is a significant contribution to the overall aircraft weight. Rather than in the numerical results of the sizing process, the value of the design work described in this paper should be found in the very design approach and the preliminary ideas for integrating the passenger docking system and the nuclear power plant.

1 Cruiser/feeder Operations and Cruiser Top Level Requirements

The cruiser/feeder operational concept is currently investigated within the FP7 research project RECREATE (REsearch on a CRuiser Enabled Air Transport Environment) as a designed to account for the big dimensions of these aircraft, as well as for the safety requirements associated to the presence of the nuclear power plants. When flying at cruise

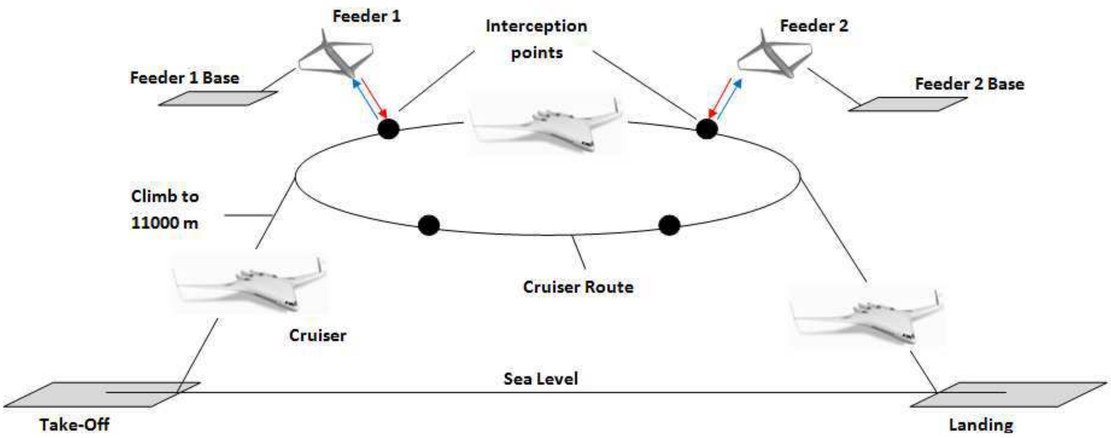

Figure 2: the cruiser/feeder operational concept

promising pioneering idea for the air transport of the future. One of the objectives of this project is to assess, on a conceptual design level, the feasibility of the cruiser/feeder operations as a potential solution to reduce fuel burn and CO_2 emission levels [1]. The operational concept is schematically illustrated in Figure 2. The cruisers take off from dedicated airfields specifically altitude, the cruiser is supposed to follow a closed loop trajectory, mainly located upon oceans or un-inhabited regions. While cruising, the cruiser is intercepted at various locations by feeders, which dock and allow the exchange of passengers, crew members, goods and waste. Thanks to the nuclear power plant, the cruiser can achieve such high levels of endurance, that in

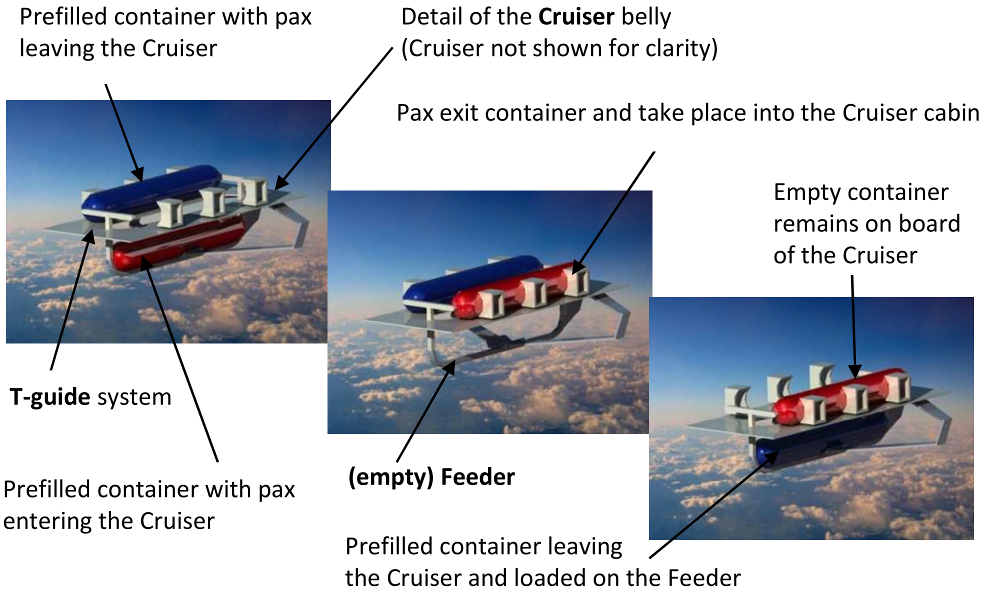

Figure 1: in flight docking and payload exchange concept

practice, the need to land is limited to the need of extraordinary maintenance, which cannot take place on board during flight, or in case of emergency.

At the moment of writing, a box wing type of configuration is considered for the role of feeder, due to its good take off and landing performance and the possibility to have direct lift control, thanks to movable surfaces that can be installed both on the front and back wings. Besides these features, the closed wing system appears a suitable structural solution to enable the detachment of the prefilled pressurized containers, which are the envisioned means to transfer payload to and from the cruiser.

The proposed docking and payload exchange approach is schematically illustrated in Figure 1. After the feeder has docked below the cruiser (a trapeze system is foreseen to facilitate the attachment of the feeder under the large cruiser belly and guarantee its stable positioning), the feeder detachable fuselage is lifted into the cruiser and, through a T-guide mechanism, shifted on one side to allow the passengers disembarking and accessing the cruiser main decks. A second detachable fuselage, prefilled with the passengers and goods that must leave the cruiser, will be loaded onto the empty feeder (using the same T-guide mechanism), in the place left vacant by the just delivered fuselage. Then the feeder will detach from the cruiser and reach the nearby landing destination. These exchange operations will be performed several times, as different feeders will intercept and dock on the cruiser, during its long range orbiting trajectory.

Parameter	*Value*	*Note*
nr of passengers	1000 PAX	100 kg each
MTOW	900000 kg	
Range	> 60,000 nm	1 week endurance
Cruise speed	M = 0.8	
Docking Speed	M= 0.7	
L/D	>20	
Cruise altitude	h_{cruise} > 11000 m	
Reactor Lifetime	Between 5000 and 10.000 hours	
Payload Transfer Concept	Single container exchange concept (100 pax each)	

Table 1: Cruiser Top Level Requirements

Table 1 collects the top level requirements established within the RECREATE project for the design of the cruiser. The high aerodynamic efficiency required for making this operational concept worthwhile, plus the demands set by the aforementioned docking and containers exchange approach, have led to the selection of a blended wing body configuration for the cruiser.

2 Preliminary Sizing Process of the Nuclear Propelled Blended Wing Body Cruiser

The peculiar nature of the aircraft under consideration has required a somehow different conceptual design approach, than generally used for conventional passenger transport aircraft. The fact that the considered configuration is a blended wing body, where the center section of the aircraft is required to perform more functions (e.g., lift generation, control, payload transfer and storage) has required an integrated and iterative approach to define the interiors layout, the aerodynamic shape and the masses distribution.

The typical aircraft conceptual design process starts with a preliminary weight estimation, where basic performance equations are used to estimate the necessary amount of fuel. From that, plus the aid of statistical data from reference aircraft, an initial estimation of the aircraft MTOW and OEW can be achieved. However, in the case of a nuclear propelled aircraft, where the amount of fuel mass used to perform the mission is negligible, a different approach was required to pursue the initial aircraft weight breakdown.

The design process implemented to achieve the preliminary sizing of the nuclear propelled blended wing body cruiser is summarized by means of the N2 chart provided in Table 4. The main phases of the design process are shown on the diagonal of the chart and all the input/output required/generated by each phase are listed on the upper and lower part of the matrix, respectively.

3 Definition of the Cruiser Planform

As a first step, the typical inside-out approach has been used to derive a suitable planform for the cruiser center body. The following assumptions have been made:

- Total deck area sufficiently large to accommodate a total of 1000 passengers in two classes.
- Cargo volume equal to 322.6 m^3. This amount was estimated on the basis of the passenger/freight ratio of existing wide body aircraft.
- Two nuclear reactors with an approximate cylindrical shape of 5 m diameter and 10 m length, including shielding (core cylinder 3m by 3 m). Two reactors were selected for pure redundancy purposes, although one would have been sufficient to deliver the required power. The initial size of the reactors was based on reference values provided by the nuclear energy experts in the consortium and will require verification, in a later stage of the project.
- Sufficient space to accommodate two fuselage-like containers (to be exchanged with the feeders), sufficiently large to transport 100 passengers and some freight. On the basis of the typical fuselage dimension of existing aircraft able to accommodate 100 passengers, it has been assumed the use of cylindrical containers with diameter of 3 m and length of 25 m.

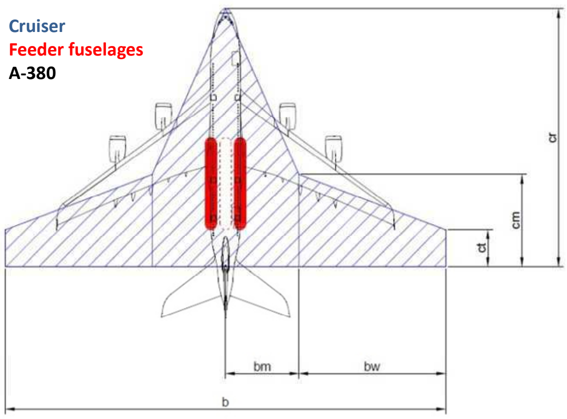

Figure 3: first iteration of the cruiser planform

The rest of the planform, i.e. the span and the shape of the actual wings of the Cruiser (in other words, the outer sections of the BWB lifting surface) was sized in view of achieving the required high aerodynamic efficiency value indicated in Table 1. To this purpose, different values of the total cruiser span have been investigated, by modifying solely the outer wing planform, until a design was found able to achieve an aerodynamic efficiency value larger than 20. A textbook method was used to estimate the parasite friction coefficient *f*, while the maximum aerodynamic efficiency was estimated using the following equation [2,3]:

$$\left(\frac{L}{D}\right)_{max} = \sqrt{\frac{\pi \cdot b^2 \cdot e}{4 \cdot f}}$$

The simple double trapezoidal planform shape (center body and outer wing) resulting from this very first iteration is shown in Figure 3. The two exchangeable fuselages (plus some space in between for the T-guide mechanism) are shown in red. The top view of an Airbus A-380 is superimposed on the picture to give a sense of the overall Cruiser dimensions. The data of this preliminary aircraft sizing are summarized in Table 2.

Description	*Symbol*	*Value*
Maximum root thickness	t_{root}	10m
Root chord length	c_r	60m
Inner part taper ratio	l_1 (c_m/c_r)	0.416
Main wing taper ratio	l_2 (c_t/c_m)	0.25
Inner part length	b_m	20m
Outer wing length	b_w	40m
Span length	b	120m
Wing Surface	S	2947m^2
Aspect ratio	A	4.89
Zero Lift Drag Coefficient	C_{D0}	0.006
Maximum aerodynamic efficiency	$(L/D)_{max}$	23.32

Table 2: Preliminary sizing and analysis of the cruiser planform

The simplified shape resulting from this preliminary sizing step was subsequently refined to account for the actual integration of payload, interiors and main systems. The external shape was refined as result of a more accurate, although simple, aerodynamic study performed with a commercial vortex lattice method tool. A limited number of airfoils was selected, scaled and twisted in order to achieve a quasi-elliptical lift distribution for minimum induced drag, while minimizing the aerodynamic pitching moment (in view of the controllability aspects) and maintaining the target value of aerodynamic efficiency. The main views of the aircraft with relevant sections are illustrated in Figure 8-Figure 10.

On the lower deck there is space for two passengers seating areas, a front and a back cargo hold, and two resting areas that can be used by passengers and the crew. In the middle, space is reserved for the pressurized containers for payload transfer (there will always be one on board of the cruiser) and the T-mechanism. The middle deck accommodates the majority of economy passengers (730 seats) and the cockpit. The top deck accommodates the business class. The two nuclear reactors are located in special bays, on the right and left side of the passenger area, well separated and isolated by protection walls. The two bays can be opened in flight to jettison one of reactors in case of emergency, without drastically affecting the longitudinal position of the aircraft center of mass.

4 Preliminary Weight Estimation

The Cruiser maximum takeoff weight WTO is the sum of the following three weight components:

- WPL (Payload Weight). It is the sum of passengers weight Wpax and cargo weight Wcargo.
- WOE (Operative Empty Weight). It includes the weight contributions of structures, engines, lubricants, and crew.
- WP (Power Plant Weight). It includes the weight of the nuclear reactors, the cooling system and the shielding. It does not include the weight of the engines, whose contribution is accounted in WOE).

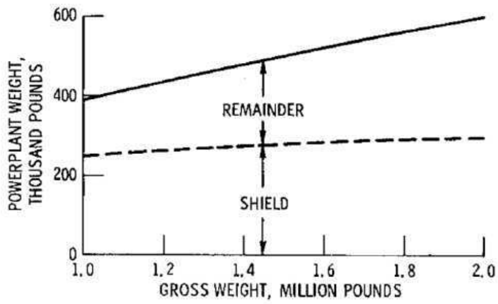

Figure 4: Nuclear power plant weight estimation

In order to estimate the Power Plant Weight WP, the key plot provided in Figure 4 is used [4,5]. Here WP is expressed as a function of WTO and is defined as the sum of two main contributions, namely the *shield* weight and the *remainder*, which includes the weight of the nuclear core and the cooling system. The following linear relation was derived based on the plot above (WTO is in 10^3 kg):

$$WP(WTO) = 0.143 \cdot WTO + 116.6$$

By expressing WOE as function of WTO, the following relation is derived:

$$WOE_I\,(WTO) = WTO - WP\,(WTO) - WPL$$

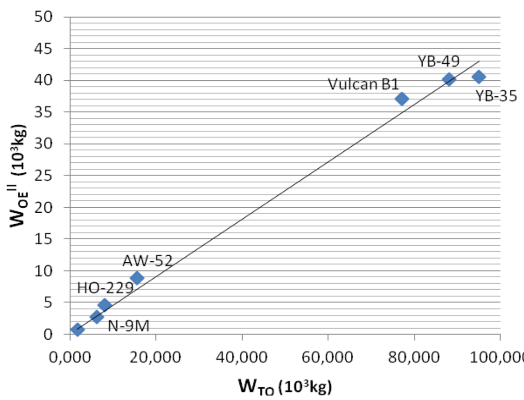

Figure 5: WOE vs WTO relation based on statistics (only blended wing body and flying wing considered)

A second equation is required to derive WOE and WTO. To this purpose, statistical analysis has been performed to derive a relation between WOE and WTO, where only flying wing type of

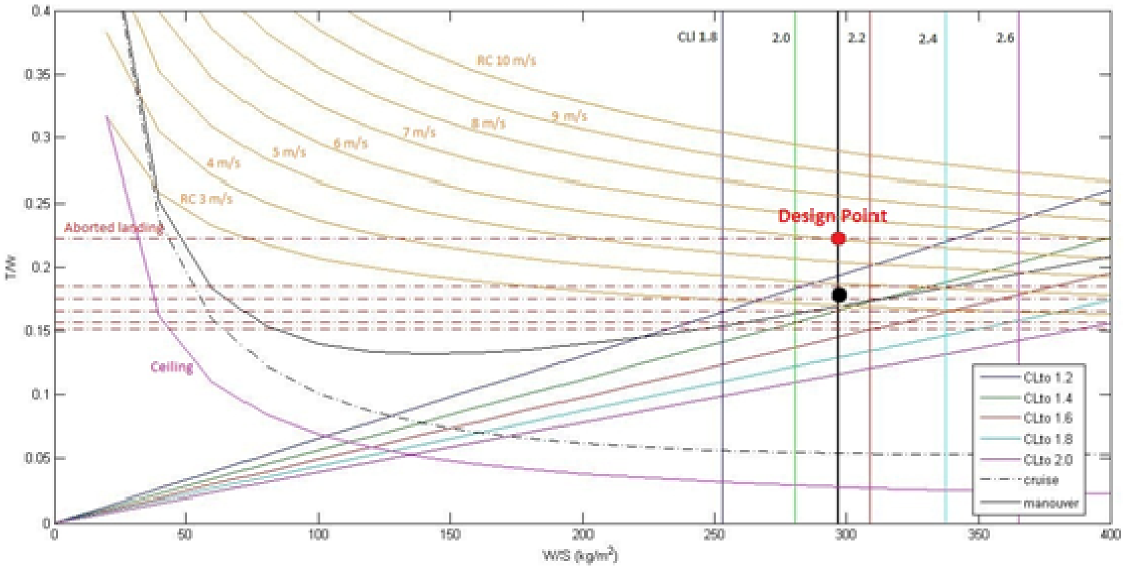

Figure 6: Wing loading vs thrust loading plot and cruiser design point

aircraft have been taken in consideration. The result is shown in Figure 5, from which the following equation was derived (WTO is in 10^3 kg).

$$WOE_{II}\ (WTO) = 0.46 \cdot W_{TO}$$

By imposing $WOE_I = WOE_{II}$ it is possible to derive a first estimation of WOE, WTO, and WP. The results are shown in Table 3 and compared to the values of the two largest wide body passenger aircraft now in operations, namely the Airbus A-380 and the Boeing B747-800 [6]. It can be noticed that WTO is lower than the value provided as top level requirements, while the estimated payload weight percentage is almost twice the value of the wide body aircraft considered in the comparison.

	Cruiser	*% W_{TO}*	*A-380*	*% W_{TO}*	*B-747*	*% W_{TO}*
W_{TO} (10^3kg)	**875**	-	560	-	343	-
W_{OE} (10^3kg)	**383.3**	**43.7**	277	49.5	212	61.8
W_{PL} (10^3kg)	**250**	**28.6**	85	15.2	60.5	17.6
W_P (10^3kg)	**241.7**	**27.6**	-	-	-	-
W/S (kg/m^2)	**297**	-	662.7	-	850	-

Table 3: Weight breakdown of the cruiser & comparison with A390 and B747

The particularly low wing loading of the cruiser is noteworthy. BWB have generally low wing loading (around 350 kg/m^2), although not as low as the cruiser. At this stage it was not possible to increase it by reducing the wing area, because this reduction could have been achieved only affecting the outer wing area (the planform area of center body being dictated by the interiors constraints discussed above). Reducing the outer wing area would have induced a negative effect on the maximum L/D and a reduction of the cooling system area, now assumed to be integrated in the wing.

5 Required Thrust Estimation

In order to estimate the required thrust and power plant power and then proceed with the selection of appropriate engines, the classical wing loading (W/S)–thrust loading diagram (T/W) plot was generated. To this purpose, a number of possible sizing conditions (take off, landing, stall, climbing, ceiling, maneuver) was selected, as detailed in Table 5. The final plot is shown in Figure 6. The design point (red dot) is set by choosing the minimum thrust required to meet all the operational requirements, at the maximum allowed wing loading computed in the previous section.

It can be noticed that for take-off and landing, the following value of maximum lift coefficient are sufficient: CL_{TO} = 1.4 and CL_L= 2.2. Both these values are relatively low, when compared to those of conventional wide body aircraft (up to CL_L = 3). This is mainly a consequence of the low wing loading of the cruiser.

The sizing requirement for T/W appears to be the one related to aborted landing with one engine inoperative (OEI). It follows that a total thrust of 1900 kN is required, which could be provided by four engines similar to the GE-115B. This is currently the most powerful jet engine and can provide a maximum thrust of 512 kN [7].

For what concerns the power, a maximum value of 344.5 MW is required during maneuvering. This value is the one to be used to size the nuclear reactors (see Table 5).

From the graph, it is possible to estimate the rate of climb RC achievable by the Cruiser, which is equal to 6 m/s and very close to that of other wide body aircraft such as the Airbus A-380 and the Boeing B-747 [6].

6 Refined Weight Estimation approach and balance of the aircraft

In case of conventional aircraft, so called Class II methods are usually applied to estimate the weight of the main structural component groups (Wing, fuselage, empennages, etc.). The sum of these components generally yields a different operative empty weight value (WOE) than obtained during the initial weight estimation phase, using Class I methods (statistics and Breguet formulas). Hence, Class I and II methods are generally iterated until a consistent set of weight estimates is obtained. Various Class II weight estimations are available in literature [2,3], but they are not generally applicable to aircraft such as the one under consideration here, given its unconventional design and the lack of statistical values to perform suitable regressions.

To this purpose a more physics based weight estimation approach, a so called Class II and half method, has been adopted to achieve a more reliable weight estimation, at least for the primary (load carrying) structural elements of the aircraft. The employed approach is based on a method specifically developed by Torenbeek for lifting surfaces [8], which makes use of the actual loads acting on the main structural components (spars, skins, ribs) to estimate their thicknesses and thus their weight.

This method has been applied to the outer wing of the BWB, first, and then to the center body of the BWB, which is also a lifting body. This latter weight contribution was then corrected by adding the weight contribution of the internal multi-bubble structural system used to accommodate the payload and carry the pressurization loads (see Figure 10). To this purpose, the sizing approach proposed in [Ref. 9] has been used. Finally, the weight contributions of engines, landing gears and other systems are added. In this case manufacturers' data and some semi-empirical rules (such as Class II weight estimation method for landing gear) have been used.

The total weight estimation for the cruiser is computed by adding the derived structural weight contributions to the payload and the power plant system weight contributions (as computed in Section 4).

WTO = Wwing + Wfus + WPL + WP = 924.7 10^3 kg

Since the obtained weight estimation does not differ significantly from the initial Class I estimation (which was 5.4% lower), no iterations were considered necessary.

A preliminary estimation of the center of gravity (c.g.) range of the aircraft was used to define a proper positioning of the landing gear. Aerodynamic simulations have been performed to estimate the position of the neutral point and assess the controllability of the aircraft, even in the most adverse (forward) position of the c.g, at approach speed and with deployed flaps. The aircraft appears to be slightly unstable when the c.g. is in its most aft position. However, the presence of one empty payload container on board is sufficient to move the c.g. in front of the neutral point and achieve stability. More details on all the weight calculations, and the stability and controllability analysis can be found in [ref. 10].

7 Considerations on the use of nuclear propulsion

The dream to achieve a nuclear powered aircraft has existed for a very long time. Extensive research took place during the cold war [4,5]. However, environmental concerns and depletion of fossil fuel resources have recently rekindled the interest in nuclear powered aircraft also for civil applications [11]. Indeed, a turbofan engine that utilizes heat energy from a nuclear reactor, does not require fossil fuel and does not emit carbon dioxide or nitrogen oxide, therefore it does not contribute to global warming. In addition, the range potential of a nuclear powered aircraft is substantially greater in comparison with a conventional aircraft. Because energy from nuclear fuel costs only a fraction of that for fossil fuel, nuclear powered cruisers also hold out significant promise to reduce the cost of air transportation.

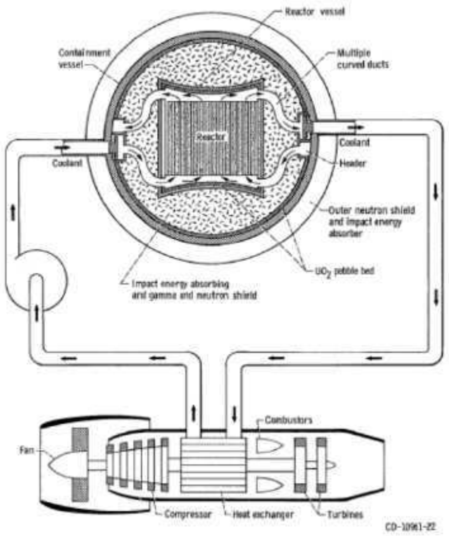

Figure 7:indirect Brayton cycle using a heat exchanger to extract the heat generated by a helium cooled reactor

The major disadvantages of nuclear propulsion are the obvious safety and security concerns. A practical nuclear cruiser design must have complete shielding to reduce the radiation doses to allowable levels in all directions, so that neither the crew and passengers onboard, nor the maintenance and servicing crew on the ground, receive radiation doses significantly greater than that normally received from natural sources. A nuclear cruiser must also have safety provisions that are designed to prevent the release of radioactive material in the worst aircraft accidents.

At the current state of work in the RECREATE project, the use of turbofan engines based on the indirect Brayton cycle and the use of compact helium cooled reactors are considered (see Figure 7), as described in [12]. Differently than a conventional gas turbine, the combustion chamber is replaced (or complemented, in case of hybrid configurations) by a heat exchanger, which transfers the heat generated by the nuclear reactor to the compressed air. Although this concept was selected because of its compactness, and the possibility to adopt a hybrid fuel system, preliminary studies reveal that, due to the poor heat transfer properties of the air, the use of helium as coolant might lead to very large heat exchanger, with severe consequences on the aircraft weight and the practical ability to place the heat exchanger between compressor and turbine. The use of another medium as reactor coolant (e.g. liquid metal or molten salt) may alleviate this problem, while retaining a compact core.

A parallel study has been performed to investigate the benefit of replacing the Brayton cycle with a Rankine cycle [13]. Indeed, this is a common solution for nuclear power stations and marine applications (large vessels and submarines). The adoption of the Rankin cycle would lead to the replacement of the turbofan engines with ducted fan engines, driven by the steam obtained from the nuclear reaction. The steam would need to be cooled down and the water sent back to the nuclear reactor in a closed loop cycle. However, this appears to be less convenient for cruiser, because of the very large condensers needed to reject the waste heat that cannot be converted into work. Although the wing surface is suited to facilitate condensation, it is not capable of rejecting all the waste heat to its surroundings (again because of air poor heat transfer properties). Extra complex and heavy air cooled condensers would be required, as well as the need to fly at lower altitude. As described in the next section, the design and integration of the nuclear propulsion system will be object of further research within the RECREATE project.

8 Conclusions and future work

The work presented in this paper represents the first step into the feasibility study of a nuclear propelled aircraft for the cruiser/feeder concept. Although the proposed concept has been supported by some preliminary calculations, significant developments are required to turn the nuclear cruiser design from an interesting exercise into a credible option for future aviation. The purpose of the RECREATE project, in this respect, is to perform only a basic exploration of this concept, to provide a preliminary assessment of the possible technical, safety and certifications related issues to be included in development roadmap. The very next steps concerning the conceptual design of the nuclear cruiser include a general review and consolidation of the results presented in the previous sections, plus the set-up of an aerodynamic analysis campaign to derive a proper combination of airfoils and planform parameters. Although a detailed aerodynamic analysis might appear premature for a concept that is still so fluid, the integrated nature of the BWB configuration requires a proper simultaneous choice of the aerodynamic shape and the rest of the parameters governing the interiors layout and the overall aircraft flight performance. Considering the absence of an actual tail, a thorough assessment of the stability and controllability performance of the aircraft, both longitudinal and lateral-directional, is necessary.

The design of the docking and loading mechanism of the detachable fuselages will require also careful attention. At the moment no sufficient information was available to propose even a simple relation to account for the weight penalty of this mechanism.

For obvious reasons, the most urgent research activities concern with the nuclear propulsion system and its integration. The number of reactors, their type (nuclear fuel and coolant), their size, the accurate sizing and weight estimation of the shielding, the layout of the energy conversion system, the choice of the Brayton or Rankine cycle to drive turbofan or turboprop engines are just some of most urgent topics to be addressed before the closure of RECREATE.

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External Inputs	• PLW • PW = PW(TOW) • OEW = OEW(TOW) • Feeder fuselage lenght • Cruise velocity • Stall velocity • Cruise altitude • T.O. distance	• Passengers Surface • Cargo Volume • Reactor Volume • Coolers Volume • L.E. sweep angle • Airfoil type • Airfoil positon	• Number of reactors • Engines Weight • Fixed L.E. and T.E. surfaces • Slats and Flaps Surfaces • Ailerons Surface • Flap Type • Material density	
	Preliminary Sizing	• Root chord lenght • Fuselage span, Wing span • Taper ratio 1, Taper ratio 2 • $C_{L\alpha}$, C_{D0} • Aspect Ratio • Wing Surface • TOW, OEW, PW • Root thickness • Tip chord, Center Line chord	• Number of engines • Reactors Weight • MZFW • MLW	
	• Aerodynamic Efficiency	**General Anrchitecture**	• t/c ratios • Coolers dimensions • Mean chord sweep angle • Volume Pressurized • Wing Surface	• 3D rendering • Mesh
	• TOW • OEW		**Detailed Weight Estimation**	
		• L.E. sweep angle • Airfoil type • Airfoil positon • Aerodynamic Efficiency		**CFD Analysis**

Table 4: N2 Chart illustrating the main design parameters computed and exchanged during the various steps of the conceptual design process

Operative Condition	*Assumptions*	*T/W*	*T (kN)*	*P (MW)*
Cruise	• $C_{D0c} = C_{D0} + 0.03$ • v = 236.3 m/s • h = 11000 m	0.053	457 @ h 1254 @ s.l.	108 300
Maneuver	• $n_{max} = 2.5$ • h = 11000 m • v = 236.3 m/s	0.17	1458	**344.5**
Take-off	• $X_{TO} = 3000$ m • Sea level			
Landing	• $v_{st} = 43.73$ m/s • Sea level			
Rate of Climb	• $C_{LTO} = 1.4$			
Ceiling	• $RC_{ceiling} = 1.5$ m/s	0.0273	234 @ h 637 @ s.l.	55.3 150
Climb Gradient	• 4 engines • $C_{LTO} = 1.4$ • $C_{LL} = 2.2$ • $v_2 = 1.2^* v_{st}$	Initial climb 0.157 Transition climb 0.165 Second part climb 0.174 Route climb 0.151 Aborted landing 0.184 Aborted landing 0.222	**1900**	100

Table 5: T/W needed in different flight conditions

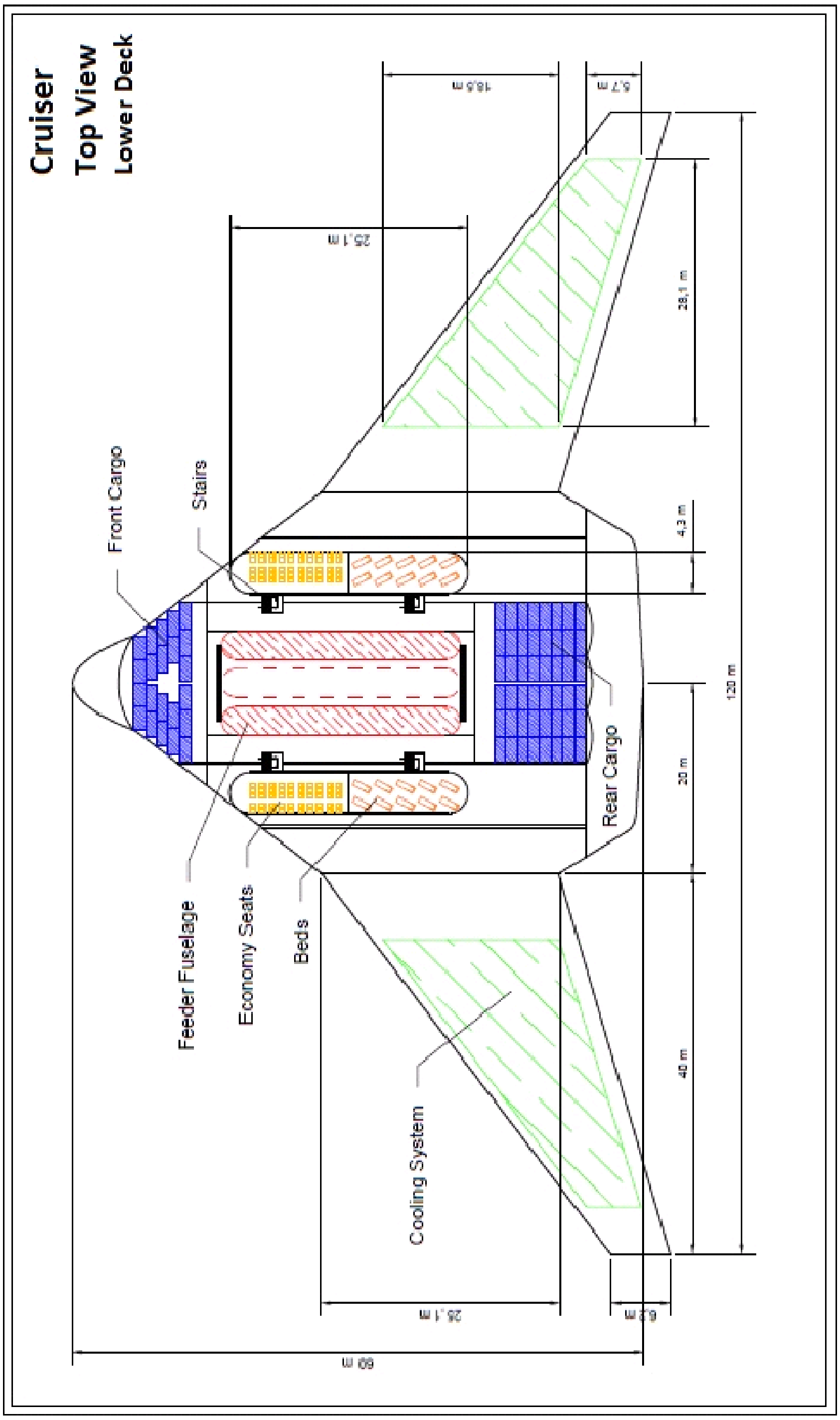

Figure 8: top view of the cruiser

Figure 9: top view of the upper and middle deck

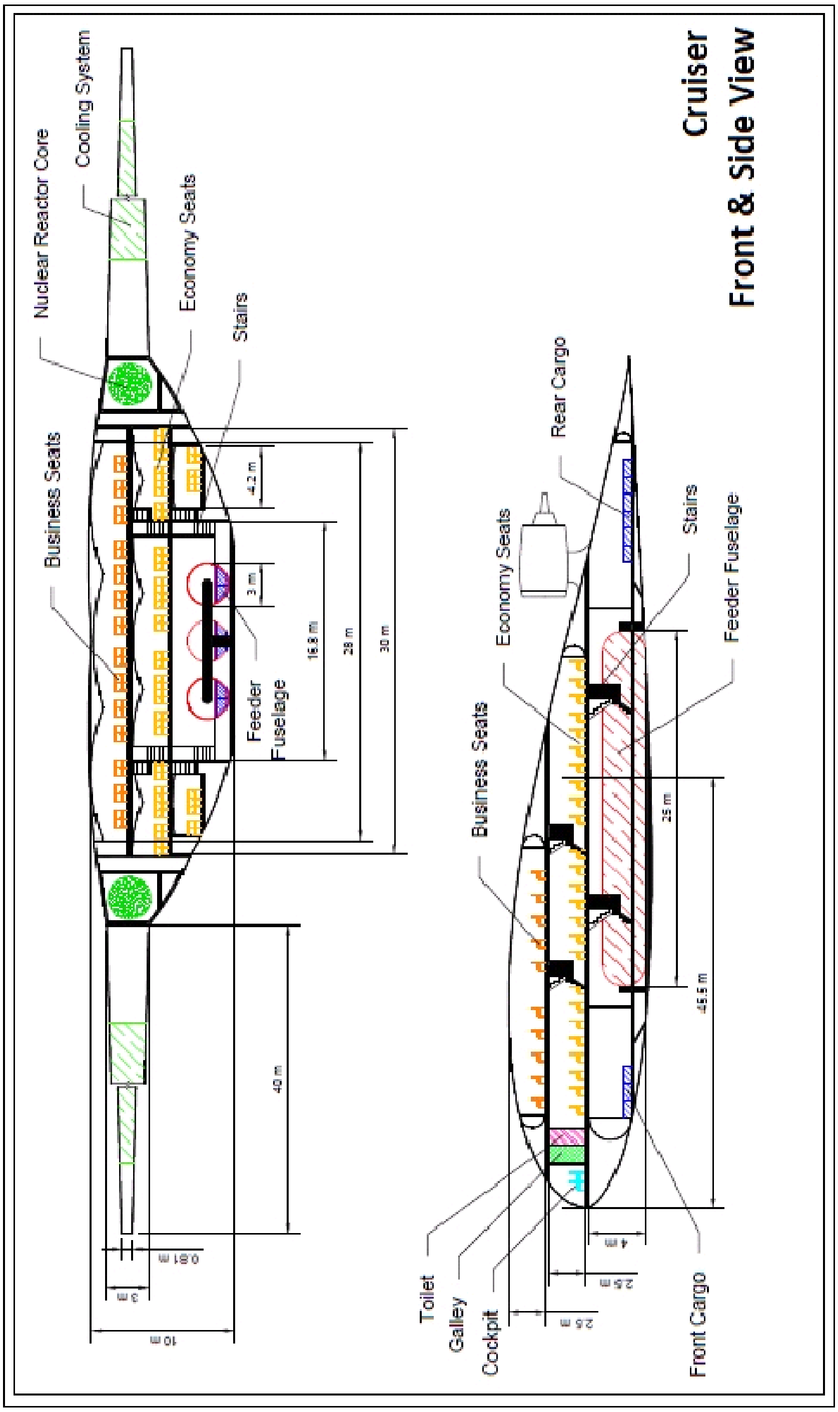

Figure 10: front and side view of the cruiser

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Collaborative understanding of disciplinary correlations using a low-fidelity physics based aerospace toolkit

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Keywords: *Collaborative Design, Multidisciplinary Design and Analysis, Knowledge Management, CPACS, RCE*

Nomenclature

CPACS	Common Parametric Aircraft Configuration Scheme
RCE	Remote Component Environment

Abstract

Covering all relevant physical effects and mutual influences during aircraft preliminary design at a sufficient level of fidelity necessitates simultaneous consideration of a large number of disciplines. This requires an approach in which teams of engineers apply their analysis tools and knowledge to collaboratively approach design challenges.

In the current work, recent technical advancements of the German Aerospace Center (DLR) in data and workflow management are utilized for establishing a toolbox containing elementary disciplinary analysis modules. This toolbox is focussed on providing fast overall aircraft design capabilities. The incorporated empirical and physics based tools of low fidelity level can be used for setting up modular design workflows, tailored for the design cases under consideration. This allows the involved engineers to identify initial design trends at a low computational effort. Furthermore, areas of common physical affinity are identified, serving as a basis for communication and for incorporating tools of higher fidelity in later phases of the design process. Clear visualisation methods aid in efficiently translating knowledge between the involved engineers within the identified areas of common affinity.

A system-of-systems approach is established by applying the elementary aircraft design toolbox for the establishment of requirement catalogues for engine preliminary design. The engine designers at their turn deliver initial performance correlations for application in the aircraft design toolbox. In this way, a clear synergy is established between the design of both the airframe and power plant. Using this approach, engineers of different technical backgrounds share their knowledge in a collaborative design approach.

The use case guiding the present work involves a conventional short to medium range aircraft sent at half the design range. The wing area and aspect ratio are varied to investigate the influence on the engine requirements catalogue for this particular mission.

1 Introduction

Aircraft design is a complex procedure, which involves an increasing amount of disciplines considered simultaneously. During recent years, Multidisciplinary Design & Optimization (MDO) techniques have become state-of-the-art and are evolving continuously. Applications to design of novel aircraft are however only occasionally seen and wide exploitation of modular MDO processes at industry level is not yet clearly observed [1], [2]. Due to the large complexity of analysing the multitude of relations between involved design disciplines, the analysis of novel configurations cannot be handled by a single person anymore. Collaborative approaches in teams of specialists and integrators are required to master the challenge of understanding the relevant physical effects involved in the design of aircraft [3].

A lot of effort has been put in generating technical solutions to aid design teams in connecting their disciplinary analysis capabilities. The virtual extended enterprise as developed during projects VIVACE [4] and CRESCENDO [5] forms a tangible example of this development. Within these and similar projects, focus has been placed on exchanging explicit[1] knowledge by using common data exchange formats and setting up technical design frameworks for interconnecting analysis codes. Aside this development, methods for collaboration in teams of engineers have also been investigated.

The Common Parametric Aircraft Configuration Scheme (CPACS) is an xml-based data model developed at the German Aerospace Centre (DLR), representing an explicit description of the aircraft in a structured manner. Aside a geometrical description of the vehicle, other relevant conceptual design data such as missions, fleets and airports are exchanged using CPACS [6]. With the parallel development of the Remote Component Environment (RCE) at DLR, a framework for connecting analysis tools on distributed servers has been created [7], using CPACS as interface.

The technical achievement of using frameworks for interconnecting analysis tools applying the aforementioned data exchange methods is showing large benefits. Experience gained during the DLR collaborative design projects "TIVA" and "VAMP" [8] however shows that operating a numerical analysis system in a team of specialists presents a large challenge of its own. Therefore, as also introduced by Kroo [9], a larger part of the research should focus on addressing challenges at the organizational level of MDO. The collaborative way of working, indicated as third generation in Fig. 1, is required to share implicit[1] knowledge within the design team. The indicated shift in focus toward organizing effective collaboration among all involved engineers is however still in its early stages.

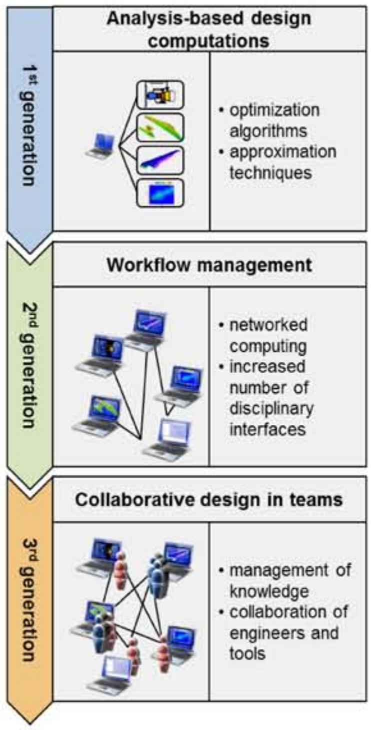


Fig. 1 Evolving generations in MDO

[1] 'Explicit' (or formal) knowledge: knowledge that can be captured in design rules, implicit (or tacit) knowledge: knowledge possessed by an individual, mostly based on experience, which is difficult to communicate via words and symbols [17].

The main question guiding the collaborative design effort is:

How to enable communication among engineers having different specialisms?

In the present study, it is investigated how multidisciplinary interactions and affinity for common disciplines can be identified and used as a basis for communication (see Fig. 2). Using a practical design problem, experience is gained on the needs to ensure effective collaborative approach in aerospace design teams. As indicatively shown in Fig. 2, common disciplinary affinity between knowledge bearers serves as starting point for comprehensible communication within the team. This area of common affinity can be defined by shared explicit knowledge, e.g.: design parameters exchanged between disciplines, but also by the less straightforwardly identifiable implicit knowledge, e.g.: common theoretical methods applied within the analysis codes.

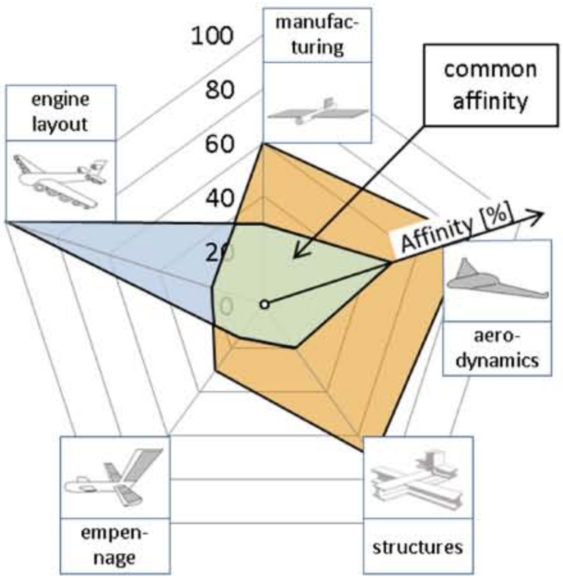


Fig. 2 Common affinity of two knowledge bearers serving as basis for communication.
- blue: pre-engine designer,
- orange: aircraft pre-designer,
- green: area of common affinity

2 Low-fidelity toolkit for mutual understanding and knowledge transfer

In a previous study, the authors investigated the possibility to perform a system-of-systems approach in aircraft design [3]. Defining the area of common affinity (see Fig. 2) between the involved engineers proved not to be straightforward. On the implicit level, this was mainly caused by the difference in engineering backgrounds of the involved parties. On the explicit level this was due to the difference in applied design methods and – practically – due to differences in applied data exchange formats. For serving the assessment of the overall system under analysis, large commonality among the involved analysis tools is required. Furthermore, the incorporated tools (and maybe even engineers) should be modular in a sense that a change of analysis methods within the process requires only little effort. For the current investigation, a basic pool of low-fidelity physical analysis tools is created using the technical capabilities provided by the CPACS data exchange format and the integration framework RCE as a basis. The main goal of the modular system of analysis tools is to create the possibility to quickly identify physical effects and cross-disciplinary influences.

The studies at low fidelity level are used for identifying common knowledge affinity between the involved disciplines. After identifying these correlations, higher-level analysis modules can be incorporated in the design system to increase the certainty of the identified correlations. Since expert knowledge is required to interpret results of the overall system, this process tends to go beyond plainly connecting analysis tools and observing the results. Instead, a system of distributed low and high-level competencies is created.

The fidelity level of analysis modules used in aircraft design can be subdivided in four levels:

Level-0 tools are based on statistical or empirical design rules and allow exploration of the conventional design space only.

Level-1 tools are based on a simplification of the physics of the design problem. These tools are applicable to simple extensions of the conventional design space and mostly involve physical behaviour of a linear nature.

Level-2 tools are based on accurate physical representations of the disciplines involved in the design problem: the geometrical representation is much more detailed; the physics underlying the analysis code is of high detail or a combination of the both. Tools of this level may be used for analysing unconventional designs.

Level-3 tools represent the most accurate simulation capabilities. These are used to capture detailed local effects and mostly do not allow for automation.

Tab. 1 Main properties of analysis modules, per fidelity level

	Assumed accurateness	Computational speed per analysis	Design space exploration	Application to unconventional Designs	Automation easiness
Level-0	-	++	+	no	++
Level-1	-	+	++	+/-	+
Level-2	+	-	-	++	-
Level-3	++	- -	- -	+	- -

The main properties of the analysis modules of different fidelity level are summarised in Tab. 1. The current work focuses on the interconnection of tools of level-1 fidelity in order to efficiently scan the design space at low calculation effort. The level-0 tool VAMPzero is used for initiating the aircraft as well as for closing the iterative design loop [10]. It calculates the aircraft properties for which level-1 analysis modules are currently still under development.

After analysing physical properties of the aircraft concept model, its 'goodness' is evaluated according to the requirements set in the initiation phase of the concept assessment. As can be seen in Fig. 3, within such an evaluation again multiple disciplines are represented. In the current study the aircraft costs are analysed using a low-level DOC calculation module. Climate impact, as well as noise and capacity assessment is part of future work.

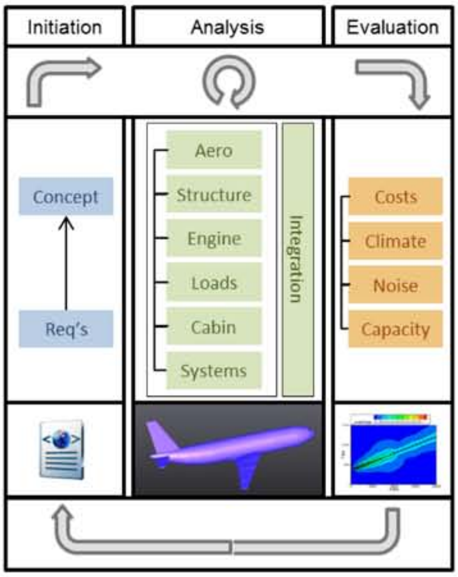


Fig. 3 Phases in aircraft concept assessment

All tools within the toolkit under development, both in the analysis as in the evaluation category, include a connection to the central data exchange format CPACS. The tools are therefore modularly applicable; the user can for example choose to exchange individual analysis modules using different approaches or of different fidelity level. The modules making up the analysis toolkit are hosted on multiple dedicated servers and analyses can be triggered using the RCE framework.

To provide the workflow integrator[2] clear and concise information on the analysis modules

[2] As elaborated in [3], design teams within multidisciplinary design approaches ideally consist of one or more *workflow integrators* connecting all involved analysis modules to logical design workflows, supported by the *specialists* individually interpreting the results of their disciplinary modules. An *operator* takes care of the overall course of action within the design process.

within the toolkit, a standard has been developed for connecting the tools to the RCE framework. This tool wrapping plainly consists of a standard folder structure to be used for input and output data, as well as scripts for encapsulating the tool. These scripts trigger the actual calculation and control tool execution behaviour. Furthermore, the end user is provided a well-balanced amount of status information through filtering the often excessive output information for main output messages. The excessive calculation logbooks can be used by the specialist for debugging purposes on the dedicated server when a tool does not provide the intended results.

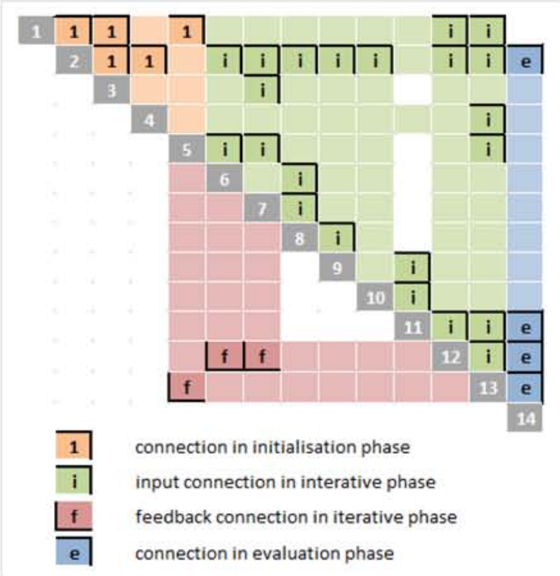
The main purpose of having a standard for tool wrapping is generating the possibility for flexible application to a multitude of design questions and aircraft configurations. From experience it is found that this collaborative approach requires a change in mind-set of the developing engineer: (s)he needs to be constantly aware of how external users without the experience of a disciplinary specialist will try to approach the tool at hand and clearly define its application boundaries. In this *design for collaboration* approach, putting large effort in writing a proper wrapping code generally saves lot of time during the application period of the module. This wrapping code has to provide the end user with clear information on assumptions, warnings and errors encountered during tool execution. Assumptions and warnings need to be built up to flexibly react on the contents of the provided input.

3 Simultaneous aircraft and engine design

As can be seen from Fig. 2, the area of common affinity between aircraft and engine designers is relatively small. This is also seen in the industry, in which the airframe and engines are often designed by separate parties. At the DLR, two parallel projects for aircraft and engine preliminary design are currently executed. The design cycles are synchronised in such a way, that the aircraft design workflow provides design points for the design of the corresponding engine. The generated engine performance data is at its turn used to determine the performance of the complete integrated airframe.

In light of these projects, the current study encompasses the generation of an aircraft analysis workflow aimed at generating request for proposal (RFP) documents for the layout of a corresponding engine concept. Fig. 4 shows an N2-chart of the connections between the low-level tools as used within the analysis, as well as the purpose and name of each tool. This chart has been established through communication with all specialists that programmed the individual analysis modules. Since within the actual tool connections data of an explicit nature is exchanged, this step in the setup of the analysis workflow will be aided by automatic identification of required input data in future work. This will allow for more time to be spent on exchanging implicit knowledge, e.g.: on the appropriateness of a tool to generate required input data.
After identifying the required input and available output of each analysis module, the N2-chart aids in logically ordering the workflow in an initiation, iterative and evaluation phase.
The application of CPACS as central data exchange format considerably reduces the required amount of actual connections between the modules within the RCE framework, since information of consecutively executed modules is appended to this single data file.

To reduce complexity in the analysis workflow, the engine is represented by a database containing pre-calculated performance data. The database tables are created by performing thermodynamic analyses of the engine cycle at a multitude of operating points. Therein, the underlying engine deck is fixed in terms of principle cycle parameters such as turbine entry temperature (TET), overall pressure ratio (OPR) and fan pressure ratio (FPR). However, using ‘rubber engine’ scaling principles, the available engines can be scaled in mass flow by +/- 20%.



#	purpose	tool
1	TLAR & basic aircraft geometry	user input
2	geometry variation	GPP
3	mass initialisation	VAMPzero
4	aerodynamic performance map	Tornado
5	engine mass & performance map	TWDat
6	loadCase determination	LCG
7	weight and balance	WandB
8	spanwise loading	TRIM_VL
9	wing primary mass	PESTwing
10	wing secondary mass	PESTsewi
11	mass tree update	CMU
12	aircraft mass synthesis	VAMPzero
13	fuel mass and engine scaling	FSMS
14	direct operating costs	DOC

Fig. 4 N2-Chart providing the connections between analysis modules in the aircraft analysis workflow

The more the engine differs from its validated unscaled basic thermodynamic cycle, the more care has to be taken in interpreting the corresponding performance data. In Fig. 5, an engine performance map as read out from TWDat and interpreted by the mission simulation module FSMS is shown. As concluded during the design studies, the current simplified representation however has its limitations: no engine ratings are included, allowing the aircraft engineer to theoretically let the aircraft fly at full thrust throughout the entire design mission. In setting up a workflow involving engine data, the aircraft engineer needs to provide the engine designer the intended mission data of the airframe in order to attain proper performance data coverage.

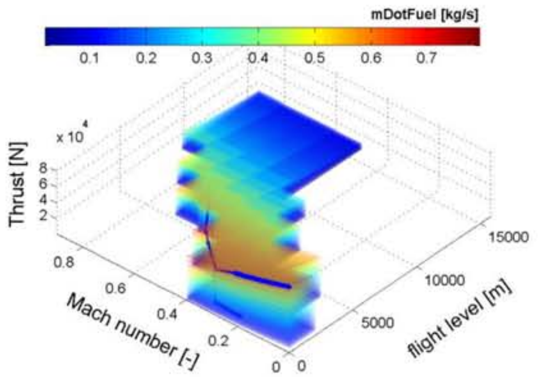


Fig. 5 Interpolation within the performance map of the CFM56 engine. Blue line: interpolation trajectory throughout the simulated mission

A resulting engine requirements catalogue for the short- to medium range A320-like reference aircraft ‘D150’ is shown in Tab. 2. The mission simulation tool FSMS is adjusted to specifically calculate the following design points for the catalogue:

One Engine Inoperative (OEI) condition determines the required engine scaling factor according to Certification Specifications chapter 25.121 [11]. For a fly out manoeuvre with engine failure exactly occurring at decision speed V1, the engine is scaled such that the minimum fly out gradient and velocity are attained by the aircraft.

End of Field (EOF) is the condition with the largest fly out climb angle, reached shortly after the ground run. This is generally the point with the highest shaft speed and turbine inlet temperature requirements.

Mid Cruise (MCR) is used as the aerodynamic design point providing the highest component efficiencies for minimizing engine specific fuel consumption.

Top of Climb (TOC) is the point just before the aircraft starts its cruise phase, used to determine the maximum non-dimensional engine performance parameters, such as corrected component mass flows and speeds.

Once the engine performance data is calculated, an additional database entry in TWDat can be added to verify its correspondence to the established requirements. This at its turn might lead to an update of the requirements catalogue.

Tab. 2 Engine design point data for the requirements catalogue [a/c: D150, engine: CFM56-5A5, des. range: 1800 nm]

		one engine inoperative (OEI) [JAR 25.121]	end of field (EOF)	mid cruise (MCR)	top of climb (TOC)
$T_{required}$	[N]	82383	78327	19936	26973
$T_{delivered}$	[N]	80880	78327	19936	26973
time	[m':s'']	0'50''	0'45''	139'	29.6'
altitude	[m]	64	45	10376	10000
Mach	[-]	0.23	0.26	0.78	0.78
α	[deg]	9.4	8.0	4.1	3.6
γ	[deg]	2.4	8.0	0.0	1.1
θ	[deg]	11.8	16.0	4.1	4.7
dT_{ISA}	[deg]	0	0	0	0
rating	[-]	OEI	MTO	MCR	MCL
ECS	[-]	on	on	on	on
WAI	[-]	on	off	off	off
HPX	[-]	tbd	tbd	tbd	tbd

nPax	[-]	150	H_{OEImax}	[m]	tbd
nEng	[-]	2	$H_{airport}$	[m]	0
t_{climb}	[m']	28'	MTOM	[t]	73500
TOFL	[m]	2120	MLM	[t]	64500
Vappr	[m/s]	tbd	ESF	[-]	1.019

ECS: env. control system, WAI: wing anti-icing, HPX: eng. power off take, ESF: eng. scaling factor

Using the N2 Chart (Fig. 4), the required modules are connected using the CPACS data format within the integration framework RCE. Fig. 9 shows the resulting workflow, specifically aimed at generating requirement catalogues for engine predesign. After initializing the aircraft geometry according to the design of experiments study at hand (see section 4), an iterative loop is started in which the engine scaling factor is brought to convergence. In the current setup, the wing and engine mass is determined using level-1 tools, whereas the other aircraft masses are determined using VAMPzero. Modules having no direct input connection as identified in the N2-chart (Fig. 4) are executed in parallel to save calculation time. After reaching convergence, the engine requirements catalogue is obtained for the configuration under investigation.

As already stated in section 2, in setting up such an analysis workflow, the need for a balanced combination of workflow integrators with general knowledge in connecting the specialists' tools on the one hand and disciplinary specialists on the other hand is clearly observed. The specialists need to ensure the connected tool is used properly and results are interpreted in a proper way, whereas the workflow integrator should provide general knowledge for the integration in analysis workflows and question the generated overall results at hand.

4 Design Study: influence of wing planform on engine scaling requirement

In the present work, it is chosen to keep the fidelity level of the applied tools low enough to provide relatively quick calculation results, although modelling the effects to be studied with physical relations. The workflow for the design study, depicted in Fig. 9 can be divided in six main parts.

The **initiator** part will use a geometric pre-processor to adjust the baseline aircraft geometry in CPACS. For the current study, a predefined geometrical description of the D150 aircraft is applied. As indicated in Fig. 6, the wing area and aspect ratio are varied around the baseline values of the D150 aircraft. VAMPzero is used to obtain a first mass estimation and in parallel, the aerodynamic performance map is generated using Mach, Reynolds and angle of attack sweeps in the vortex-lattice programme Tornado [12].

After the initiation, an engine performance map and weight is loaded from TWDat (see section 3) and in two parallel branches, the wing primary and secondary masses are estimated. Within the tools PESTwing and PESTsewi, a beam model representation for main wing structure sizing and empirical relations for secondary structure mass estimation are applied. The required wing loading is determined using a trimming routine incorporating a connection the vortex-lattice code AVL [13]. To complete the aircraft mass determination, VAMPzero is again used to **estimate the aircraft masses** not belonging to the wing group.
Knowing the aircrafts aerodynamic, engine and mass properties, the design mission is flown using the mission simulator FSMS to obtain the fuel requirements and the required **engine scaling factor**. Aside required fuel mass, payload-range diagrams as well as emission values are calculated, and the requirements catalogue for the new engine is provided (see section 3).
The determination of aircraft masses and engine scaling factor is iteratively performed, until the scaling factor **converges** and the engine required for the investigated configuration is obtained.
Within the **concept evaluation**, the direct operating costs are determined, after which the **DOE** is continued.

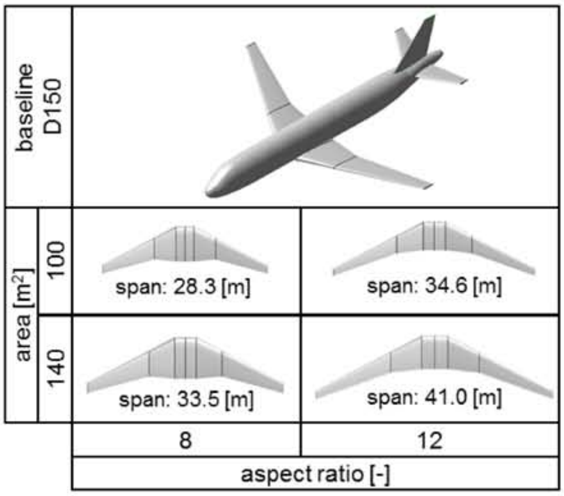


Fig. 6 Geometry changes within the performed design of experiments. Wing area: 100-140 [m^2], aspect ratio: 8-12 [-].

Applying proper visualization methods aids considerably in establishing clear interdisciplinary communication among involved engineers. In [14], the usage of "level transfer functions" to assist in communicating physical relationships among the parties involved in a design exercise is suggested. Transfer functions are used for communicating metrics on one design level to understandable research objectives for another level. Such plots provide a "feel" for the involved engineers on how known geometrical parameters influence higher-level objectives.

Fig. 7 shows the required engine scaling factor and aircraft operating empty mass (OEM) for the studied geometric parameters. For the D150 reference aircraft, a scaling factor close to 1.0 is obtained. The difference is caused by the low-level physics being used in the workflow. A technology factor of 1.069 is used to correct the determined wing mass within the workflow to its known baseline value for the reference aircraft. It can be concluded that the aircraft with a slender wing and low wing area has the least stringent requirement on engine performance. The classical opposing aeroelastic correlation is seen when combining parts (a) and (b) of the figure: a slender wing leads to better aerodynamic efficiency (and thereby a low engine scaling factor), however the aircraft mass increases due to the large structural loads imposed by such a configuration.

Fig. 8 shows a resulting performance correlation for the aircraft. Within this level transfer function, the influence of the performance measures wing loading (W/S) and thrust-to-weight ratio (T/W) on fuel requirements is shown for the geometries with correspondingly scaled engine. The boundaries of the T/W-W/S area are a consequence of the parameter variation chosen within the current study.

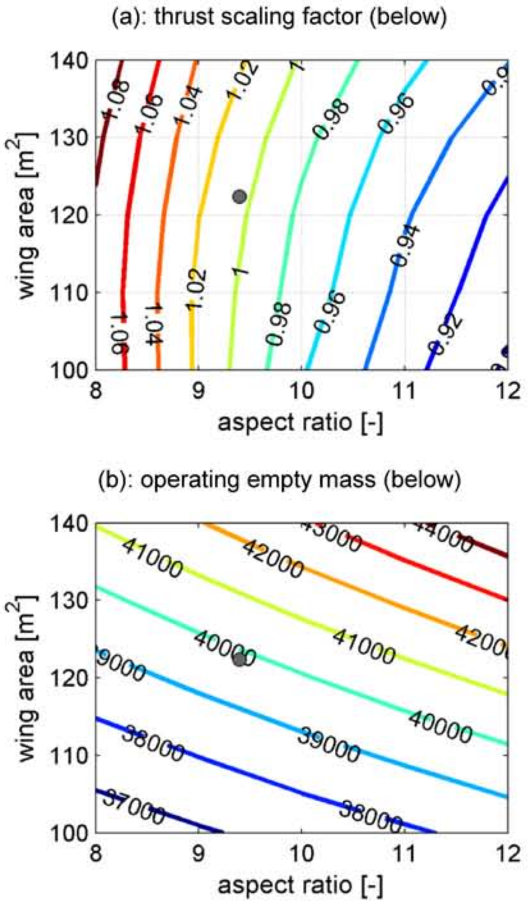


Fig. 7 Disciplinary parameter transfer plot: the influence of wing area and aspect ratio on engine scaling requirements (a) and aircraft empty mass (b) [D150 reference aircraft indicated by grey dot]

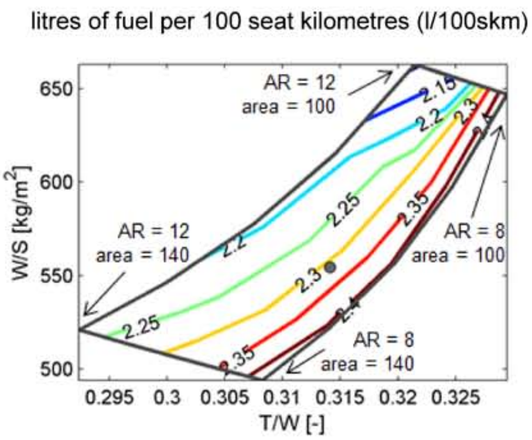


Fig. 8 Level transfer function showing relative effect on litres of fuel per 100 seat-kilometres for changing wing loading and thrust-to-weight ratio [D150 reference aircraft indicated by grey dot]

The data represented within the figures above are obtained using a scalable database entry in the engine performance database TWDat. When a team of engineers chooses to further investigate a specific design point, a new data deck should be generated for the scaled engine at hand, in order to improve the accuracy of the results. For this the requirements catalogue as in Tab. 2 can be used.

In future work, correlations like the ones shown in Fig. 7 and Fig. 8 will be used as a basis for communication within teams of engineers. Disciplinary dependencies can be identified and the decision making process is supported by clarifying visualisations. After extending the toolkit with physical analysis modules for disciplines not yet covered, the design space is extended by considering less conventional aircraft configurations. Instead of using a predefined geometrical description of the reference aircraft in CPACS, an aircraft initiator based on knowledge-based engineering principles can be applied to attain a starting configuration [15].

When needed, connections to modules of higher fidelity level can be established using RCE, to cover the parts of the underlying physics that cannot be handled by level-1 tools.

5 Conclusion

Although the technical means to connect aircraft analysis modules are available, large potential for improvement is still found in the application of these modules within multidisciplinary analysis workflows. Methods aimed at efficiently translating knowledge between researchers of various backgrounds involved within aircraft predesign are currently under development. The current work investigated how multidisciplinary interactions and areas of common affinity might serve as initial basis for communication among engineers.

The generation of modularly applicable analysis components requires a change in attitude of the design engineer. It proves to be a large effort to program these components such that a wide variety of aircraft configurations can be analysed without the need for problem-specific tool adjustments. Furthermore, providing disciplinary specific output using visualisations and messages understandable for a widely oriented public, such as workflow integrators, requires major thoughts. Identifying areas of common affinity between the engineers involved forms a starting point for the latter issue.

An initial application of a low level toolkit for combining aircraft and engine predesign has been shown. In the future, the toolkit will be extended with more low-level physics based analysis tools and applied to generate visualisations of cross-disciplinary correlations. When operators, workflow integrators and specialists gather in design teams, these kind of visualisations aid in understanding each other's considerations and interests. The flexibility of arbitrarily connecting analysis modules facilitated by RCE allows the design team to investigate physical trends at a level of detail appropriate to the question at hand.

Once mutual understanding of physical correlations is created, initial design space extensions can be studied using the combined explicit and implicit knowledge of the involved design team members. Extending the design space requires careful analysis of tool results and applicability considerations, since results cannot directly be validated by comparison to familiar aircraft designs. Especially at this stage, clear and streamlined communication among engineers is of utmost importance.

Outlook

In future work, more level-1 modules will be incorporated within the toolkit. When developing these new modules, the modularity of its application in workflows specifically aimed at providing a quick answer to the design question at hand should always be kept in mind. Furthermore, the level-1 toolkit will serve as basis for incorporation of uncertainty considerations within the analysis modules. By adding uncertainty values to the results, the possibility to not only determine the 'goodness' of an aircraft concept or requirements catalogue, but also with which certainty such a statement can be made is established.

A continuation of simultaneous aircraft and engine design is foreseen. The workflow and toolkit will be used to investigate combined unconventional aircraft and engine concepts, among which a strut-braced wing configuration with counter-rotating open rotor (CROR) engine is anticipated. A semi-automated aircraft and engine concept analysis workflow is to be established by incorporating the thermodynamic performance analysis and preliminary engine design environment GTlab [16]. In contrast to the pre-calculated and scaled performance decks used in the present study, airframe and engine conceptual design processes will be directly coupled in order to find the optimum engine cycle parameters for a given set of airframe and mission requirements. This will bring collaboration among aircraft and engine specialists and integrators in predesign phases to a higher level.

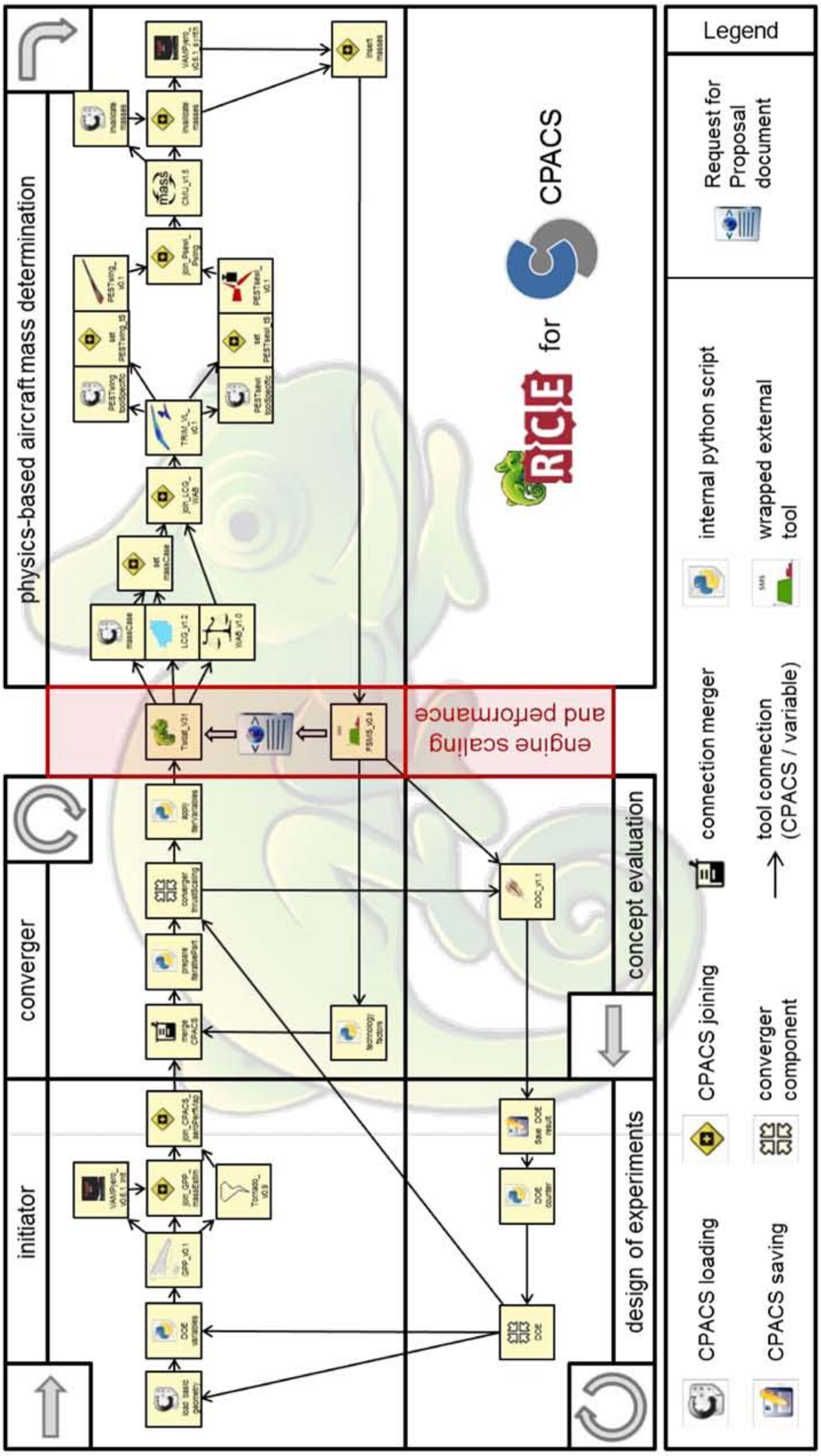


Fig. 9 Workflow of level-1 fidelity in RCE for CPACS

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Integrated Aircraft Design Network

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Keywords: *aircraft conceptual design, parametric modeling, Knowledge based, sizing, XML database*

Abstract

This paper describes the XML based multidisciplinary tool integration in a conceptual aircraft design framework, developed by the Division of Fluid and Mechatronic Systems (FluMeS), Linköping University. Based on a parametric data definition in XML, this approach allows for a full 3D CAD integration. The one-database approach, also conducted by many research organizations, enables the flexible and efficient integration of the different multidisciplinary processes during the whole conceptual design phase. This central database approach with a detailed explanation of the developed geometry description and the data processing, focusing on the CAD integration is presented. Application examples of the framework are presented showing the data build up and data handling.

1 Introduction

Information is generated by tools, normally coupled towards intern or proprietary data structures. In a multidisciplinary design process information has to be propagated among tools and has to be fully accessible to any tool at any time. This dilemma leads either to a central "one-tool" or a "one-database" approach.

The one-tool approach cannot solve the problem since it is not a practical and justifiable solution as different applications need different tools for different needs. Hence the best and optimal solution would be the one-database approach. RAPID and Tango are tools are being developed in CATIA and Matlab respectively, to address one-database approach. In order to maintain flexibility and allow the developer to choose the preferred work method, both programs are implemented in parallel. Switching between the two is possible at any time [1]. Within this framework traditional handbook methods [2] till [4] are employed in the design. Similar aircraft conceptual design programs, [5] till [9] are developed by research institutions, universities and companies.

2 Data Management

Data created in RAPID or Tango can be delivered in the *"eXtensible Markup Language"*, (XML) format [15]. XML allows applications to represent electronic documents or text data in an easy to understand and transferable format between programs.

XML is made up of markup tags and data to represent the information. An XML forms a tree structure, this makes it easy to retrieve data and find relationship between different information represented in the XML.

Transformation of XML Document is favorable performed by XSL Transformations (XLST). XSLT uses XPath language to navigate in XML documents. It can serve for complex translations such as element and attribute editing (add, remove, replace), rearrangement, sorting, perform tests and make decisions [15].

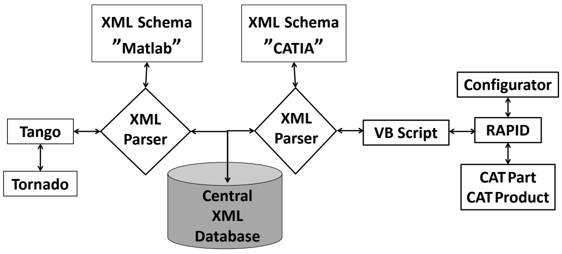

Fig. 1 XML data flow the two main applications RAPID and TANGO with the help of XSLT.

2.1 XML Integration

2.1.1 RAPID XML Export

Excel Visual Basic Application (VBA) is used to configure the CATIA [16] parameter or geometrical sets and generates into an XML. The following steps are implemented in creating XML from RAPID

- **Configuration of Parameter and Geometric sets through Excel:**
  Configuring the parameters through Excel will reduce the effort of adding changes to the code whenever a new parameter/geometrical set need to be added to the XML. The configuration contains three main parts in Excel:
  <u>Parameter String</u>: represents the parameter set/geometrical set from CATIA. All the parameters within the parameter set will be made as XML. Example:
  `reference\inputparameters`
  <u>Parameter Array</u>: used for making XML tags to the parameter sets or geometrical sets and parameters. Depending on the depth of the XML tree, number of values in the Array String is needed. Example: `XML node-` `<part name= “reference”>`.
  <u>Array List</u>: Needed to put together parameter sets from the same part into one list. Each part will have one corresponding Array List. Example: `fuselage\inputParameters\&` `“fuselage\instantiatedGeometry\”` should come under the same part fuselage in XML. So they have same array list Name `fuselageList`.

- List “Hash”, is a dictionary object [18] (key, value) that is used in the code because of the Array List column that comes from Excel. The Array List column gives only Array List Names but does not create them. This handles the grouping of the parameter sets with the same Array List into one list instead of separate ones. For the first time an array list for a given name is created, thereafter it does not create a new array list if the name already exists.

- **Value Parsing:**
  To parse the CATIA parameters and translate them to XML, two loops are used: The outer loop runs through all the parameter lists from CATIA and inner loop, runs through the parameter list of the Excel sheet. Strings from CATIA are compared with strings from Excel and the matching strings from CATIA are created as XML.

- **Writing into XML using DOM Object:**
  For efficient XML editing, Microsoft. XMLDOM object is used in the VBA section to translate the parameter/geometric sets into XML. The DOM object creates the XML file and takes care of the formatting and structure. This data set tree related access method also helps in modifying the XML without any hassles or cumbersome coding.

- **Spline from CATIA to XML:**
  The spline in CATIA cannot be handled similar to that of the rest of the parameter/geometrical sets, as the coordinates of the points in the splines are not available directly in CATIA tree. The geometrical set in CATIA is taken

as a parameter string from Excel, where the sketches are added. One array each is used to store the x, y, z coordinates of the spline control points from the `exchange Curves`. Example: `"fuselage\exchangeCurves"`.

- Finally the XML DOM object is written to file and saved as XML.

2.1.2 XML to RAPID Import

The following steps are performed to read XML to RAPID:

- **Parsing the XML using DOM object:**
The XML file is loaded into a DOM Object. This DOM object is parsed for the required information and tags.

- **Recursive Function to get child nodes:**
The values of parameters that need to be updated into CATIA are stored in the child nodes with a `value tag`. A recursive function is used to get all the child nodes with a `value tag` from the XML and the corresponding text in these nodes. These texts are the new values to be updated.
- **Constructing the Parameter Strings to be updated:**
The parameter string that needs to be updated in CATIA needs to be constructed; a recursive function is used to get the parent nodes for the child nodes with the `value` tag. These parent node tags are appended along with "\" to form the string.

- **Spline from XML to CATIA:**
The existing spline is deleted first. The spline values in XML are stored as Control Points with x- and y-value Nodes `(xvalue, yvalue)`. These Nodes are recursively read using DOM object. Using these x/y points, new Control Points are formed and then a new spline is created in CATIA

- **Updating CATIA:**
The parameter Strings along with the corresponding values are updated in the CATIA using VBA – CATIA Functions.

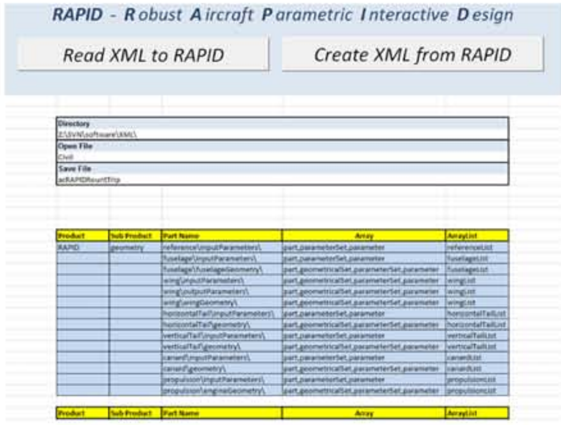

Fig. 2 The RAPID-XML Interface

2.2 Tango XML

Tango makes usage of the underlying Java DOM application classes in Matlab that serves for the XML data handling. This data is handled object oriented within geometrical or functional classes, so that every class includes the class-related XML parsing functionalities. This method allows for greater flexibility and fast replacement or appending of new classes.

The basic classes are product–geometry related arranged (e.g., wing and underlying wing partition class), whereas the higher level classes are product-functional (system) related (e.g., fuel system, primary flight control system). This class reference transition within the dataset makes it necessary to work with part pointers in order to link the functional classes with its related geometrical properties in the geometry related classes; Examples are the control surfaces (geo. def.) that are part of the PFCS (sys. def.) and the wing fuel tanks (geo. def.) that are part of the fuel/propulsion system (sys. def.). By these links, the strict hierarchal XML (tree) data structure becomes extended by cross-branch couplings, described by the part pointers.

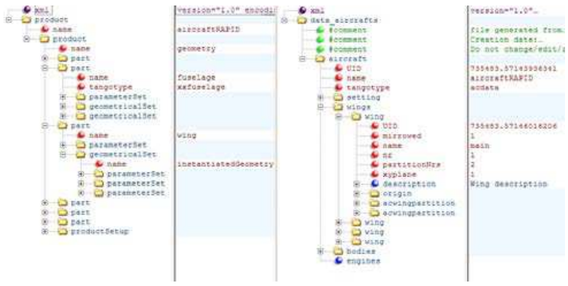

Fig. 3 Data Structure adapted towards the tools needs (Right side: Tango XML, Left Side: RAPID XML

3 Aircraft Geometry Data Description

Aircraft geometry is one of the most import features as it holds the entire information that is needed for the whole aircraft analysis. The aircraft data stored in XML format can be exchanged between different software, thereby decreasing the need and time to redo the aircraft.

3.1 Fuselage geometry description

The geometry is generated with the help of four splines namely `upper curve`, `bottom curve`, `side curve` and `center curve`. These splines form the base for the generation of the fuselage; later the number of frustums for the cross-sections definitions can be instantiated automatically depending on the necessity. Frustums are formed by joining two Bézier cubic curves at each end by means of a surface. The instantiated frustums can be modified to form a wide range of fuselage cross section geometries.

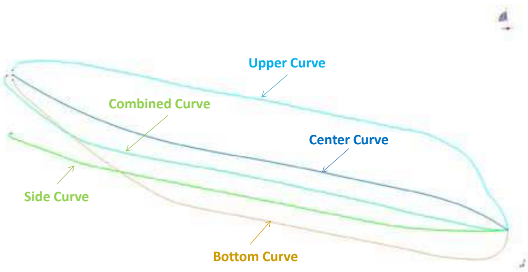

Fig. 4 The spline line fuselage curves

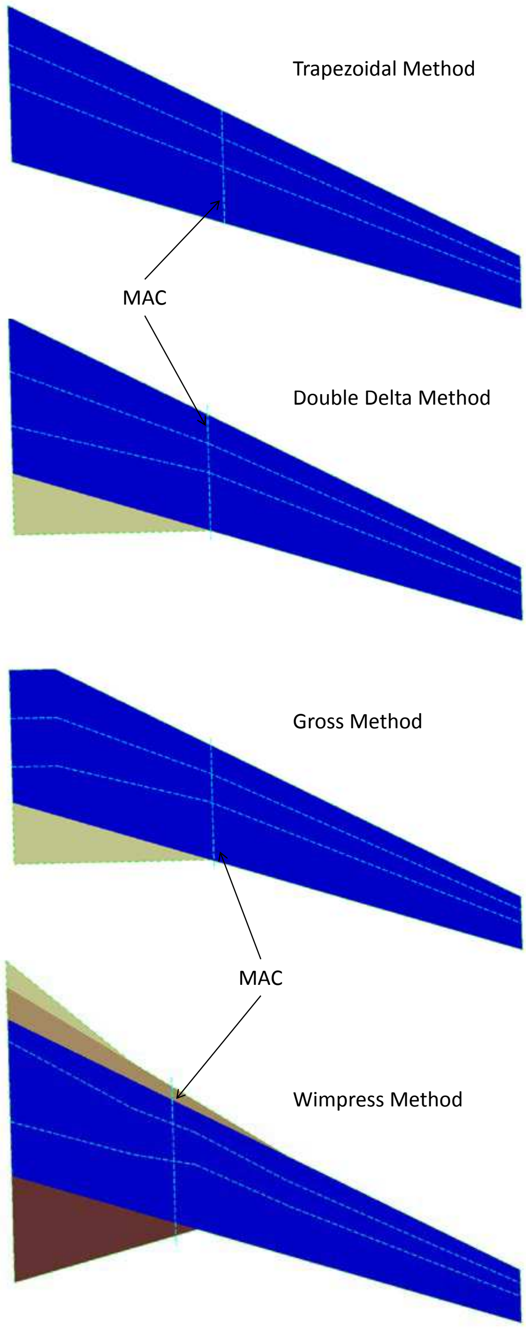

Fig. 5 The four different wing reference area methods used in RAPID

3.2 Wing geometry description

The reference area is the foundation to create a wing. Four different reference area methods are implemented [12]:

- Trapezoidal Method
- Double delta Method
- Gross Method
- Wimpress Method

During instantiation first the trapezoidal area is created, thereafter this area is used as a building block and the rest of the area methods are implemented as in Fig. 5. The wing boundary modifies itself depending on the specified reference area method. The number of wing partitions chosen by the user can be instantiated automatically. Each wing partition is formed by joining two airfoils by a surface. The airfoil is completely parametric and can be modified to obtain a wide variety of airfoils [10].

4 Framework approach

The flow of data between each discipline in a multidisciplinary design environment is coupled and saved in XML format [13] [14], and is accessible by all the required tools. The database definition (including several component libraries like functional assemblies) is parametrically defined in such a manner that a data refinement over time alongside the project is possible. In this way, a transition-less process from low or medium fidelity (in e.g. Tango) up to high fidelity (e.g., in RAPID) is realized as shown in Fig. 8

5 Application examples

This section shows the application examples of the framework, showing the data build up and data translation between RAPID and Tango and vice versa. Two examples have been tested to investigate the data flow processed in the correct approach. In RAPID, as the user has different options of reference area, this might be difficult to pick the correct method. A number of parameters are accessible for the user in order to obtain various configurations. This might lead to a geometry that is over-defined or has a lot of parameters to play with.

5.1 Example 1

In this example the double delta reference method is used. The cross-sections of the fuselage range from a circle to an ellipse. The data was successfully exchanged in both ways.

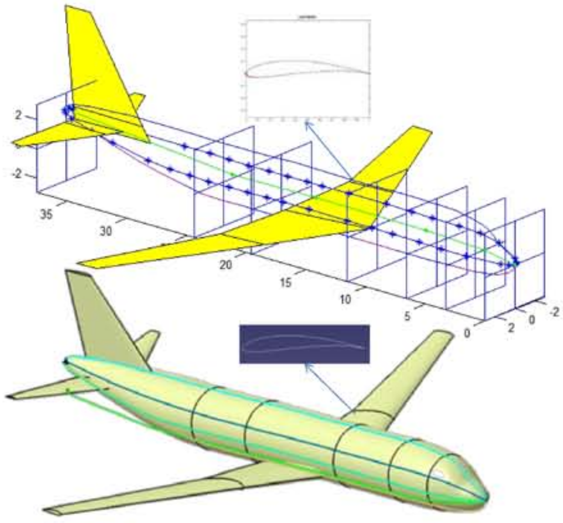

Fig. 6 Civil Aircraft in Tango (top) and RAPID (bottom)

5.2 Example 2

A much complicated fighter aircraft was selected to test as shown in Fig. 7. Data exchange showed promising results. It is to notice that the data structure in the background of both examples is similar with modified parameters with added lifting surface "canard" in the fighter example.

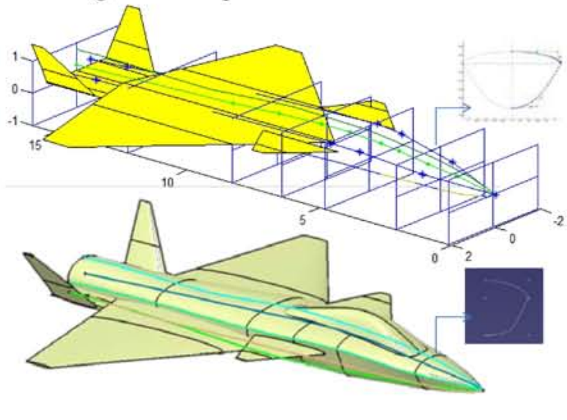

Fig. 7 Military Aircraft in Tango (top) and RAPID (bottom)

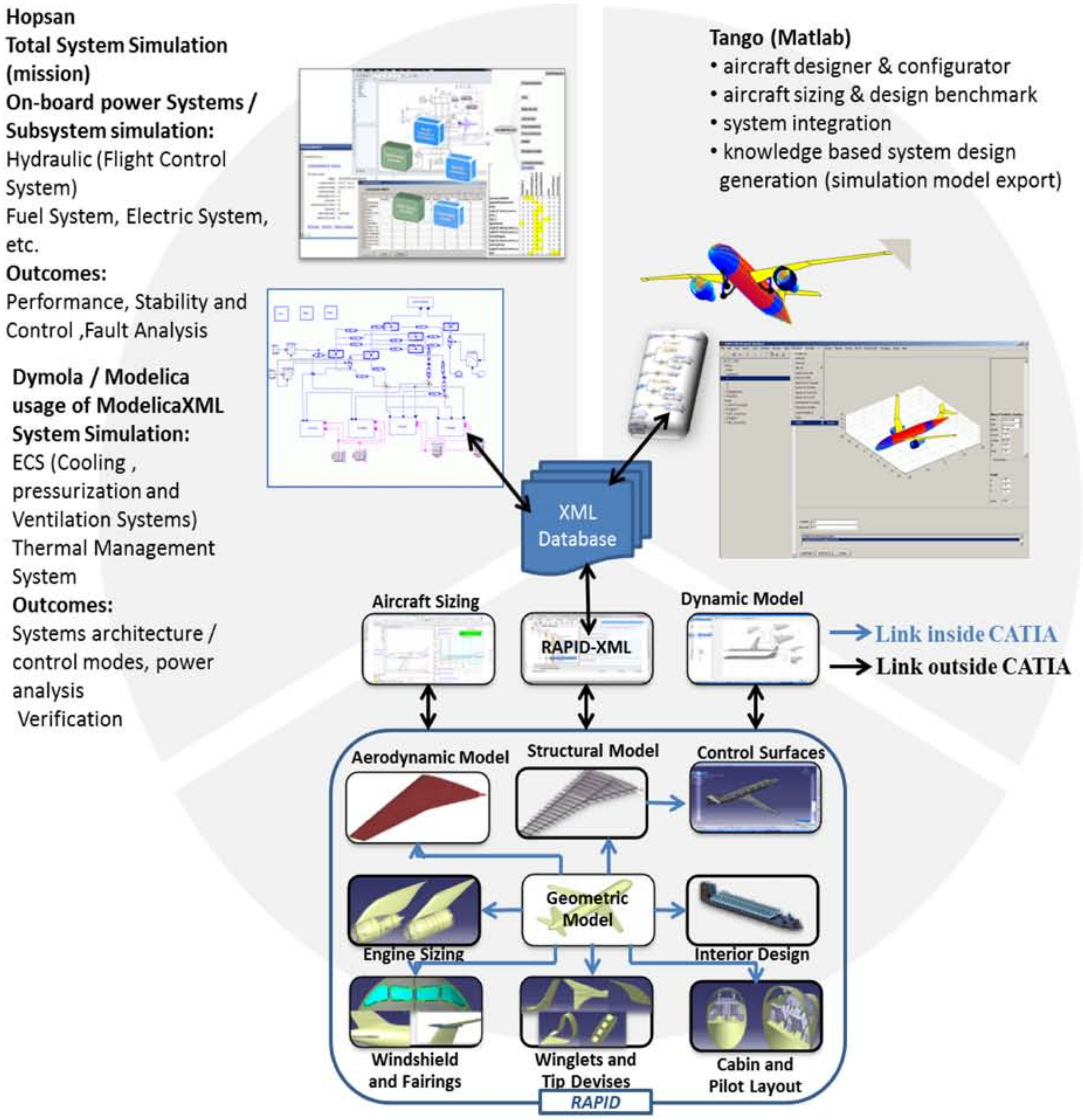

Fig. 8 Integrated Aircraft Design Network

6 Conclusion

The paper shows the multidisciplinary conceptual aircraft design analysis based on a central parametric XML database. This database -containing all project related data- is intended to grow simultaneously with the refined specification of the airplane.

Main advantage using XML is the easy and smart access from literally any programming language which makes it, together with the fact that it is human readable ASCII code, predestinated to be used in multidisciplinary and therewith multi-tool frameworks. These features serve for an easy adaptation and integration of new tools, scripts, etc. Due to the XML data tree structure, the developer has to arrange the data in a certain position, however the strict tree structure fit not totally towards the needs of a complex product as an aircraft; here, because of the transition of the class alignment from geometrical placement (low level) towards system description (high level), these trees have to be extended by cross-nodes pointers.

The 3D CAD description of this data setup is a small fraction of the original data needed in the CATIA environment to establish the geometry; here, extensive usage of knowledge base descriptions, namely *knowledge pattern* and *power copy* concepts are used. This method limits the design space in favor of a slim dataset consisting of rather significant parameters. This allows for a direct access of the geometry for other tools, like a geometrical optimization outside the CAD environment. The unified geometry makes meshing easier and serves for no aperture for high fidelity CFD analysis.

As proposed in Fig. 6 even simulation models can be generated out of the (mainly geometry) XML aircraft description.

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Preliminary Design for Flexible Aircraft in a Collaborative Environment

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Keywords: *CPACS, Collaborative Design, DEE Initiator, Aeroelastic Engine, OAD*

Abstract

The work presents a collaborative design approach, developed to account for the structure flexibility effects in the pre-design stages of generic aircraft configurations. A streamlined design process is developed between DLR and TU Delft, to support the transition from an initial aircraft conceptual solution, to physics based simulations. The TU Delft DEE initiator is the conceptual tool providing the initial design, which is used to instantiate further analysis tool. An Aeroelastic Engine module is responsible for the abstraction of the aircraft structural properties, and the generation of the fluid-structure disciplinary couplings, necessary to account for the flexibility effects. Multiple distributed disciplinary solvers are available, and accessible via a decentralized architecture. All the analysis modules are integrated in the design workflow by means of the open source distributed framework RCE, and the DLR's central data model CPACS. The approach is tested for the pre-design of a conventional aircraft and a box-wing configuration, designed for a set of top level aircraft requirements. Hence, the flexibility effects for both cases are presented. The results demonstrate the importance of accounting for the flexibility effects already in the pre-design phase, especially in case of box-wing configurations, where difference in design performance can occur when ignoring such effects.

1 Introduction

The current visions and technology roadmaps on the future of the air transportation systems pose ambitious challenges for the design of the next generations' air vehicles [1, 2]. However, the assessment of game-changing technologies cannot rely on the conventional pre-design methodologies, which are primarily based on statistical data, and on the application of technology factors to account for potential benefits. Thus, in order to correctly assess the vehicles' behavior and performance, and to minimize the risks associated with the development of unconventional aircraft configurations, physics based simulations have to be included in the early stages of the design process.

Nevertheless, the sophisticated physics based analysis codes currently available in every aeronautical discipline, can be effectively used at the early stages, only if highly automated in the model pre-processing, analysis execution and post-processing of the results.

As identified in Ref.3, automated analysis capabilities relief the designer from allocating significant part of the development cycle to repetitive and non-creative tasks, and enable the large design space exploration required by unconventional designs.

However, state of the art aircraft pre-design systems are often based on automated, but monolithic design codes which cannot easily be managed, or adapted to cope with new configurations, or as new analysis modules become available [4]. The challenge is even higher if analysis modules developed by different parties are planned to be integrated within the same design process.

Further, as soon as the interdisciplinary dependencies are accounted into the design process, the application of MDAO (Multidisciplinary Design Analysis and Optimization) techniques can support the designers to correctly capture the overall aircraft's behavior. However, the introduction of physics based models into MDAO applications demands for disciplinary expertise within the aircraft design process, and for the cross-disciplinary consistency of the analysis models.

In order to cope with the mentioned challenges, DLR is developing a design environment to enable collaborative MDAO applications, within multiple internal projects [5], and with external institutions as well [6, 7].

This paper presents the implementation of a streamlined collaborative OAD (Overall Aircraft Design) process, which makes use of the design and analysis capabilities distributed between DLR and TU Delft, in order to support physics based simulations of conventional and unconventional configurations, already in the pre-design phase.

Among the many tools and disciplines involved in the process, the proposed design system includes a dedicated tool account for the flexibility effects due to the aero-structural interactions, already at the conceptual and preliminary design stages. In fact, although well-established methods are available for linear aeroelastic analyses of modern airplanes, there is still a limited capacity to bring them into the early stages of the design process [8]. Typically the postponed assessment of these effects to the later design stages, adds an "aeroelastic penalty" to the final designed structure [9, 10], and it may even lead to a complete redesign process for novel aircraft. One of the goals of this work is to assess the effect of accounting the flexibility effects in the early design phase, which, as discussed in Section 4, are particularly significant in case of unconventional aircraft such as box-wing configurations.

The integration of the disciplinary modules, such as the aerodynamic and the structural solvers, and the coordination of the workflow governing the fluid structure interactions, is implemented by making use of a centralized data model CPACS (Common Parametric Aircraft Configuration Schema), and the DLR open source framework RCE (Remote Computer Environment).

A brief introduction to the collaborative design environment architecture and to the central data model CPACS is provided in Section 2. The design and analysis components are presented in Section 3. Section 4 describes the application of the process for two test cases, a conventional and a box-wing aircraft configuration and discusses the results. Conclusions and outlook are provided in Section 5.

2 Collaborative Design Environment Architecture

Distributed design approaches [13] offer the flexibility to adapt the design workflow, when new design modules become available, and to tailor the scope of the design investigation. The German Aerospace Center (DLR) has been developing a decentralized design environment to foster the collaboration among disciplinary specialists and the integration of disciplinary expertise into a collaborative overall aircraft design process. The design environment is built on the central data model CPACS (Common Parametric Aircraft Configuration Schema) [11, 12], an arbitrary number of analysis modules, and on the open source design framework RCE (Remote Component Environment) [13], enabling the orchestration of the design workflows.

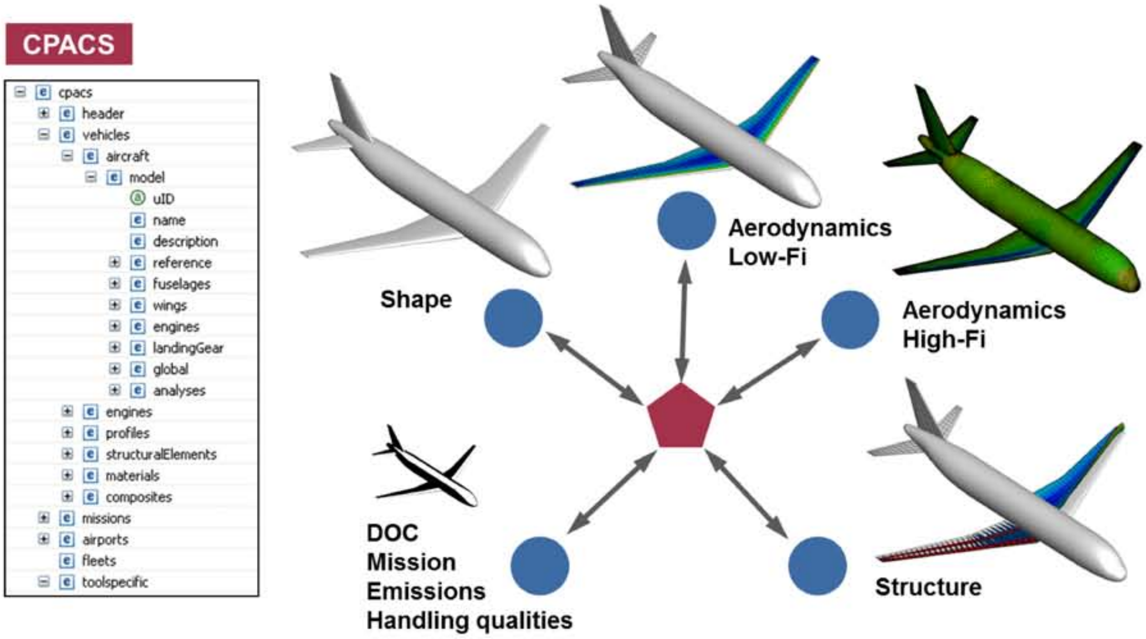

Fig. 1 CPACS (Common Parametric Aircraft Configuration Schema) concept.

CPACS is a data format based on XML technologies, and used for the interdisciplinary exchange of product and process data between heterogeneous analysis codes and name spaces. CPACS contains data such as the geometry of the aircraft model, but also all the parameters needed to initialize and to drive the disciplinary analysis modules, for instance the aerodynamic and the structural solvers. Figure 1 depicts the CPACS concept as a unique data structure, instantiating the disciplinary analysis modules.

The framework RCE enables the orchestration of the design process, and integration of the analysis modules in a workflow. The RCE architecture is based on a decentralized computing system, in which the analysis competences are hosted and run on dedicated servers. Thus, in the design workflow only input and output data are made accessible to the integrator designer, and exchanged during the process, whereas the source codes are controlled by the tools' developers and the disciplinary experts. The system is in operational use in all the DLR aeronautical branches [14, 15], and with external research and academic institutions [6, 31].

3 Overall Aircraft Design (OAD) of flexible aircraft

Typically, during the conceptual aircraft development, many design details are not available, and the overall aircraft synthesis relies on the definition of TLAR (Top Level Aircraft Requirements), such as transportation mission and operational constraints, and on the output of overall aircraft parameters, such as MTOW (Maximum Take Off Weight), aerodynamics efficiency, etc. [16, 17]. Nevertheless, the actual blending of the pre-design activities into the conceptual phases is pushing the development of more sophisticated conceptual design engines, which are capable to instantiate models with number of details beyond the typical conceptual stages [18,19]. Nevertheless, including physics based aeroelastic analyses in these early stages, has to cope with the challenge to generate the appropriate analysis models in a time efficient manner, and guarantee the automated couplings among the heterogeneous disciplinary abstractions.

Further, the shift to physics based analysis at the beginning of the design cycle is associated with the increase of the "aircraft modeling complexities" [20], typically leading to an increased number of the design variables, and a higher domain expertise required to set up the analysis parameters.

Hence, in an OAD application the designers' team faces the following challenges:

- Generation of an initial design, with a sufficient quality, and details, to serve the instantiation of further physics based analysis modules
- Automate the setup of an increased number of parameters, and design variables, associated to execution of the physics based analysis modules;
- Handle and setup consistent disciplinary couplings in MDAO applications, for a multitude of heterogeneous analysis tools.

The aforementioned challenges depend on the complexity of the modeling, and on the physics phenomena representation supported by the disciplinary analysis. Hence the following disciplinary levels can be identified:

- level 0: consisting of typical conceptual OAD approaches, based on empirical relations, and existing databases [16, 17];
- level 1: refers to disciplinary analysis based on simplification on the modeling, and on the representation of the physics phenomena, mainly accounting for linear effects;
- level 2: refers to an accurate modeling of the aircraft components, accounting for a higher level of details, and physics representation accounting for non-linear phenomena;
- level 3: refers to the state of the art of physics simulations, mainly dedicated to non-linear local effects, and whose disciplinary models cannot be fully automated, as required for extensive MDAO applications.

The introduced levels classification is indicated in Table 1, with focus on the aero-structural applications.

Table 1 Disciplinary Levels Classification

Level	Aerodynamics	Structures
L0	Empirical performance estimation	Handbook masses estimation
L1	Subsonic analysis (VLM, Panel method)	Simplified models (FEM beam)
L2	Transonic nonlinear analysis (Euler)	Detailed models (FEM shells), non-linear analysis
L3	Nonlinear non automated (RANS)	Nonlinear local analysis (buckling, crash)

The current study focuses on the integration of L0 and L1, in OAD as a blended conceptual and preliminary design stage. The TU Delft DEE Initiator module is used to generate an initial design synthesis, providing a limited number of top level aircraft requirements. Hence the initial design is coupled via the CPACS format to the physics based modules, such as the aerodynamics and the structural solvers, whose results are integrated into the aircraft synthesis process, till convergence.

The next sections introduce the main aforementioned design modules.

3.1 DEE Initiator

The DEE Initiator [18] is a MATLAB based conceptual design tool able to generate a baseline aircraft configuration, starting from a limited set of top level requirements, such as payload size and arrangement, range, cruise speed, takeoff and landing field length. Apart from conventional turboprop and turbofan aircraft, the Initiator can deal with some non-conventional aircraft configurations, such as box-wing aircraft and blended wing bodies. This is a clear distinctive feature, which makes the Initiator different than any other commercial conceptual design tool currently available on the market.

The Initiator implements some of the classical aircraft synthesis methods available in literature, but integrates and supports them by means of simple geometry models generated on the fly, a vortex lattice aerodynamic simulation tool and an optimization toolbox. These "extra ingredients" make the design process much less dependent on statistics and allow addressing other concepts than conventional aircraft. As shown in Fig.2, the Initiator mainly consists of an initialization module, a geometry model generator, some analysis modules and an optimizer. The "Initiator's initiator", called Initializer, has the task of deriving a first aircraft guesstimate, based on pure statistical data. To this purpose the Initiator can automatically access a large and extensible aircraft data base, which includes also data of non-conventional aircraft configurations extracted from design studies available in literature.

Before proceeding with any further analysis, wing loading and thrust weight ratio are automatically adjusted using an optimization routine, to make sure the aircraft design point satisfies typical top level requirements, such as takeoff and landing field length, climb rate and gradients at OEI conditions, etc.

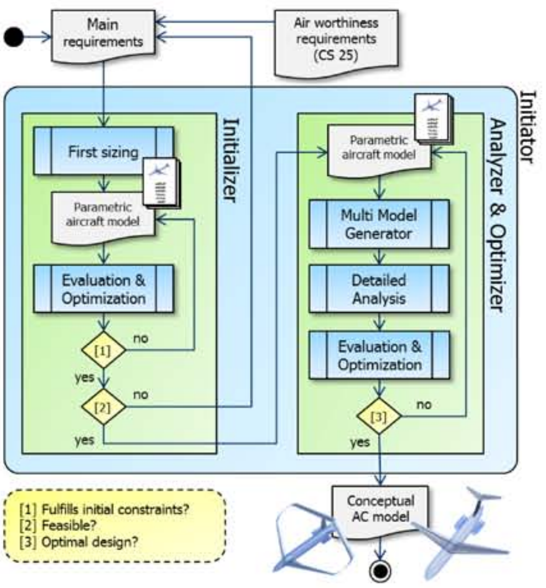

Fig. 2 DEE Initiator structure.

The Initiator geometry modeler is able to create simple aircraft models, where volumes, areas, distances, etc., can be extracted and used as input for the implemented semi-empirical analysis and sizing methods.

In particular, these geometry models are used to feed TORNADO, an open source vortex lattice method (VLM) suitable for conceptual design purpose. Although TORNADO is a low fidelity analysis tool, it allows the Initiator to account on more physics based aerodynamic results than those otherwise assumed based on statistics and generally only valid for conventional aircraft configurations.

A genetic algorithm optimizer has been developed on purpose to endow the Initiator with robust optimization capabilities. The Optimizer allows the designers to assess the impact of various objectives and constraints on the final design of the aircraft and its performances. The optimizer and the VLM tool are particularly useful for the initial sizing of joined-wing systems, where the relative positioning of the front and rear wing and their relative lift distributions need to be properly set to achieve proper stall behaviour and exploit the Prandtl's best wing system concept for minimum induced drag [21].

Some other of the Initiator analysis modules include a class I and class II weight estimation tool, a module for parasite drag estimation and a module for stability & control.

The Initiator can be operated both interactively, via an advanced GUI, and in batch mode. The latter functionality enables the Initiator to be integrated and operated via any workflow management system, such as RCE. Functionalities are in place to export all the generated values (geometry, weights, performance parameters, etc.) in form of Excel tables, or other formats, such as the CPACS described in the previous section.

In this study, the Initiator has been used to generate, starting from a set of top level requirements, two aircraft configurations: one conventional and the other featuring a box-wing system. The generated geometrical models for these types of configurations are shown in Fig.3. The models are thus exported into CPACS format, and can be used to initiate the higher fidelity design and analysis process which is described in details in the next sections.

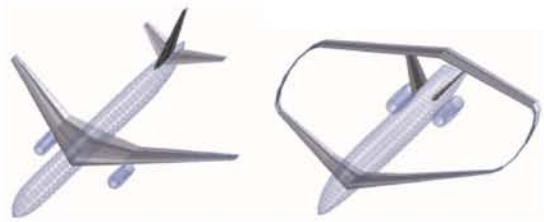

Fig. 3 Geometry models generated by the Initiator for a conventional and a joined-wing aircraft.

3.2 Physics based aeroelastic analysis

As soon as an initial design point is available, the model is advanced to the Aeroelastic Engine, a module developed to support the modeling and the analysis of the complete flexible aircraft for preliminary MDAO applications in a collaborative environment [22, 23]. The module provides hierarchy of physics based disciplinary models for the aeroelastic analysis, and supports the generation of the disciplinary couplings. Although complex analytical methods [24] exist for the structural analysis in the pre-design phases, the proposed investigation is based on the use of Finite Element (FE) representations to cope with unconventional designs. First function of the Aeroelastic Engine is to extract the structural properties that are needed for the aeroelastic modeling of the aircraft. This process, identified as *aeroelastic abstraction*, is dependent on the level of details of the disciplinary analysis involved in the modeling and analysis step. As a Level-1 model, the Aeroelastic Engine initializes the structural layout of the primary structures, extracts the structural properties of the complete aircraft, and finally assembles a multibody FE representation, based on a beam formulation. The primary structures of the lifting surfaces and of the fuselage components are identified, and beam's cross sectional properties (e.g., flexural and torsional stiffness) are derived from the geometry and from the explicit definition of the wingbox layout and fuselage's frames. Substructures, such as stiffeners, are taken into account by a smeared stiffness approach [25]. Figure 4 shows the assembled FE level-1 model produced by the module, for a conventional aircraft.

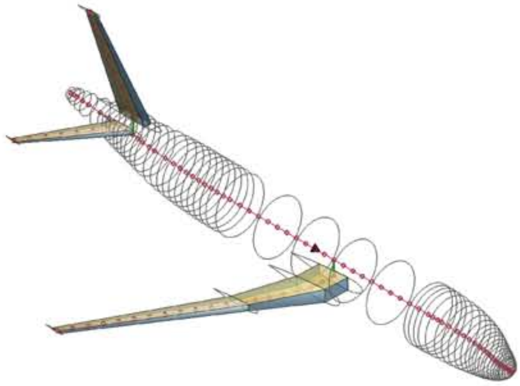

Fig. 4 Aeroelastic Engine FE level-1 Model Abstraction.

The level-1 formulation is part of a hierarchical set of models available for pre-design activities, which can be extracted from a unique centralized model definition [20, 26]. The Aeroelastic Engine provides an internal solver for the FE analysis and post-processing of the assembled models, in order to determine the displacements and the stress fields of the aircraft under multiple load cases. A number of sizing strategies, such fully stress design, and flexural buckling criteria, are implemented for the dimensioning of the selected primary structures.

3.3 Flexibility effects

In order to account for the aircraft flexibility effects, the fluid-structure interactions (FSI) need to be considered in the aero-structural analysis and sizing process. The aero-structural coupling is implemented by first mapping the aerodynamics forces on to the structural model, and then transferring the computed displacements on the structural nodes to the aerodynamic geometry. In a collaborative environment, loosely coupled analysis tools, such as the ones for the aerodynamics and for the structural analysis, are generally employed, with the consequent challenge of automating the generation of the necessary coupling links. The Aeroelastic Engine employed in this research is designed to accelerate the integration of the aero-structural discipline models by automating the required coupling operations on the base of the fidelity of the aerodynamic and structural solvers involved, and the setup of few parameters from the designer side. In the current study an available level-1 VLM aerodynamics tool, interfaced with CPACS [26], is used to estimate the aerodynamics efficiency at various conditions of the flight envelope, and to provide the aerodynamics loading distribution on the lifting surfaces, as resulting from the critical design maneuvers.

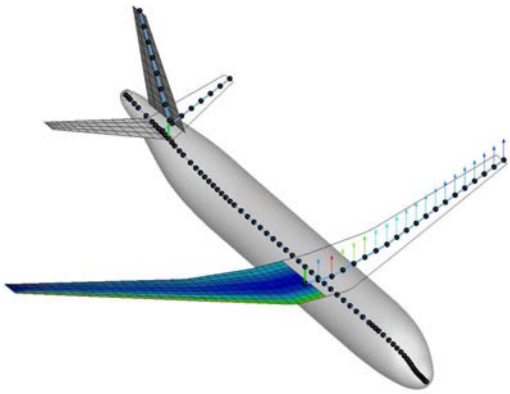

Fig. 5 FSI coupling provided by the Aeroelastic Engine. VLM lattice and pressure distribution (starboard), FE nodes, and nodal forces (port)

Figure 5 shows the results of overlaying the disciplinary models. The aerodynamics mesh and the calculated pressure distribution are shown on the starboard side of the aircraft; whereas the structural FE model is shown for port side. Further on the FE nodes of the main wing are shown the aerodynamics loads, as resulting from the mapping schema from the VLM lattice to the structural grid. Figure 6 shows the structural nodal displacements of the FE model due a test wing-fuselage loading case, and the propagation of the displacements on the geometry, via mesh deformation techniques available in the module, applied directly on the initial geometry, or on the disciplinary grid.

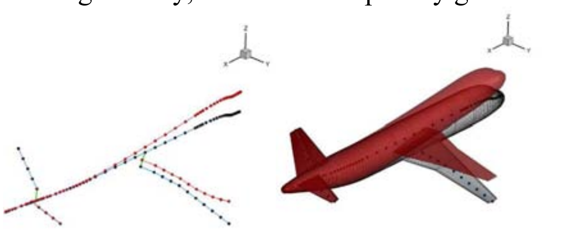

Fig. 6 a) FEA nodal displacements b) Aero-structural deformation propagated to the initial geometry.

The level of automation provided by the Aeroelastic Engine offers the possibility to iterate between the aero and the structural model, hence enabling designers to account for the flexibility effect in the early aircraft design phase.

4 Study cases

The next sections describe the implemented workflow, and two design cases. A tube and wings configuration, and a box-wing design have been selected to demonstrate the ability to address both conventional and unconventional configurations, when using physics based analysis tools.

4.1 Design Workflow

Starting with a minimum set of inputs, such as the transport mission requirements, the DEE Initiator module determines the initial estimation of the aircraft performance for the given design mission, such as the required fuel mass, and the aircraft dimensioning. Hence the initial design is forwarded to the physics based analysis modules, for the aero-structural sizing loop provided by the Aeroelastic Engine.

A 2.5 g pull-up maneuver is selected as critical loading condition, and the aero-structural sizing of the primary structures is performed under fully stressed design constraints, as typical of preliminary aircraft design. The use of the Aeroelastic Engines to size the wing allows to account for a physics based mass estimation.

The aerodynamic performance of the initial design is then calculated, accounting for the structure flexibility effect by means of the Aeroelastic Engine. The FSI coupling is taken into account to determine the lift and drag coefficients of the aircraft, for relevant combinations of angle of attack, Mach and Reynolds number. Hence, the updated aircraft aerodynamic performance, corrected by the flexibility effects, is used to update the overall aircraft design process, and the new aircraft synthesis computes new values of MTOW, and fuel weight. Hence, the design is reanalyzed through the physics based segment of the design process. The multifidelity synthesis loop will continue till the convergence of the design masses [28]. A schematic of the implemented workflow is shown in Fig.7.

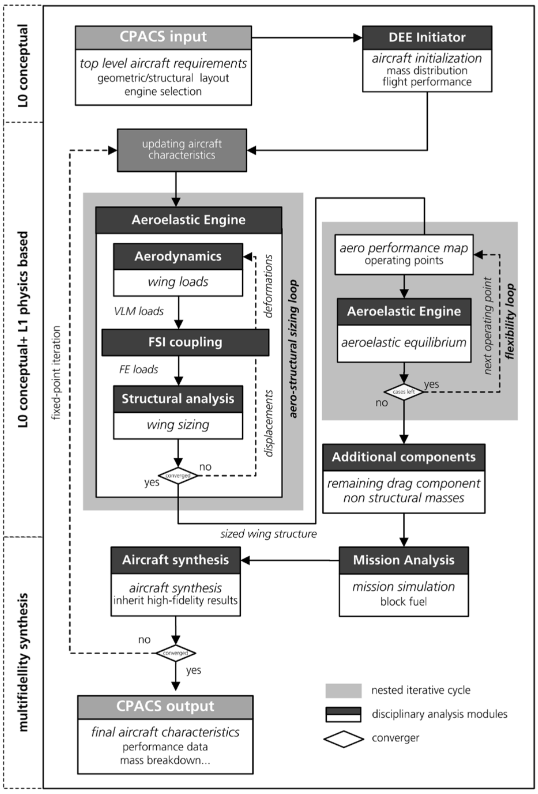

Fig. 7 Design process workflow.

The developed OAD workflow provides a significant level of flexibility, and can be executed with the following modalities:

- Only conceptual design, and excluding the physics based modules in the OAD synthesis: labeled as *L0 design process*;
- Conceptual and physics based design modules, whose analysis results are used to update the OAD synthesis. Although the aero-structural L1 solvers are employed for the structural sizing, the flexibility correction on the aerodynamic performance is excluded: labeled as *L0 + L1 Rigid design process*.
- Conceptual and physics based models, including the flexibility loop in the OAD synthesis: labeled as *L0 + L1 Flexible design process*.

In this, way the designer can tailor the process according to required level of accuracy and/or computational speed.

4.2 Conventional configuration

The conventional configuration is designed to satisfy the TLAR established for the collaborative design challenge, launched during the 2nd symposium on Collaborative Aircraft Design, held in December 2012 at DLR, Hamburg [29].

Among the others, the main mission's requirements are a design range of 2000 nm, at Mach 0.79, with 190 passengers. Although the set of TLAR is sufficient for the conceptual synthesis, additional tools' specific inputs are required for the other disciplinary modules, e.g. materials allocation, selection of the propulsion system technologies. Table 2 provides an excerpt of the design requirements, and other properties used for the aero-structural sizing.

Table 2 TLAR design challenge.

Parameter	Value
Design range (nm)	2000
PAX	190
Mach cruise	0.79
Initial climb	FL 350
Pull-up maneuver n	2.5
σ (MPa)	326
τ (MPa)	242

The overall aircraft synthesis is repeated three times: only conceptual design process (L0 level), conceptual and physics based (L0 + L1 level) with and without flexibility effects. Figures 8 shows the design solution as synthesized by the DEE Initiator, exported as CPACS format, and visualized by the CPACS geometry interpreter TIGLViewer [30]. Figure 9 shows the disciplinary models generated by the analysis tools, namely the aerodynamics VLM lattice for the lifting surfaces, and the FE beam model of the aircraft. The nodal deflections are also shown for the main wing, under the critical sizing load case. The results of the OAD process, such as the take-off mass (mTOM), and fuel mass (mFM), for each of the three synthesis cases, are reported in Table 3.

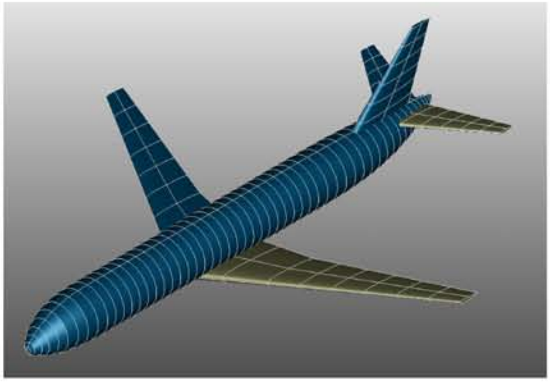

Fig. 8 CPACS Conventional aircraft generated by the DEE Initiator, as visualized in TIGLViewer.

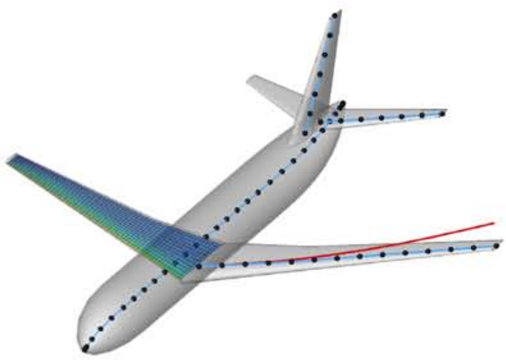

Fig. 9 Aeroelastic Engine VLM lattice (with pressure distribution) and structural model (with nodal displacements shape) of the initial conventional.

Table 3 OAD results Conventional configuration.

OAD	Conceptual L0	Conceptual L0 + Physics based L1	
	Initial	Δ^1 Rigid %	Δ^2 Flexible %
mTOM [kg]	83145.7	-13%	+1.5%
mFM [kg]	18947	-9%	+3%
OEM [kg]	45198	-17%	+1%

1: Δ% respect to initial OAD values
2: Δ% respect to rigid OAD values

The converged aircraft design masses show a difference between the L0 conceptual case, and the one including the physics based analysis. The main difference is in the operating empty mass (OEM) values, resulting by an under estimation of the computed structural masses. For a conventional configuration, conceptual design tools (L0) can provide very accurate results, since extensive database are available, and the synthesis process is calibrated on real aircraft data. On the other hand, physics based analysis would need to account for the simulation of a multitude of critical flight conditions and phenomena, to produce accurate results, without calibration factors. In the current chain a limited set of critical flight conditions, and failure criteria are taken into account, resulting in an under estimation of the sized structures. Nevertheless, the physics based chain enables the simulation of the aircraft physics behavior, by accounting for the deflected flying shape during the various mission segments. For an aircraft featuring a conventional swept-back wing system with moderate aspect ratio, the structural flexibility is known to result into a degradation of the aerodynamics performance respect to the rigid analysis [9], as shown as well by the results in Table 3. In fact the flexibility effect, when propagated through the OAD loop, generates an increase in fuel mass, and OEM in order to satisfy the defined TLAR.

4.3 Unconventional configuration

Additionally the described approach is applied for the analysis of a box-wing configuration. In order to have a reference model to evaluate the resulting designs, the set of TLAR is taken from an existing design from Ref. 30.

As for the previous design case, the aircraft is redesigned three times, using the different modalities offered by the implemented design systems.

Figure 10 shows the model generated by the by the DEE Initiator, and exported as CPACS.

Figure 11 shows the physics based analysis models, i.e. the aerodynamics lattice, and the FE model, and the wing system displacements produced by the critical loading condition.

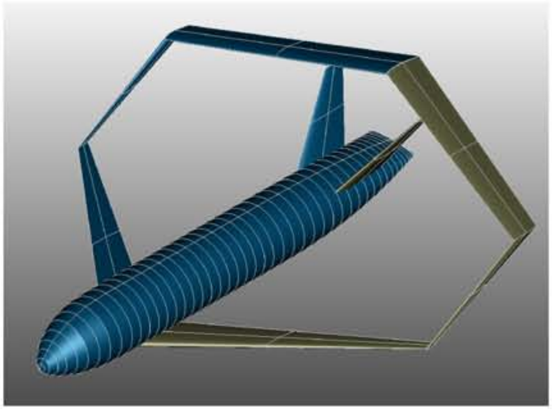

Fig. 10 CPACS box-wing aircraft generated by the DEE Initiator, as visualized in TIGLViewer.

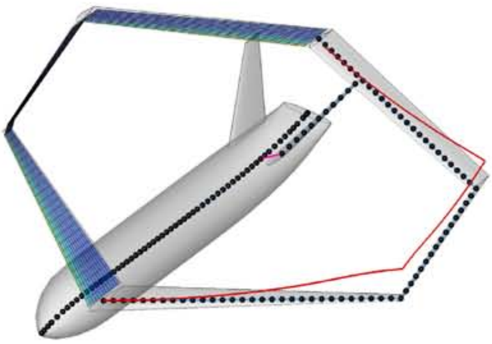

Fig. 11 Aeroelastic Engine VLM lattice (with pressure distribution) and structural model (with nodal displacements shape) of the initial box-wing design.

The results of the aircraft performance and converged design masses are shown in Table 4.

For this case the differences on the final design masses are very limited between only conceptual (L0 level), and the physics based case without flexibility (L0 + L1 rigid). The conceptual module includes in its database box-wing designs, whose data are the results of simulations as well, and it makes use of simplified physics calculation methods for the synthesis. Hence, the conceptual results are much closer to the results synthesis of the physics based approach. On the other hand, for this test case are more interesting the results when the flexibility effects are accounted in the OAD process (L0 + L1 flexible), which were not accounted for in the reference design. In contrast with the conventional case, the OAD synthesis of this specific box-wing design, results in lower design masses and fuel consumption when including the flexibility effects respect to the rigid analysis. It is necessary to point that the behavior of such a configuration is less predictable a priori by the designer, contrary to a cantilever wing type. Therefore, the aero-structural response could be design specific, and an extensive design space exploration using physics based analysis is required to generalize the exhibited trends.

Table 4 OAD results box-wing configuration.

OAD	Conceptual L0	Conceptual L0 + Physics based L1	
	Initial	Δ^1 Rigid %	Δ^2 Flexible %
mTOM [kg]	245551	+1.5%	-2%
mFM [kg]	77474	+1.3%	-2.8%
OEM [kg]	126327	+1.2%	-1.9%

[1]: Δ% respect to initial OAD values
[2]: Δ% respect to rigid OAD values

5 Conclusions and Outlook

The presented collaborative approach and the described design modules, aims at improving the conceptual/preliminary design process, for conventional and unconventional aircraft configurations. A physics based OAD process is developed by DLR and TU Delft, making use of distributed design modules, sharing the centralized parametrization CPACS, and connected by RCE framework. The proposed approach aims at enhancing the design process by accounting for the structure flexibility effects on the estimation of the aircraft performance and on the overall synthesis process. The proposed design approach is based on the use of the DEE Initiator, a conceptual aircraft design module capable to initialize also unconventional aircraft, and of the Aeroelastic Engine, a module developed to support loosely coupled aeroelastic analysis in collaborative MDAO applications. The assembled design system was tested for two design studies. The first study case, presents the OAD results of a conventional aircraft, designed to satisfy the TLAR specified in the collaborative design challenge.

Here the flexible effects have a marginal impact, and the degradation of the performance is expected by the designer. Further, the study highlights the complexities faced by the designer when introducing physics based analysis in the predesign stage.

The second case consists in the OAD of a box-wing configuration. For this design a purely conceptual approach is not sufficient to understand the aircraft physics behavior, and flexibility effects exhibit a large impact on the aircraft performance. Nevertheless, the shown response could be design dependent, and an extended exploration of the design space is necessary to capture and to generalize the trends. Further, only static aero-structural effects are accounted for in this study, and dynamic instabilities are expected to have a critical impact on the design results.

The proposed design process has shown to provide further insight into physics based modeling of aircraft at the early stages, and will be extended in future studies.

Additionally, the distributed approach contributes to the development of improved aircraft design methodologies, but also to the generation of a common, and understanding, between heterogeneous parties, on potential future aircraft configurations. A complementary study, making use of the developed design process, is presented in Ref. 33.

The synergy between the presented design competences is expected to increase in the next studies, encompassing additional design modules, and larger design space explorations, and optimization design cases.

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