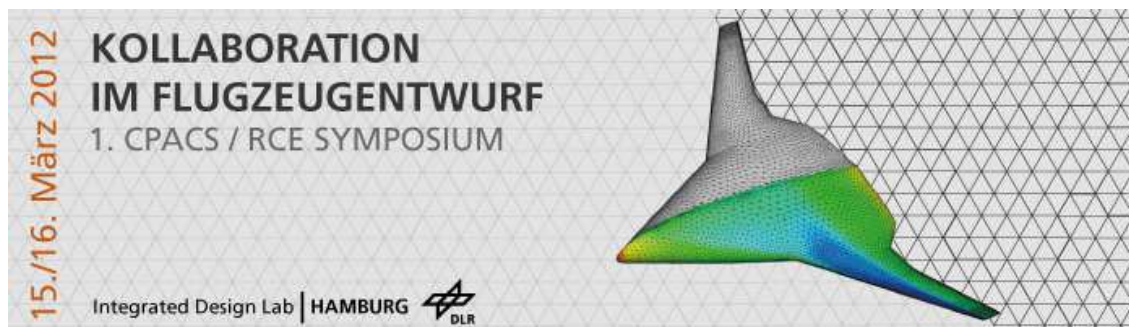


AERO – AIRCRAFT DESIGN AND SYSTEMS GROUP

## Aircraft Preliminary Sizing Tools @ Aero

SAS → OPerA → PreSTo → further Tool Chain

Dieter Scholz      Hamburg University of Applied Sciences



Aircraft Preliminary Sizing Tool



Optimization in Preliminary  
Aircraft Design



Simple Aircraft Sizing

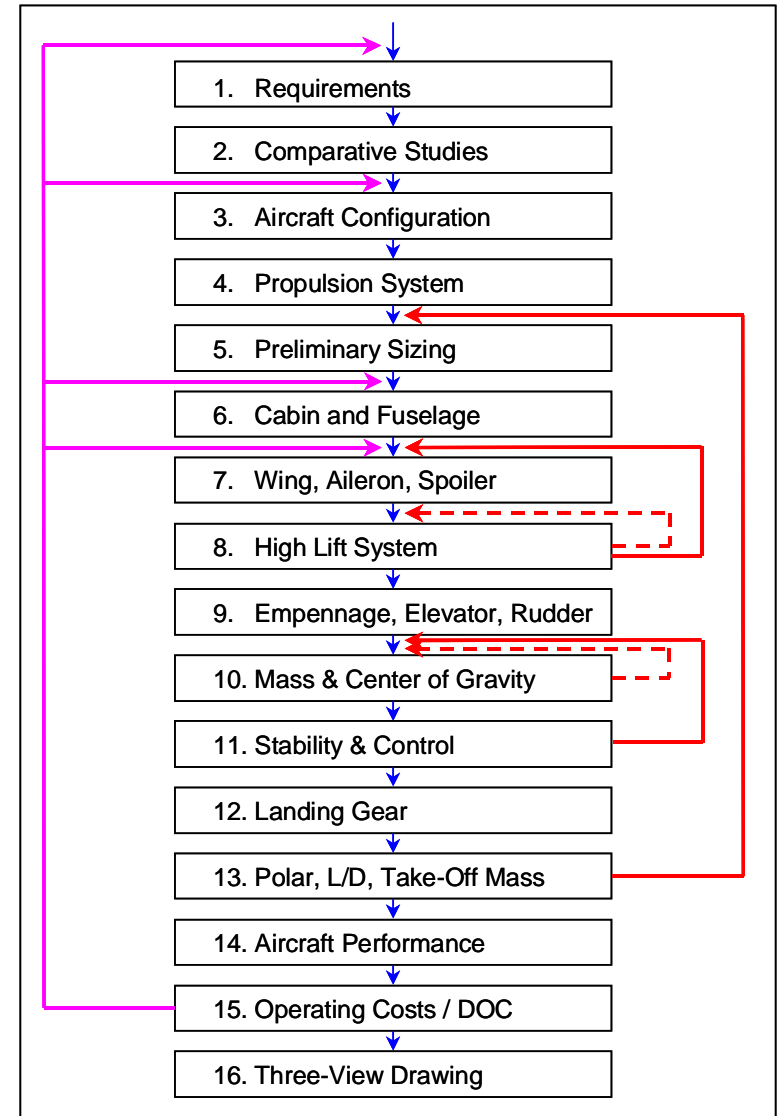
## Contents

- *Aircraft Design* Lecture
- Goals
- **SAS** - Simple Aircraft Sizing
- **OPerA** - Optimization in Preliminary Aircraft Design
- **PreSTo** – Aircraft Preliminary Sizing Tool
  - Screen Shots
  - Data Export / Visualization (CEASIOM, Catia, PrADO, CPACS)
- Further Processing in a Tool Chain
- PreSTo Homepage / Downloads
- Conclusions and Outlook

## Aircraft Design Lecture

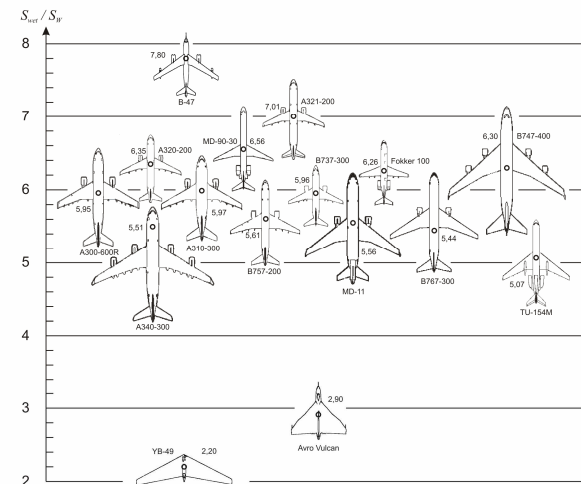
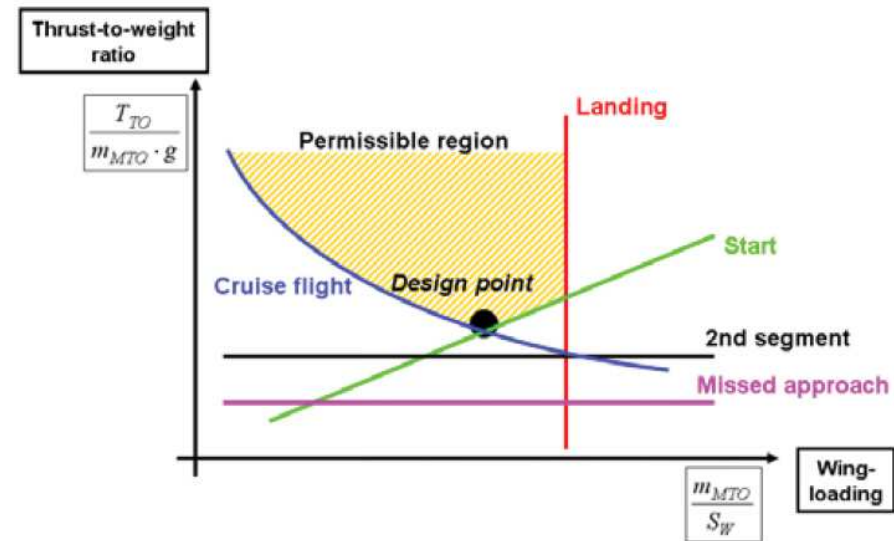
### General remarks

- Lecture is based on methods from:
  - Loftin, Torenbeek, Roskam, Raymer, ...
  - Datcom, ...
  - many own additions
- 16 design steps (see Fig.)
- Emphasis on *preliminary sizing* with *matching chart*:
  - Jet:  $T/W = f(m/S)$
  - Prop:  $P/W = f(m/S)$
- Lecture in this format since 1998:
  - More than 1000 students taught
  - many student reports and theses produced
- Spreadsheet for preliminary sizing is in service for many years: <http://FE.ProfScholz.de>
- Preliminary sizing spreadsheet has been used for:
  - tutorials, examinations
  - projects, theses



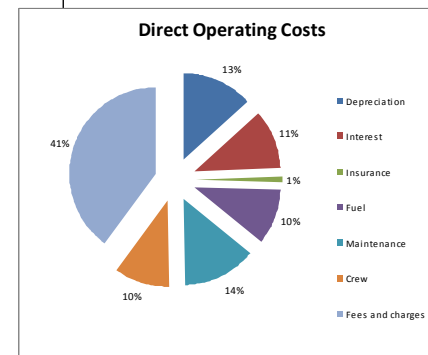
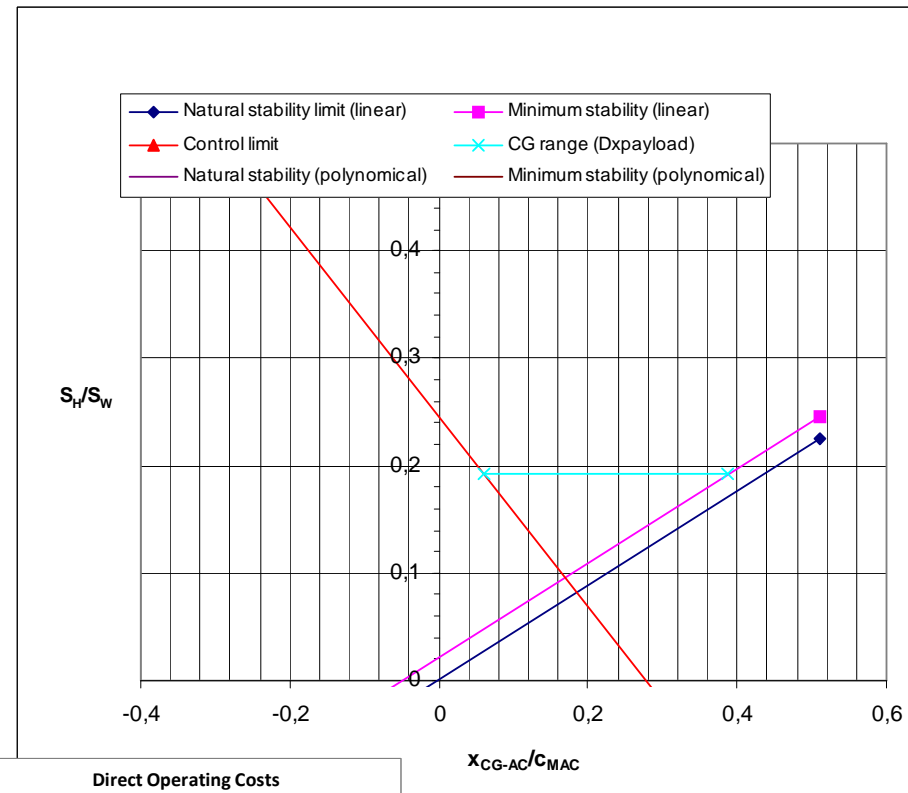
## Aircraft Design Lecture Contents

- Preliminary sizing
  - Matching chart
  - $(L/D)_{max}$  estimation with „wetted aspect ratio“
  - Fuel calculation with fuel fractions
- Cabin & fuselage
  - Seats abreast optimum
  - Baggage and cargo volume check
  - Cross section optimization
  - Cabin surface estimation
  - Ditching check: waterline & door sill
  - Exit type and location: check
- Wing
  - Wing parameters found for best operational characteristics
- High Lift
  - High lift geometry found from trial & error procedure
  - $C_{L_{max}}$  found from Datcom
- Empennage I
  - Sizing from tail volume



## Aircraft Design Lecture

- Mass and CG
  - Mass from three methods
    - Roskam (OEW distributed about A/C main components)
    - „Modified Raymer“ (mass from one key parameter)
    - Torenbeek (well proven)
  - CG determination and wing position correction
  - Loading diagramm (mass versus CG position) for all sensible load cases established
- Empennage II (stability & control power)
  - Horizontal tail
  - Vertical tail
- Landing gear (parameters selected)
  - tip over stability
  - clearance (engine, tail, L/G retraction)
  - Flotation with COMFAA.exe
- Drag
  - Drag from two methods:
    - wetted area
    - skin friction drag, pressure drag wave drag, interference drag
- Design evaluation:  
Direct Operating Coast, DOC  
Method: Association of European Airline



## Goals

- Give full computer support for the *Aircraft Design* lecture by Prof. Scholz / Hamburg
- Start tool with nothing but **requirements**
- Never ask the user for data without giving proper support
- Provide straight forward and **fast solutions** ( => **PreSTo** )
- Give the best support (**didactics, methods, statistics database, ...**)
- Keep **user in the loop**
- Include **expert knowledge** in simple „if-then“ checks and provide answers with red / green buttons
- Provide simple, traceable **optimization** capabilities at different expert levels
- Provide aircraft data for **3D-plots** and **three-view-drawings**
- Couple to higher order tools for further investigation

## SAS – Simple Aircraft Sizing

### For Jets and CS-25:

- **SAS Classic:** The tool used for more than a decade with more than 1000 students.
  - Requirements: Payload, Range, Take-Off & Landing Field Length, Mach Number.
  - Key Parameters: Glide Ratio, SFC, BPR, max. Lift Coefficients, mass ratios, ...
- **SAS Matching:** By automatically adjusting the ratio  $V/V_{md}$ , the location of the cruise line is optimized in the matching chart.
- **SAS Optimization:** An evolutionary optimization algorithm is fitted to SAS Matching.

### For Jets / Props and other Certification Base:

- SAS Jet – CS-23
- SAS Prop – CS-25
- SAS Prop – CS-23
- SAS VLA
- SAS Ultra Light
- ...



## OPerA – Optimization in Preliminary Aircraft Design

### The Aircraft Modeled in Excel:

- Automatic Design: Cabin Design, Wing, Empennage, Landing Gear, ...
- Mass Estimation, Drag Estimation
- SFC estimation
- DOC Calculation with Added Values



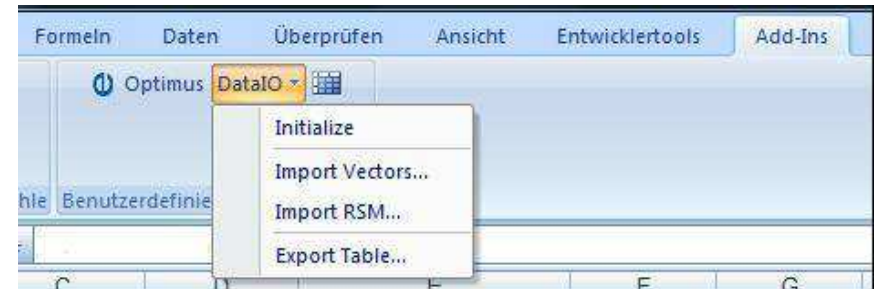
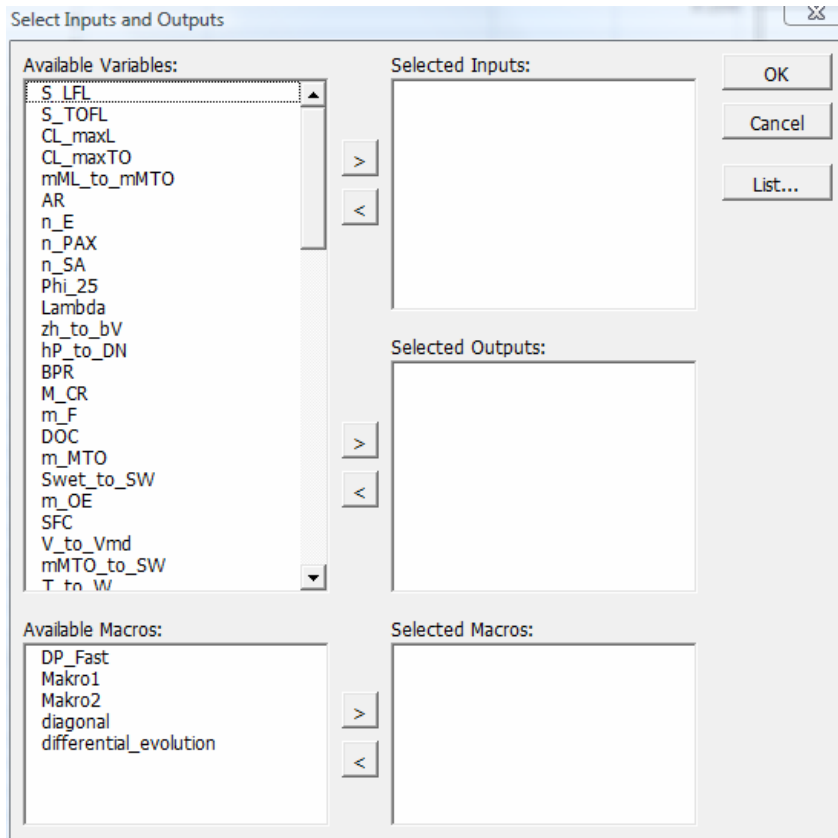
### Optimization

1. Optimus® and Excel connected via Add-In
2. Optimization directly in Excel with VBA:
  - DOE Diagonal
  - Differential Evolution (DE)



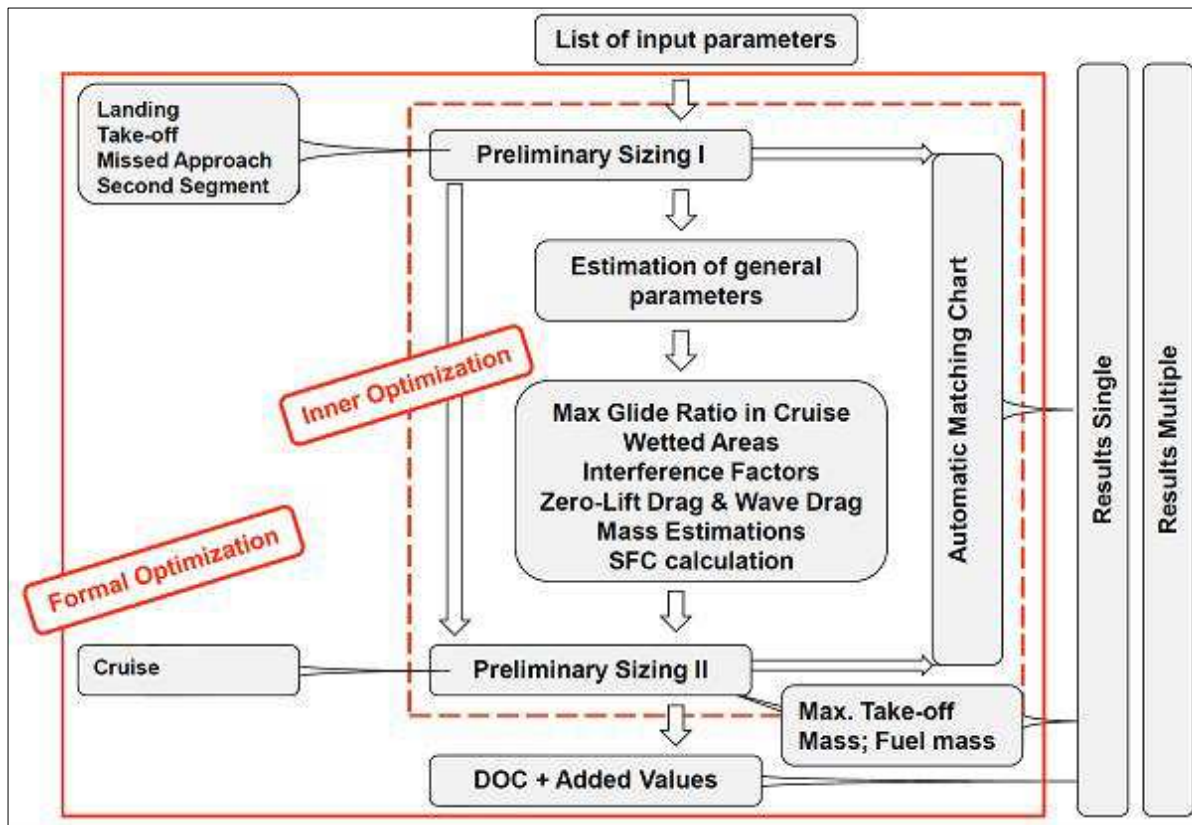
## OPerA – Optimization in Preliminary Aircraft Design

### Optimus® and Excel connected via Add-In



## OPerA – Optimization in Preliminary Aircraft Design

### Program Structure



15 iteration loops

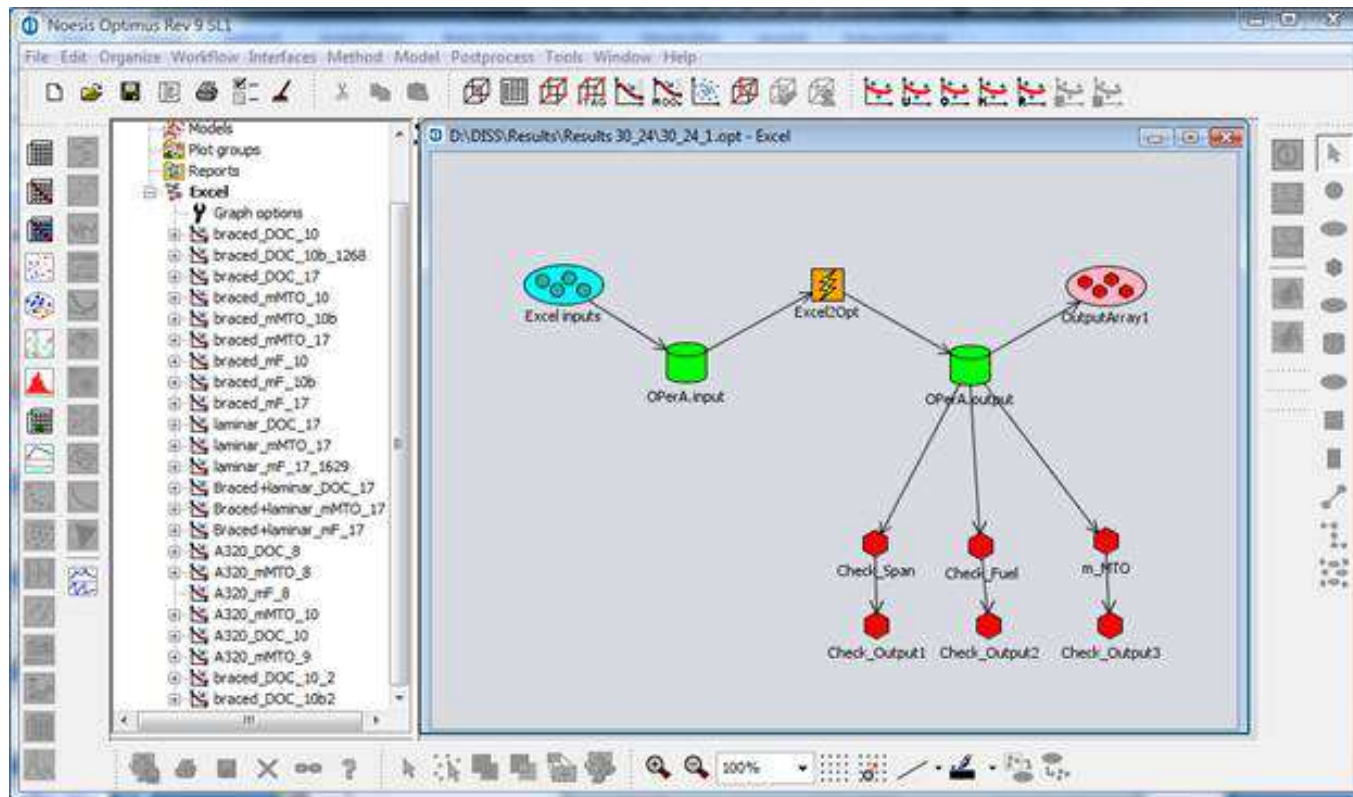
20 optimization variables

about 230 input  
variables

about 150 geometry  
parameters

## OPerA – Optimization in Preliminary Aircraft Design

### Optimus ®



Example of an active workflow window in Optimus ®

## PreSTo – Aircraft Preliminary Sizing Tool

### Screen Shots

#### PreSTo Control Center and Database

**PreSTo - Aircraft Preliminary Sizing Tool**

Version 1.0 <http://PreSTo.ProfScholz.de>

**Aircraft Name:**  
FD 728

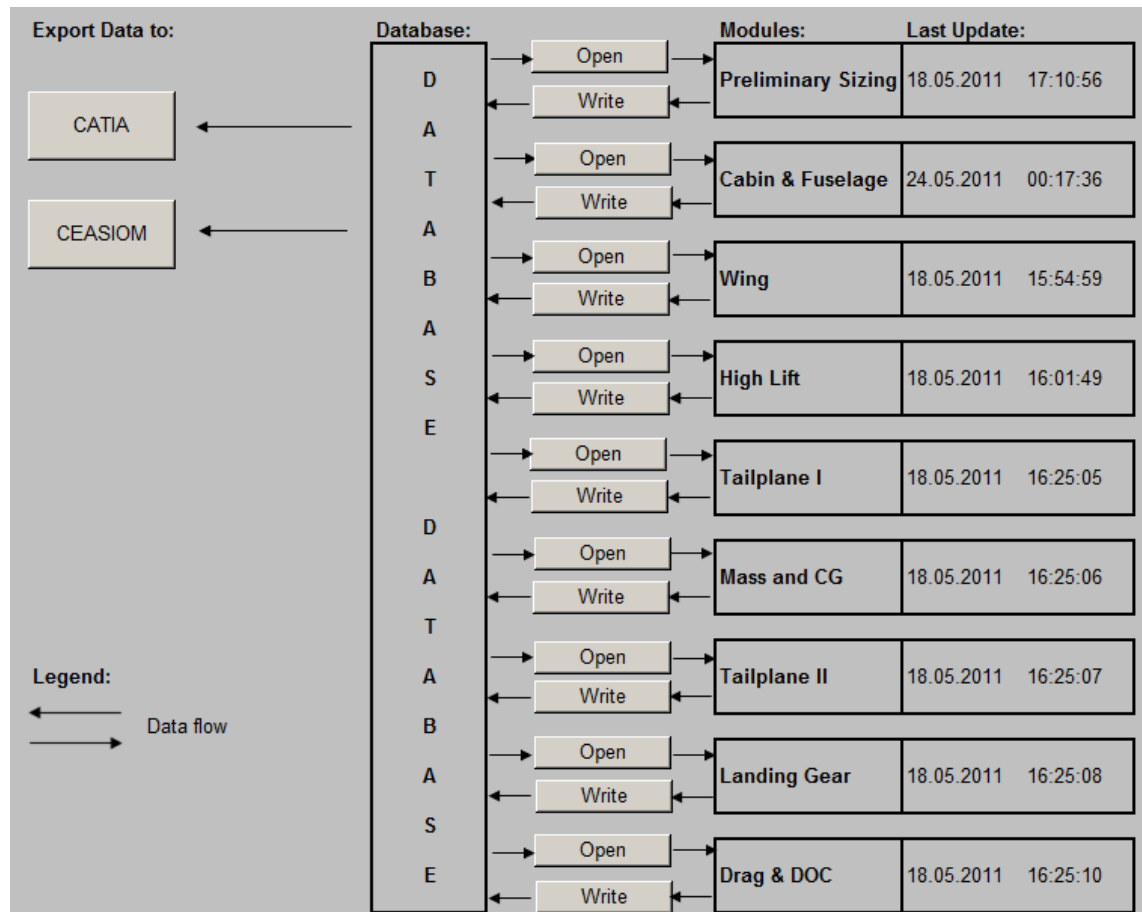
**Description:**  
Redesign

PreSTo Control Center – **Start page**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots

#### PreSTo Control Center and Database



PreSTo Control Center – **Module page**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots

#### PreSTo Control Center and Database


**PreSTo - Aircraft Preliminary Sizing Tool**  
Version 1.0

PreSTo is an Excel spreadsheets based on Prof. Dieter Scholz' aircraft design lecture. This tool allows the user to quickly design an aircraft and optimise it, starting from the basic requirements such as number of passengers, range or cargo mass to continue with its main parts: fuselage, wing, tail, landing gear,... Besides, masses and position of CG also Direct Operating Costs (DOC) are calculated. Further analysis in the area of e.g. flight dynamics or CFD is enabled with the connection to CEASIOM. PreSTo further connects to PrADO and CATIA.

For further information, documentation and downloads see: <http://PreSTo.ProfScholz.de>

PreSTo is a project by:  
Aero - Aircraft Design and Systems Group  
Department for Automotive and Aeronautical Engineering  
Hamburg University of Applied Sciences (HAW Hamburg).

<http://Aero.ProfScholz.de>  
<http://www.fzt.haw-hamburg.de>  
<http://www.haw-hamburg.de>



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PreSTo is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

<http://www.gnu.org/licenses/>

**PreSTo Control Center – License page**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots

#### PreSTo Control Center and Database

	A	B	C
1	R	2550	[km]
2	n_pax	99	[-]
3	m_cargo	0	[kg]
4	M_CR	0,81	[-]
5	S_LFL	1420	[m]
6	V_APP	135	[km/h]
7	S_TOFL	1463	[m]
8	n_E	2	[-]

PreSTo Control Center – **Database**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Preliminary Sizing

User open und close  
Chapters with + / - sign

Preliminary Sizing – **Start page**

**Preliminary sizing of jet & large propeller driven aircraft**

Please choose a design mode or press the 'COMPARE' button to compare both versions:

JET      PROP      COMPARE

1. General preliminary sizing data - JET  
2. Landing - JET  
3. Take-off - JET  
4. 2nd Segment - JET  
5. Missed approach - JET  
6. Max. Glide Ratio in Cruise - JET  
7. Cruise - JET  
8. Matching Chart - JET  
9. Preliminary Sizing - JET  
10. Preliminary sizing results - JET

**Results / selection**

Select: Aircraft type for use in following sheets

Jet

Results used in following sheets

Wing loading  $m_{MTO}/S_w$  469 [kg/m<sup>2</sup>]  
Thrust-to-weight ratio  $TTO/m_{MTO} \cdot g$  0,324 [-]

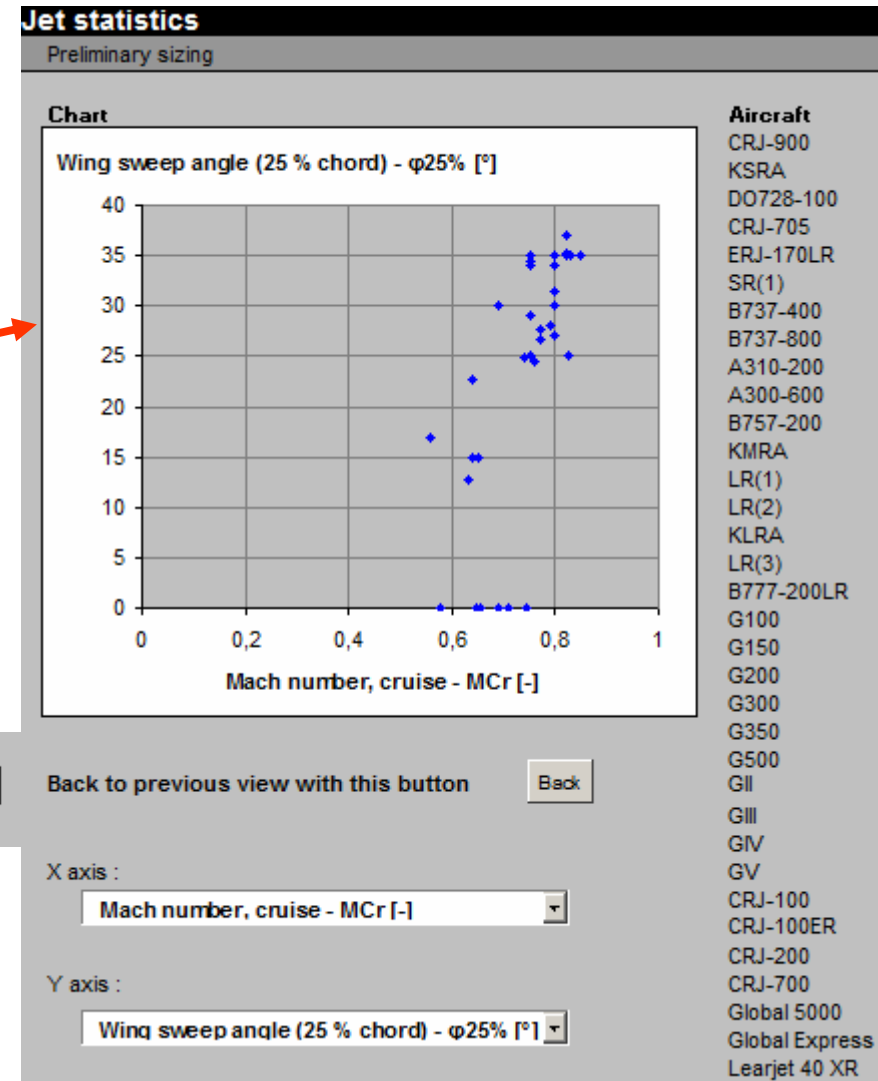


## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Preliminary Sizing

User may select data based on **statistics**

User may select data based on **pop up hints**



$S_{wet} / S_w$

6,2 [-]

**Swet / Sw = 6,0 ... 6,2 for commercial aircraft**

Preliminary Sizing – **General statistics**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Preliminary Sizing

$$E_{max} = k_E \sqrt{\frac{A}{S_{wet} / S_W}}$$

Buttons starts statistics database

Estimation of max. glide ratio, Emax

Choose: factor  $k_E$

15.8

Stat J

Relative wetted area

$S_{wet} / S_W$  6,2 [-]

Stat J

Aspect ratio

A 9,806592 [-]

Max. glide ratio

$E_{max}$

19,87 [-]

Max. glide ratio

$E_{max}$  chosen 19,75 [-]

Suggestion

White: User input data  
Gray: System calculated data

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Cabin & Fuselage

User **input and results are checked.**  
Green means „ok“

**Exit distribution analysis** Start analysis

Total of allowed passengers through exits  [-] > Number of passengers  [-]

Overall number and size of exits is correct According to CS 25.807 (d)

Distance between exits The distance is greater than the fuselage length factor According to AC 25.807-1 (6) (b) (2) (v)

Distance between exits The distance is smaller than 60 ft According to CS 25.807 (d)(7)

Check of exit zones according to AC 25.807-1 (6)(b)(1)

Zone	Allowed PAX	Effective number of PAX
A	125	66
B	125	84

Check of exits positions according to AC 25.807-1 (6)(b)(2)(vi)

Exit	Position		Type	Offset		Allowed PAX
	Nominal	Actual		[m]	[% cab. length]	
1	1,48	1,48	Type C	0,00	0,00	55
2	12,61	12,48	Double Type III	0,13	0,57	70
3	23,73	23,73	Type C	0,00	0,00	55

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Cabin & Fuselage

Cross section dimensions (from Economy Class)

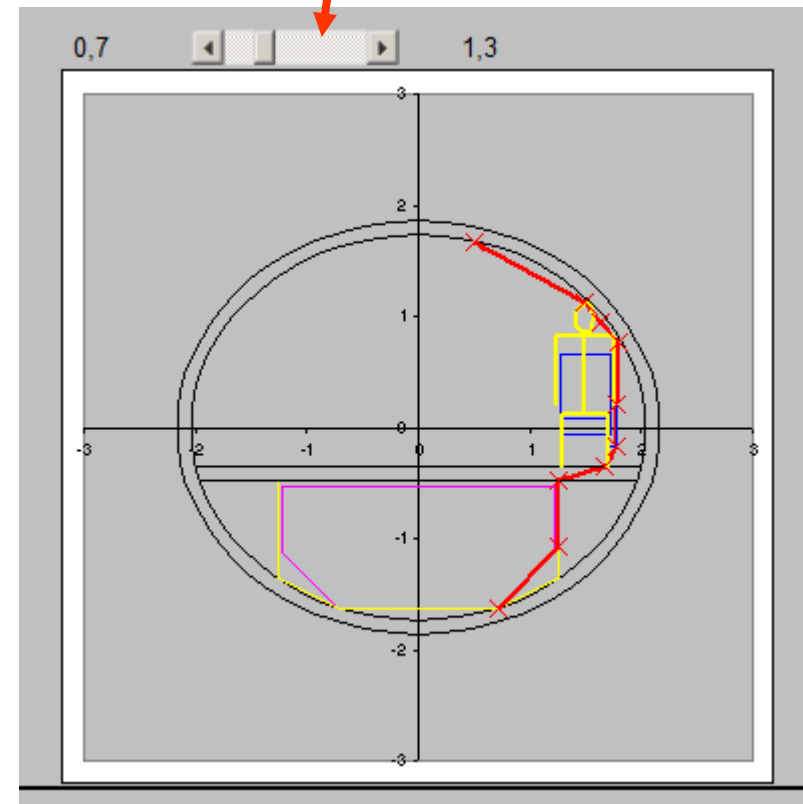
Automatic calculation

Automatic optimization

... to minimize this:

$d_{f,o}$	<input type="text" value="4,01"/>	[m]	Optimize cross section parameters such that the equivalent outer diameter is a minimum. This will lead to a minimum wetted area of the fuselage and hence a minimum skin friction drag.
$t_{floor}$	<input type="text" value="0,136"/>	[m]	
$h_{f,o}$	<input type="text" value="3,72"/>	[m]	
$w_{f,o}$	<input type="text" value="4,33"/>	[m]	

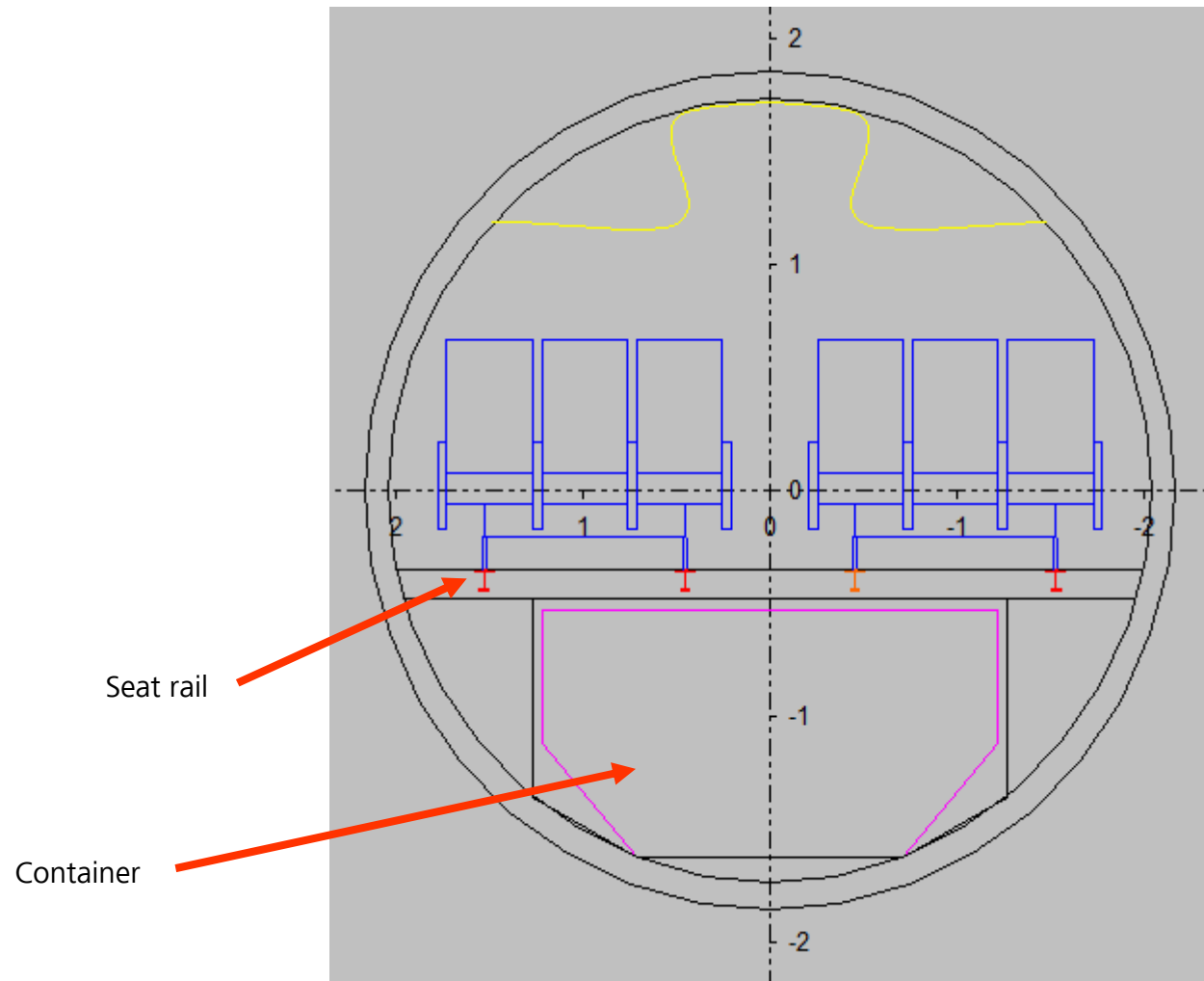
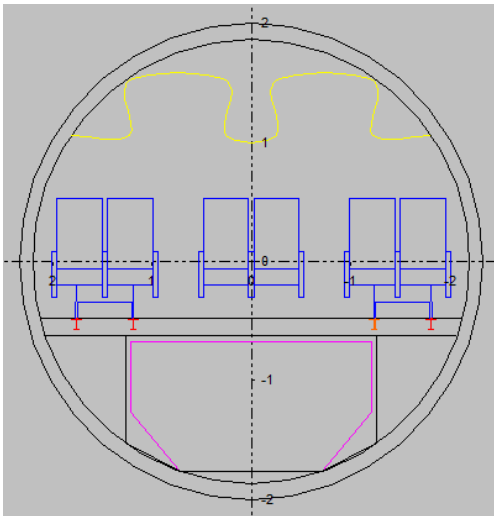
Change this ...



## PreSTo - Aircraft Preliminary Sizing Tool

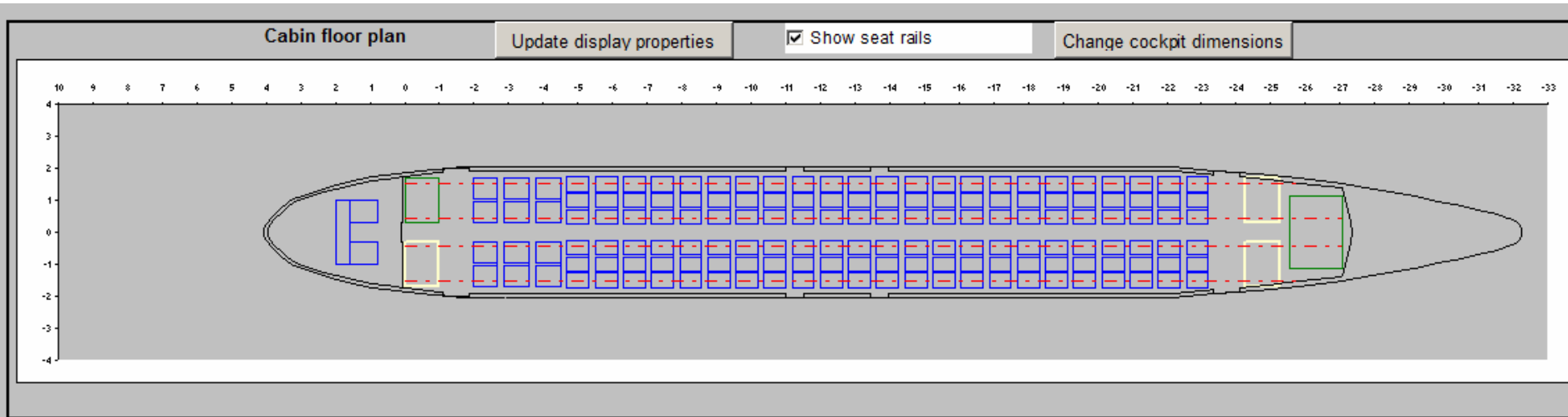
### Screen Shots Cabin & Fuselage

Alternative seat arrangement:



## PreSTo - Aircraft Preliminary Sizing Tool

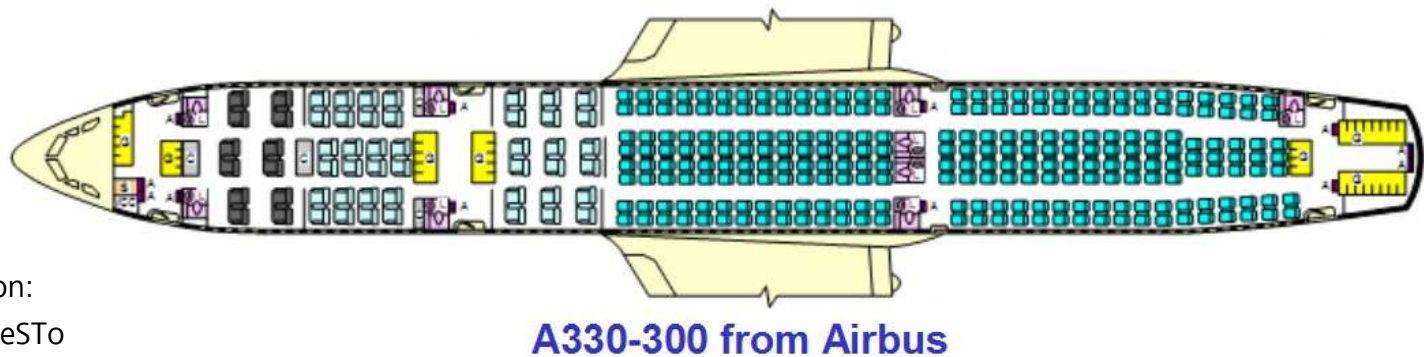
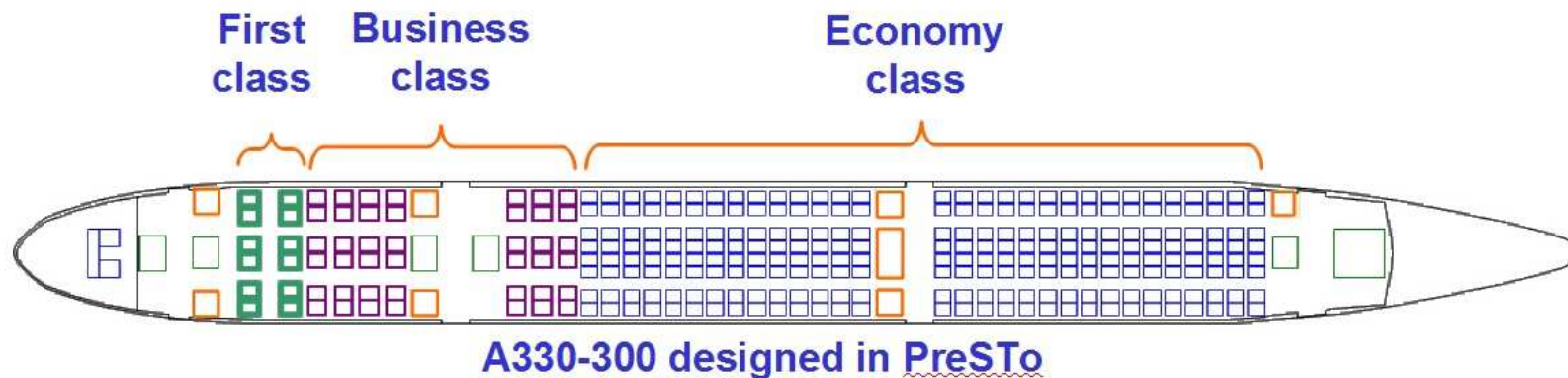
### Screen Shots Cabin & Fuselage



Seat layout

## PreSto - Aircraft Preliminary Sizing Tool

### Screen Shots Cabin & Fuselage



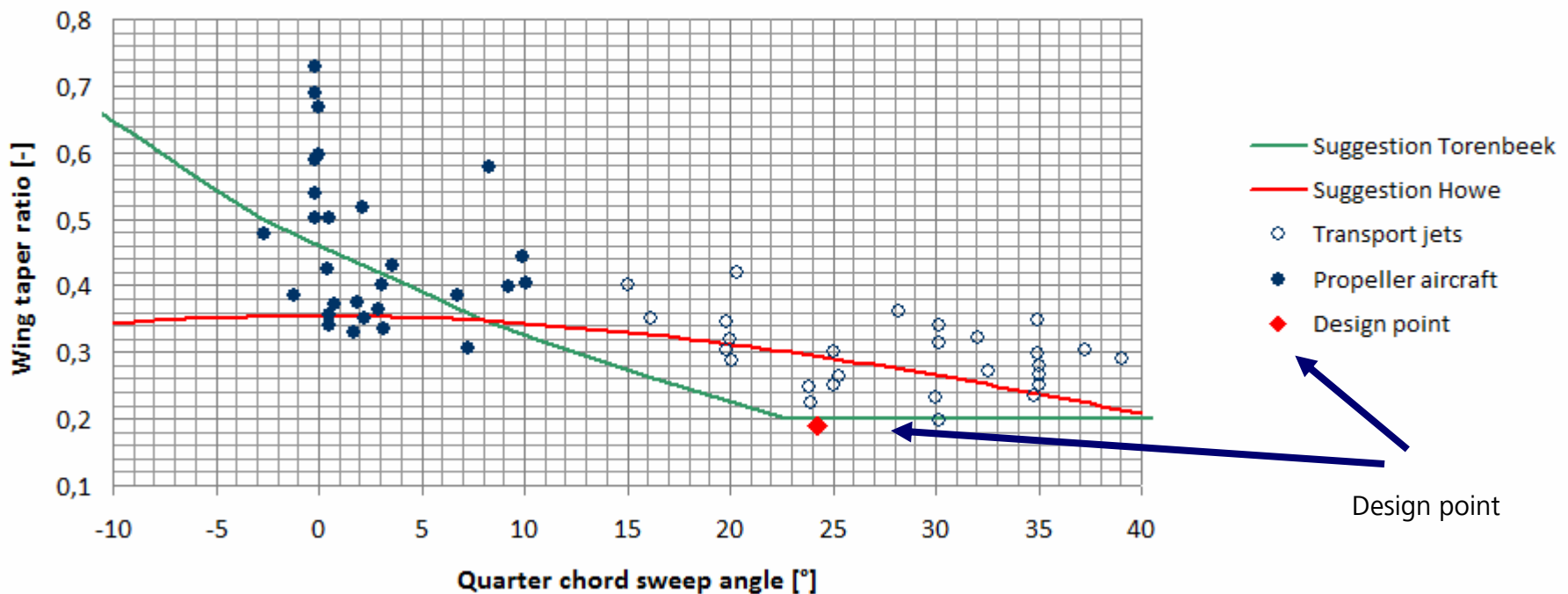
Seat layout comparison:  
Airbus original and PreSto

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots

#### Wing

#### Taper ratio suggestion



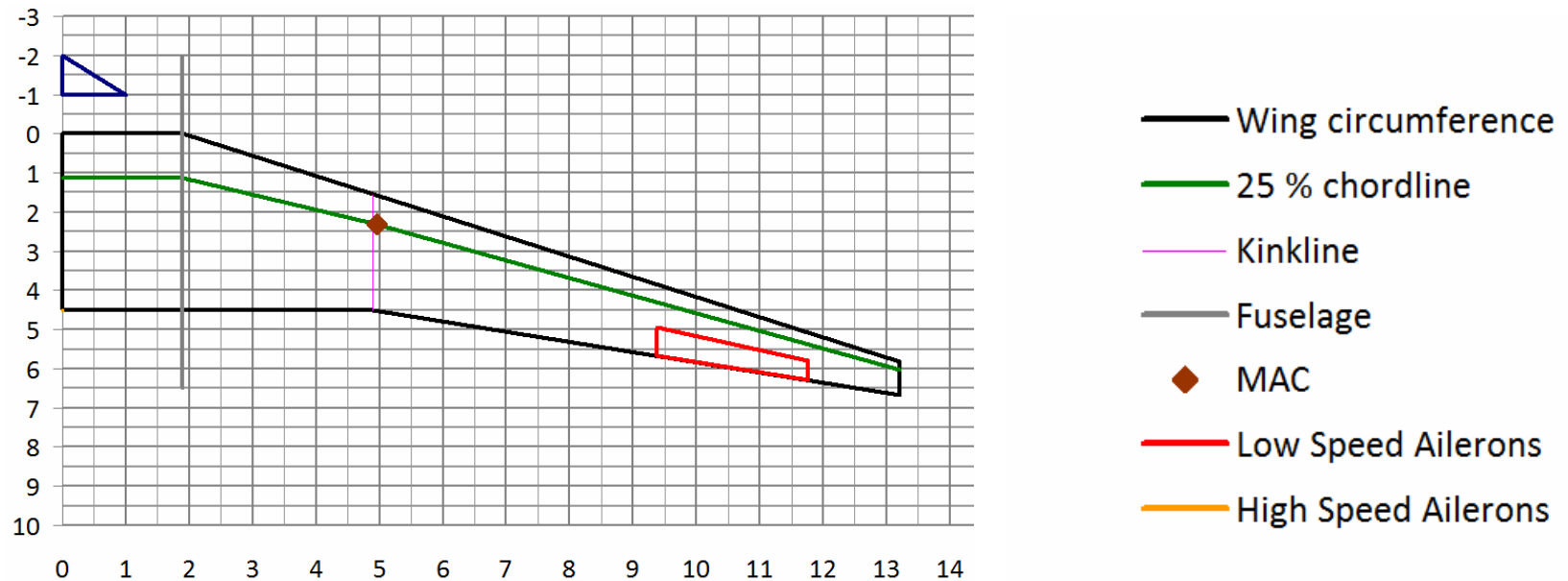
User support with **experience** from industry and academia **presented with respect to current design**



## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots

#### Wing

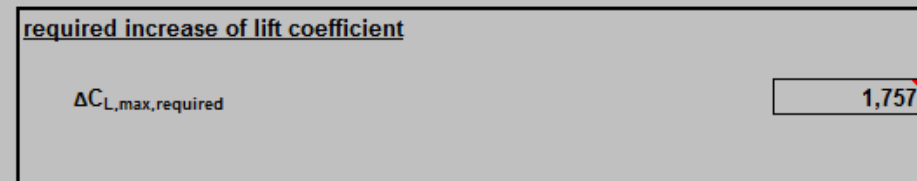
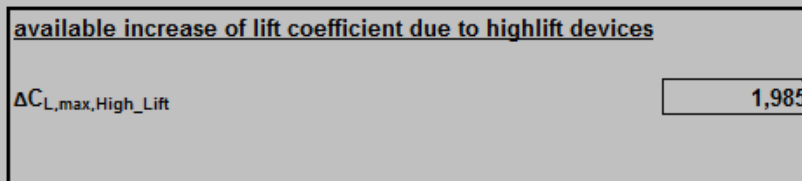


Preview of wing parameters

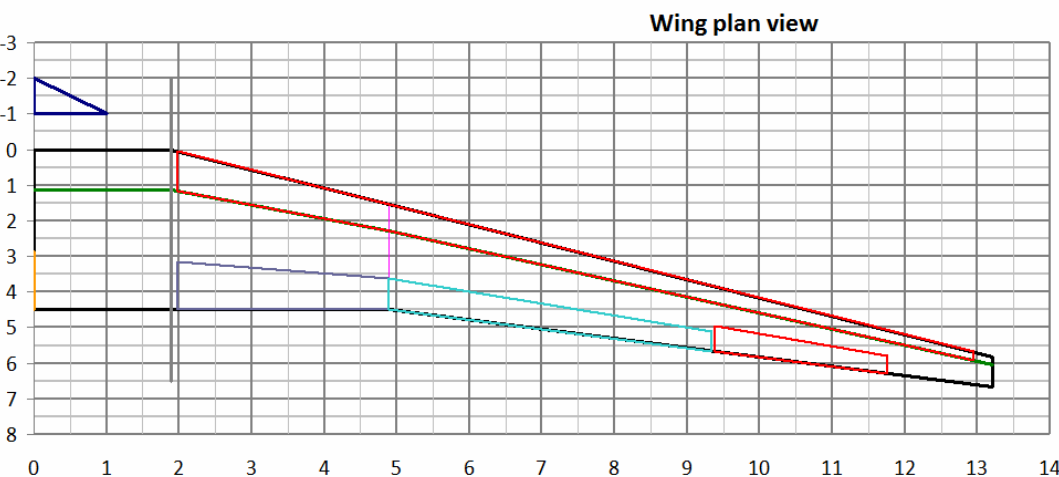
## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots High Lift

Final statement in  
high lift preliminary design



**Highlift is sufficient**



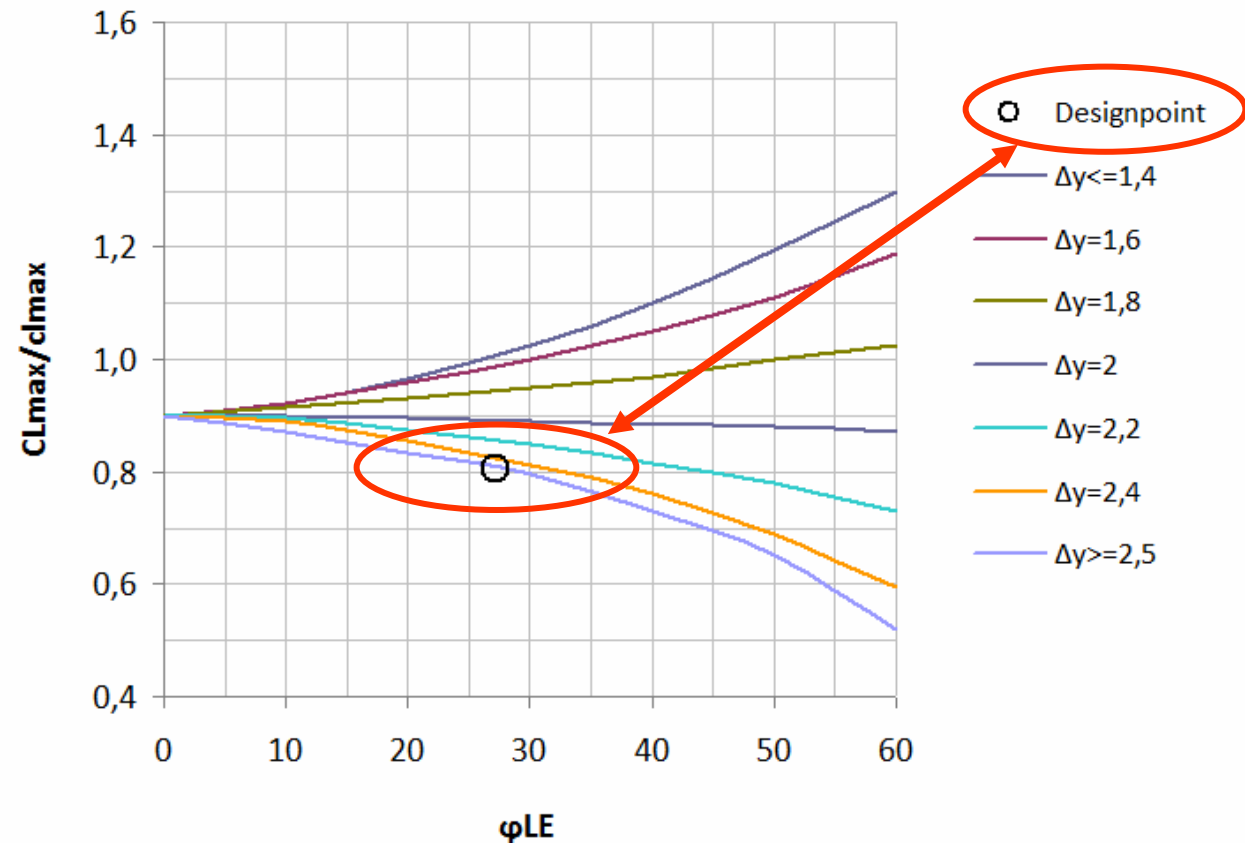
- Wing circumference
- 25 % chordline
- Kinkline
- Fuselage
- MAC
- Low Speed Ailerons
- High Speed Ailerons
- LED
- FLAP
- FLAP
- FLAP

**Preview of high lift  
parameters**

## PreSto - Aircraft Preliminary Sizing Tool

### Screen Shots High Lift

SUBSONIC MAXIMUM LIFT OF HIGH-ASPECTED-RATIO WINGS  
ACCORDING TO DATCOM FIGURE 4.1.3.4-21a



Display of calculated Datcom data  
and

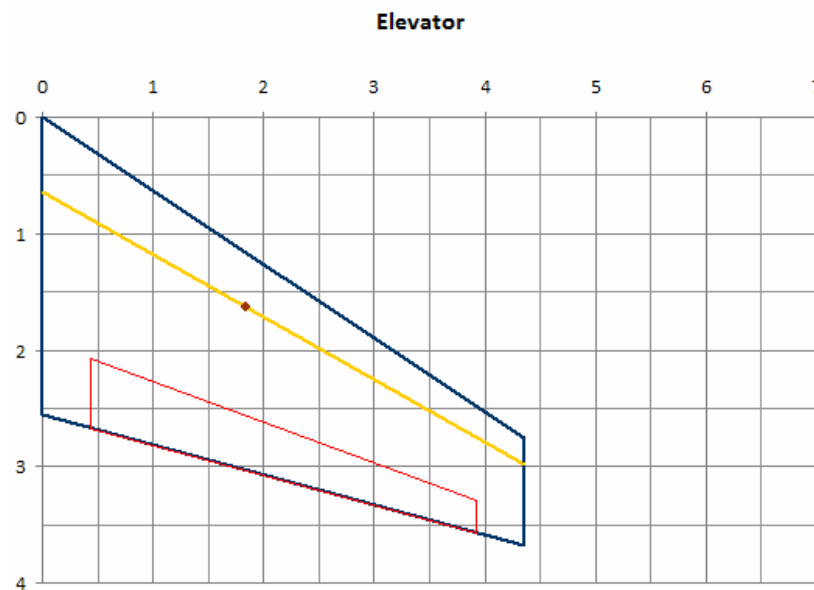
Automatic readout of parameters  
with respect of actual design point

## PreSTo - Aircraft Preliminary Sizing Tool

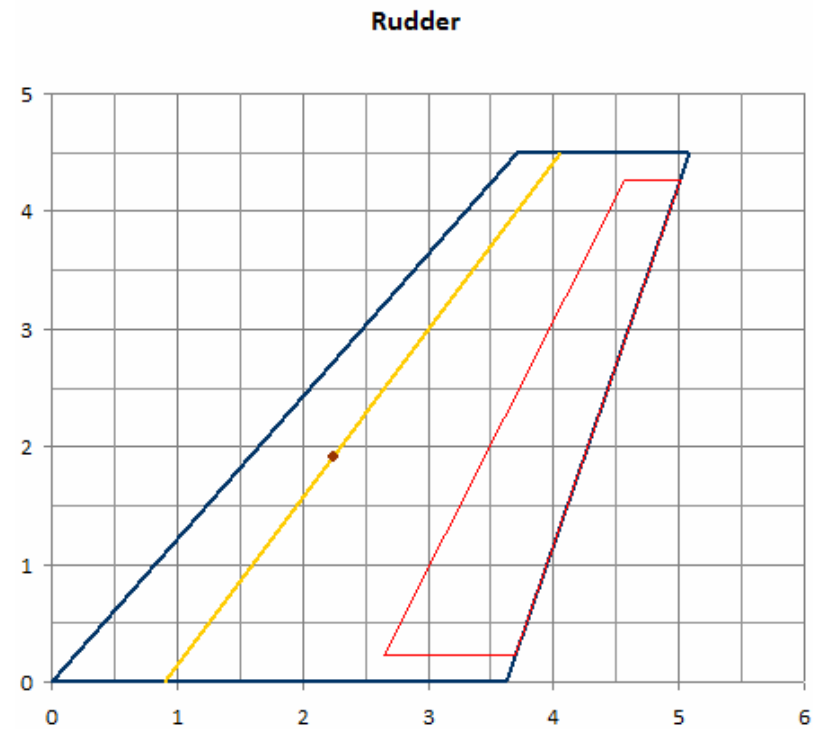
### Screen Shots

#### Tailplane I

#### Preview of tail parameters



Horizontal stabilizer



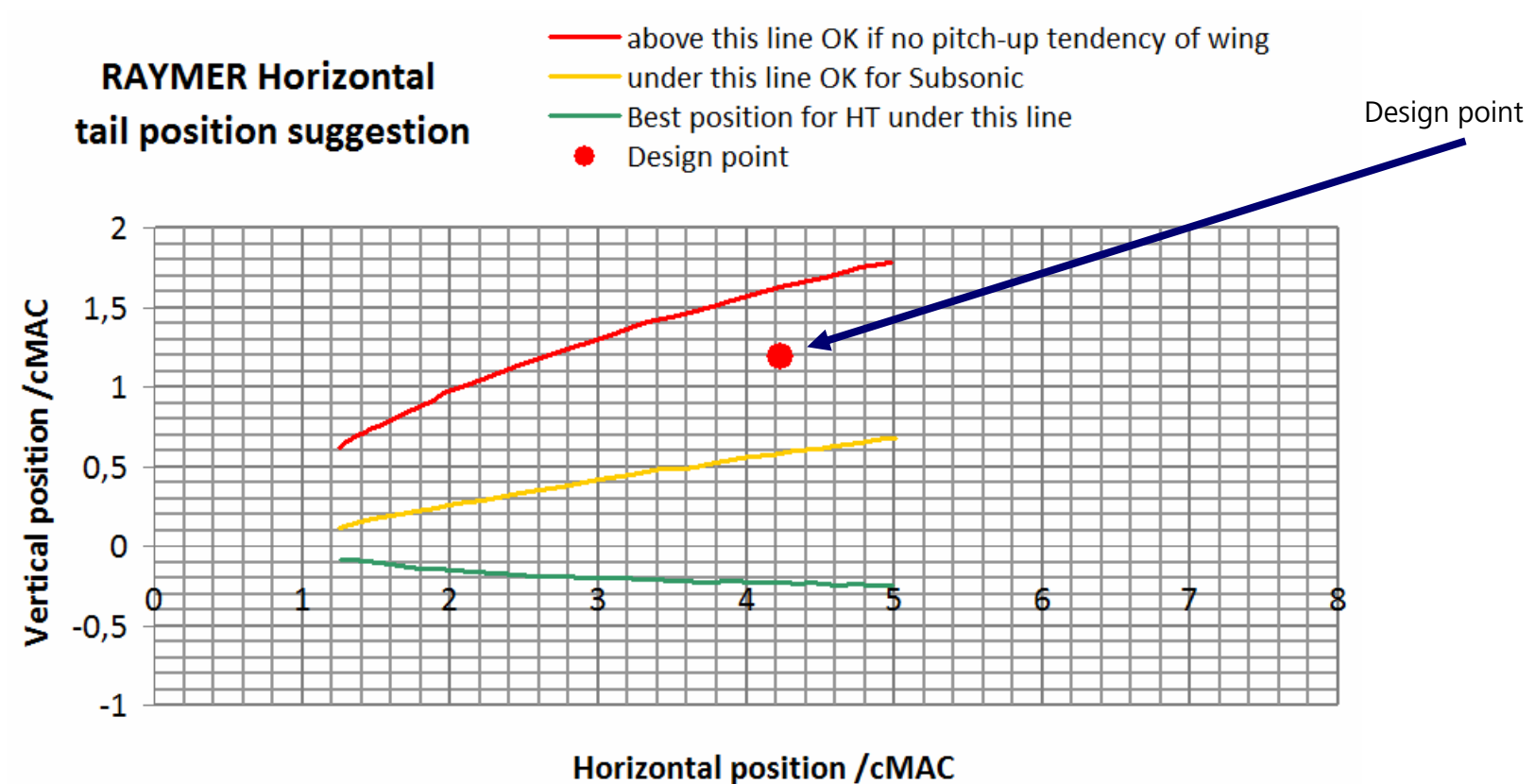
Fin

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots

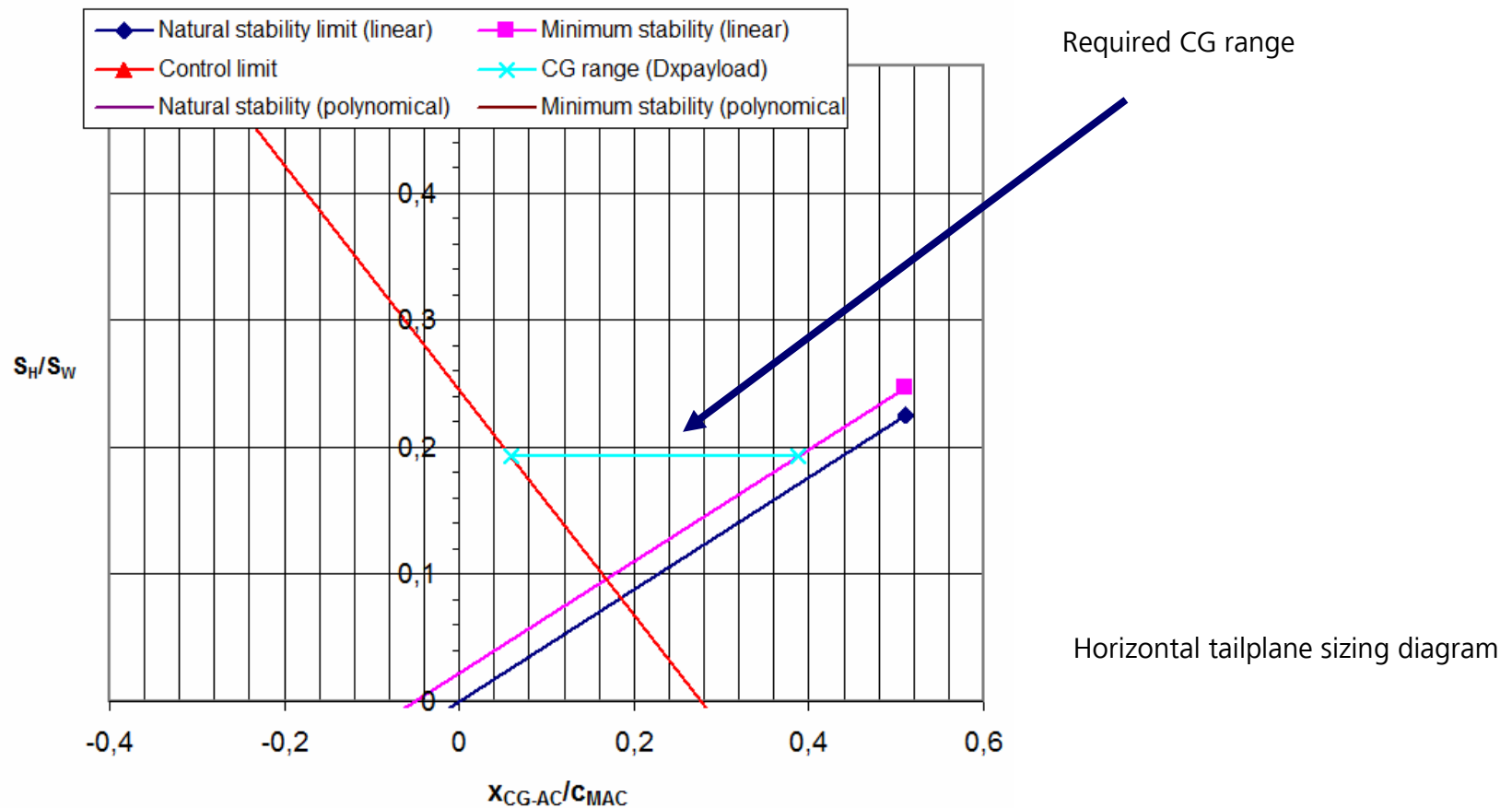
#### Tailplane I

Showing design parameters with respect to established practise



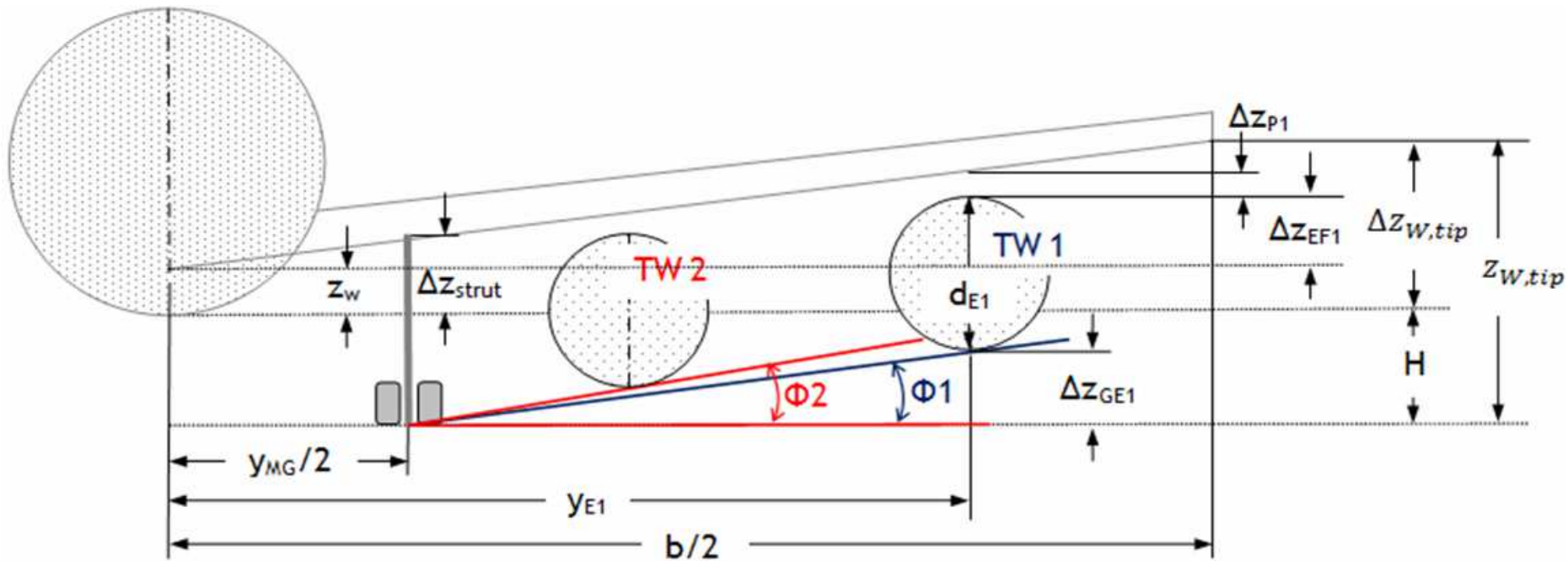
## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Tailplane II



## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Landing Gear

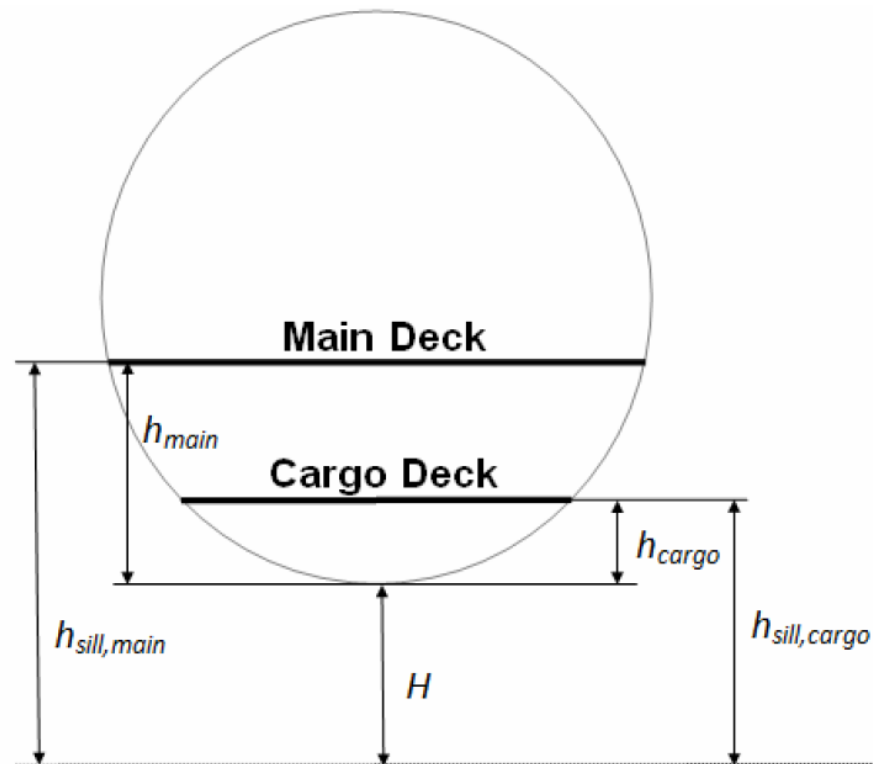


Engine ground clearance due to landing gear length

**Engine 1 bank angle is OK**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots Landing Gear



Calculating **sill height** – an important parameter for airport compatibility

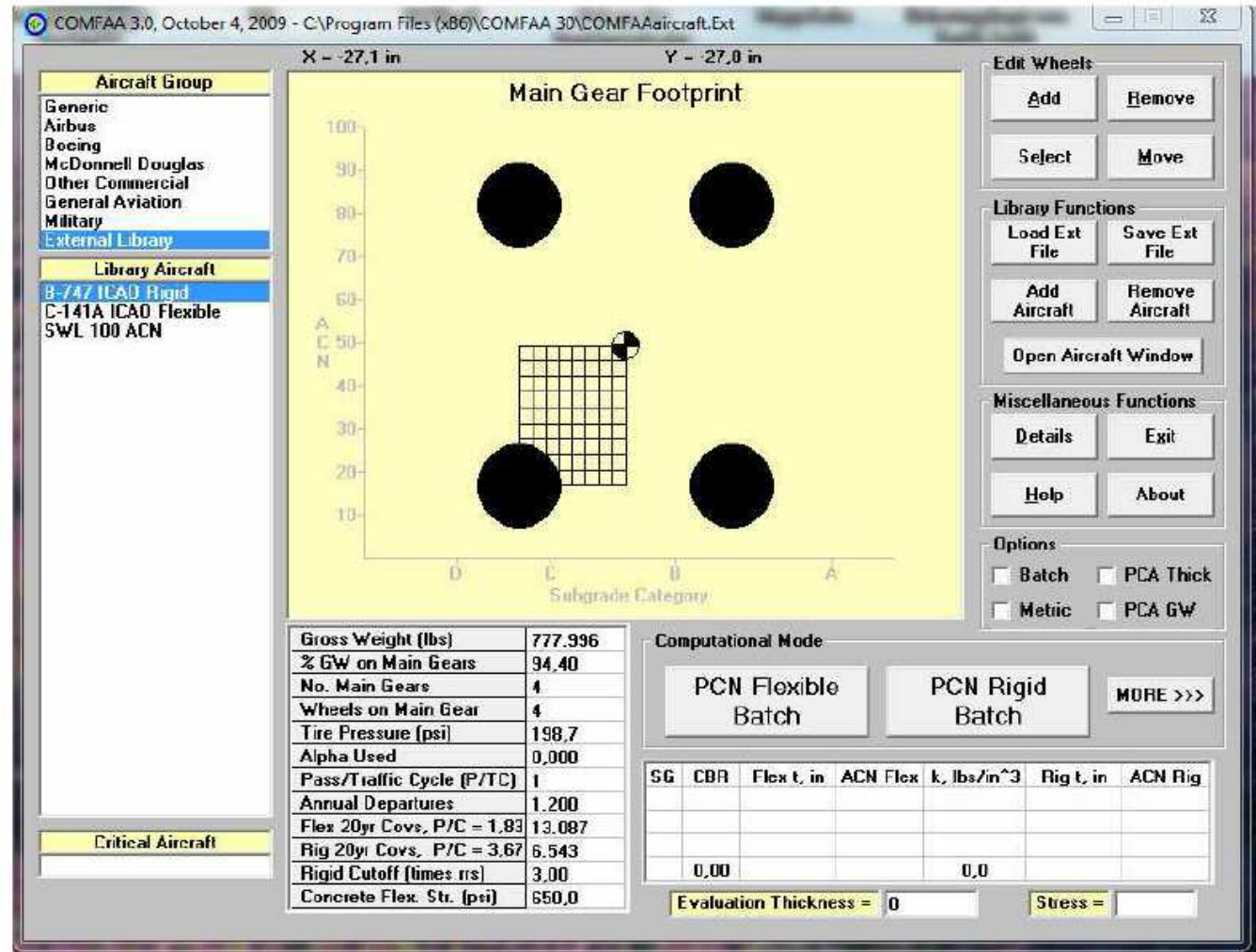


## PreSto - Aircraft Preliminary Sizing Tool

### Screen Shots Landing Gear

Calculation of **ACN** values  
Aircraft  
Classification  
Number

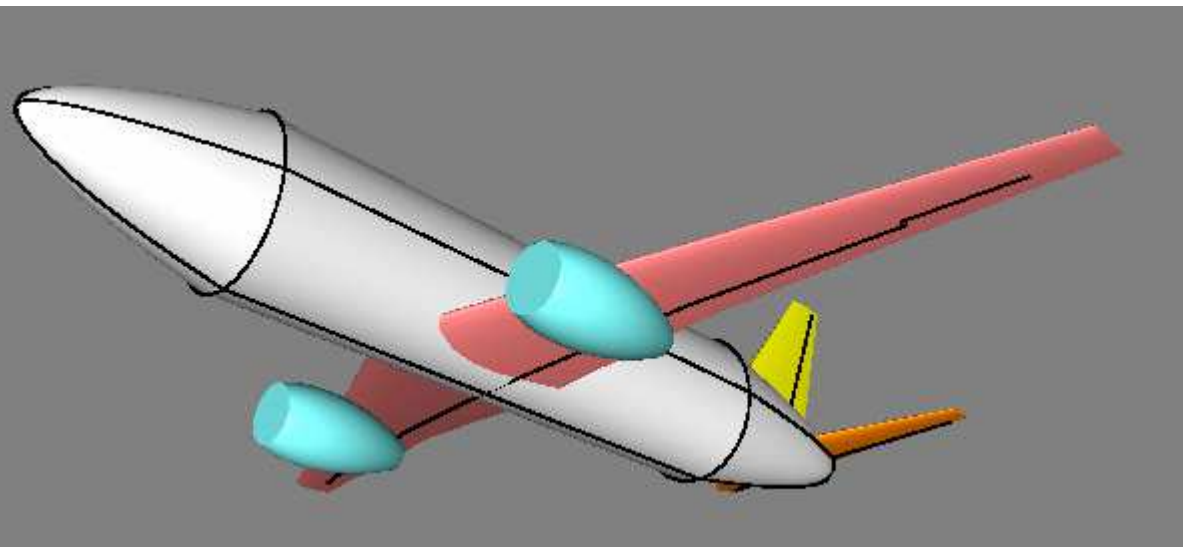
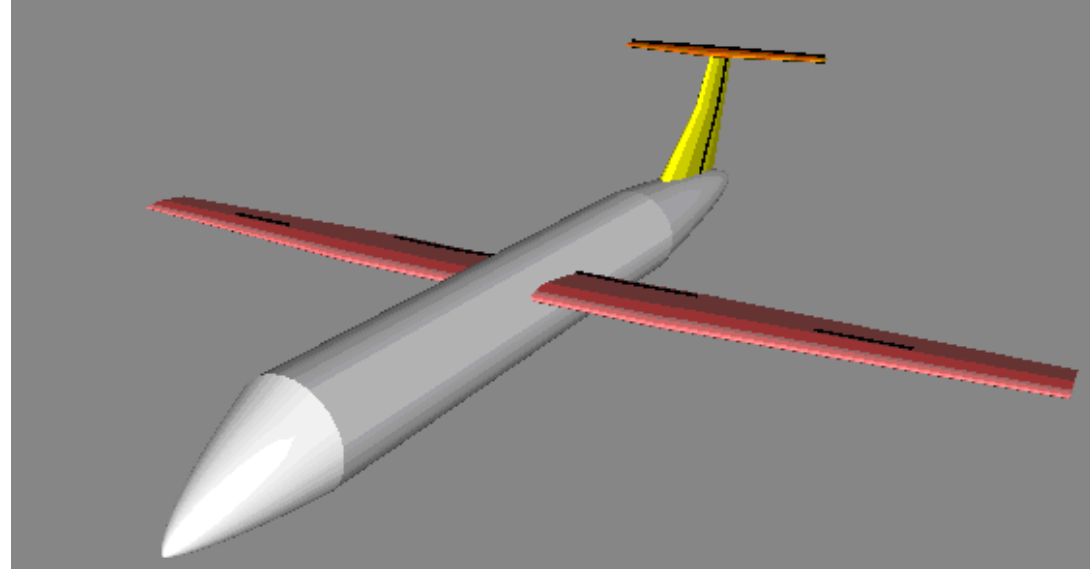
COMFAA is integrated into  
PreSto:  
o automatic input of data  
o COMFAA results stored in  
PreSto



## PreSTo - Aircraft Preliminary Sizing Tool

### Data Export / Visualization CEASIOM

FD 728 from PreSTo in  
**ACBuilder** from CEASIOM

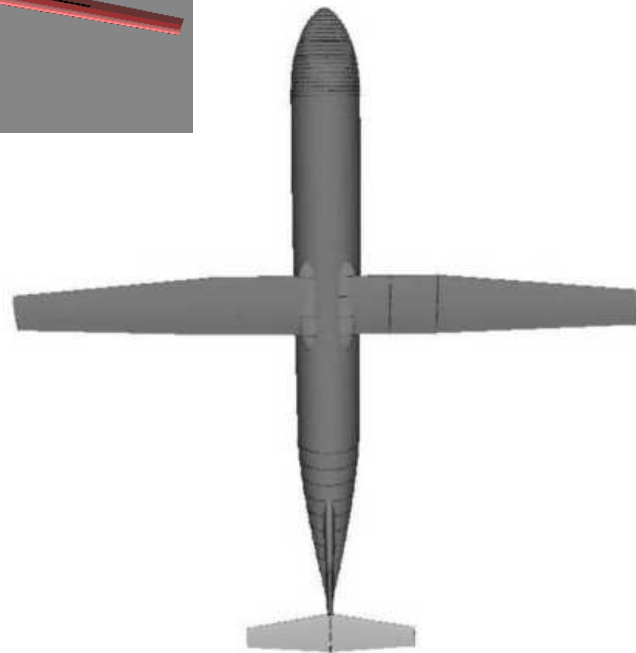
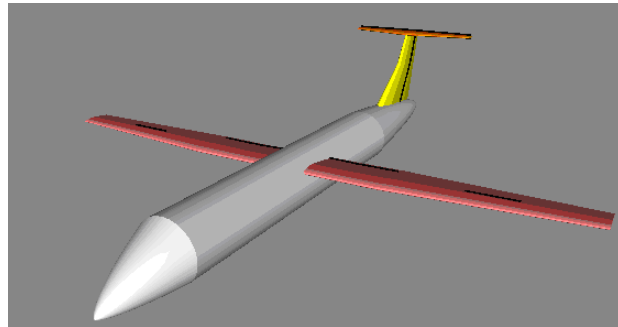


ATR 72 from PreSTo in  
**ACBuilder** from CEASIOM

## PreSto - Aircraft Preliminary Sizing Tool

### Data Export / Visualization CEASIOM

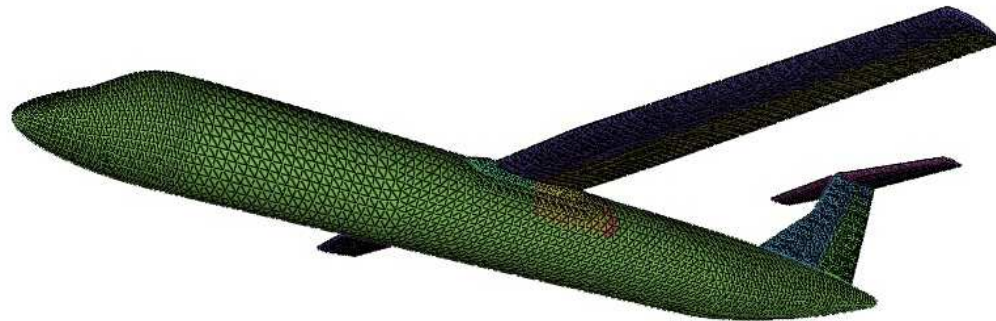
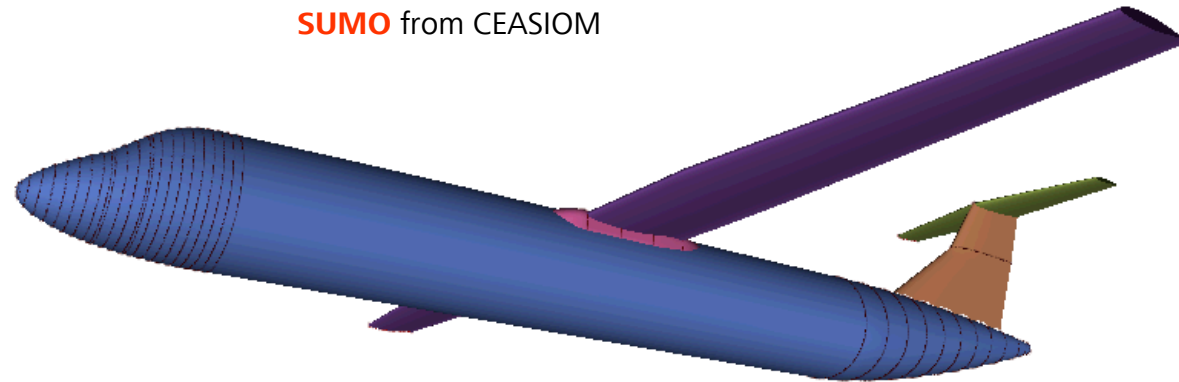
FD 728 from PreSto in  
**ACBuilder** from CEASIOM  
shown in the style of a  
**three-view drawing**



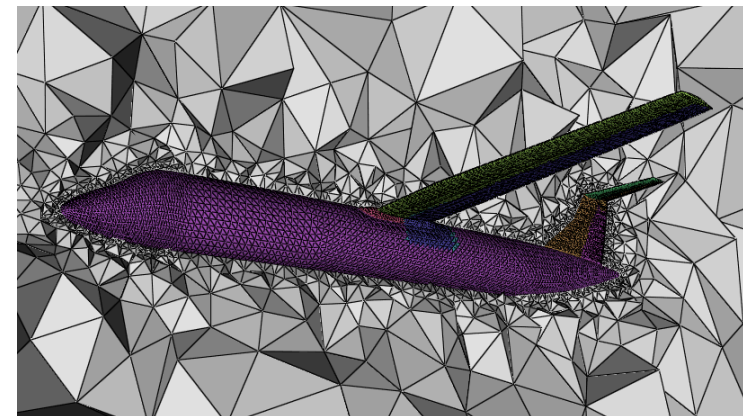
## PreSTo - Aircraft Preliminary Sizing Tool

### Data Export / Visualization CEASIOM

ATR 72 from PreSTo in  
**SUMO** from CEASIOM

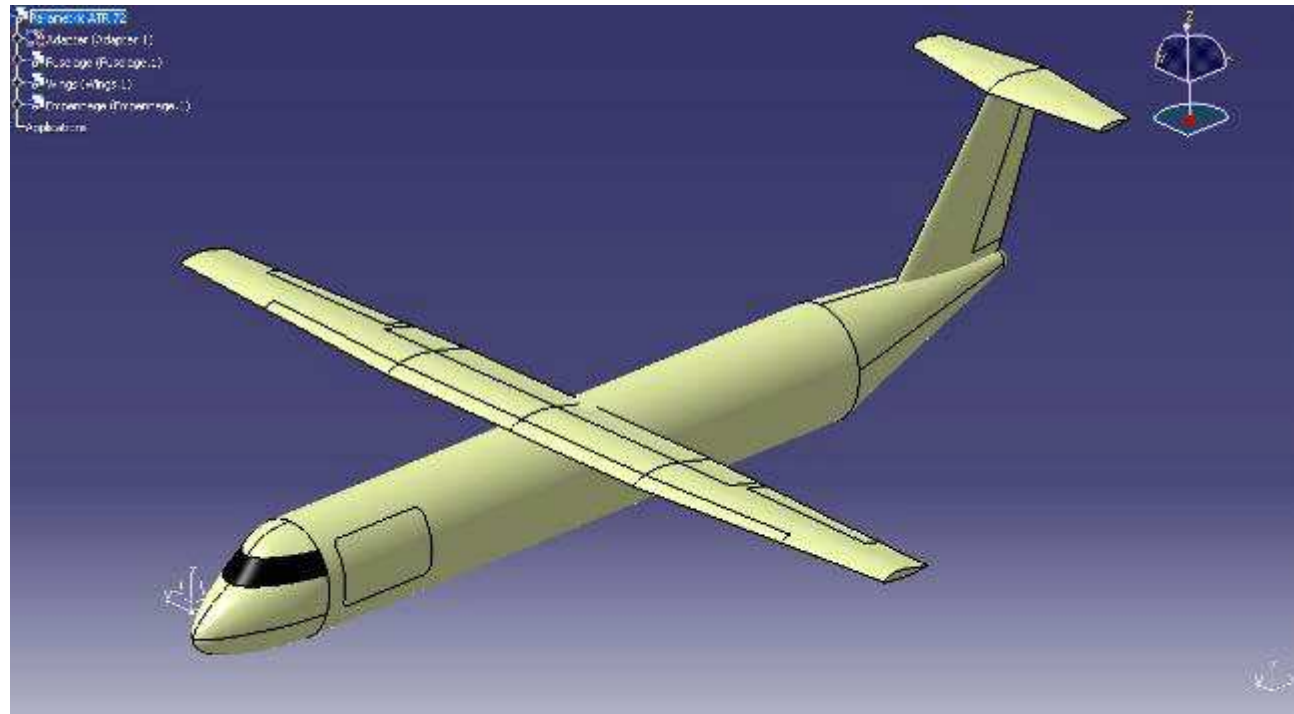


ATR 72 from PreSTo  
with surface and volume mesh generated by  
**SUMO** from CEASIOM



## PreSTo - Aircraft Preliminary Sizing Tool

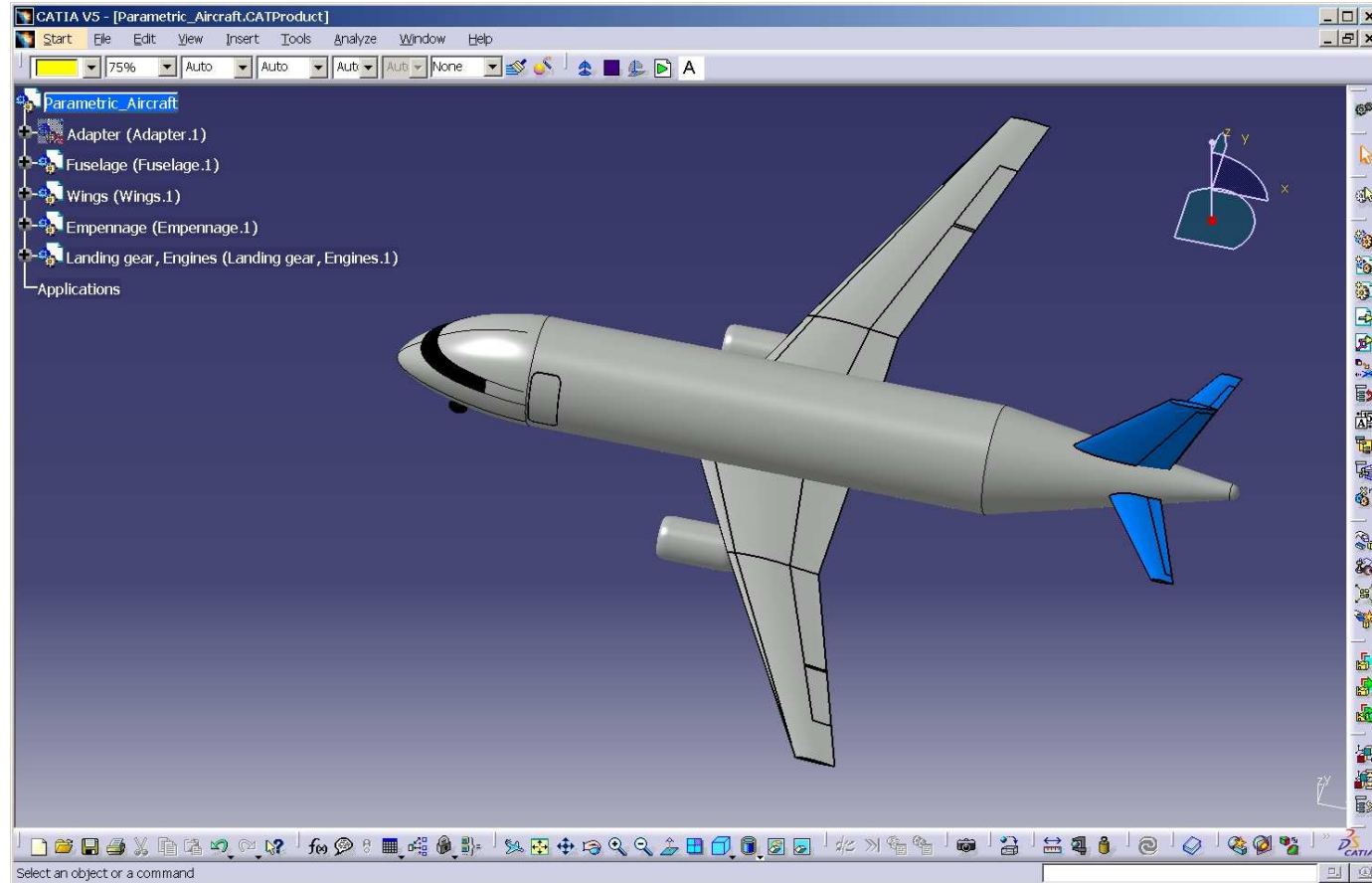
### Data Export / Visualization Catia



ATR 72 from PreSTo in **Catia**  
built with parametric model

## PreSTo - Aircraft Preliminary Sizing Tool

### Data Export / Visualization Catia

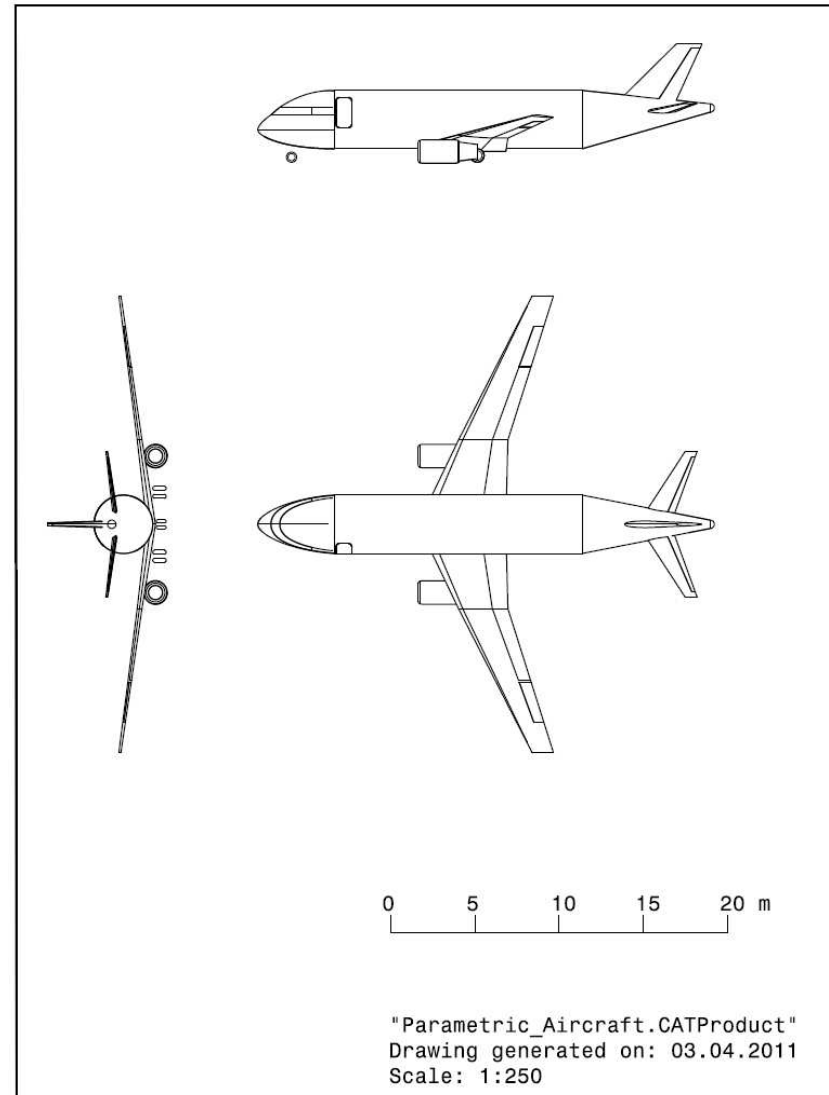


FD 728 from PreSTo in **Catia**  
built with parametric model

## PreSTo - Aircraft Preliminary Sizing Tool

### Data Export / Visualization Catia

FD 728 from PreSTo in **Catia**  
**automatically generated three-view drawing**  
derived from parametric model



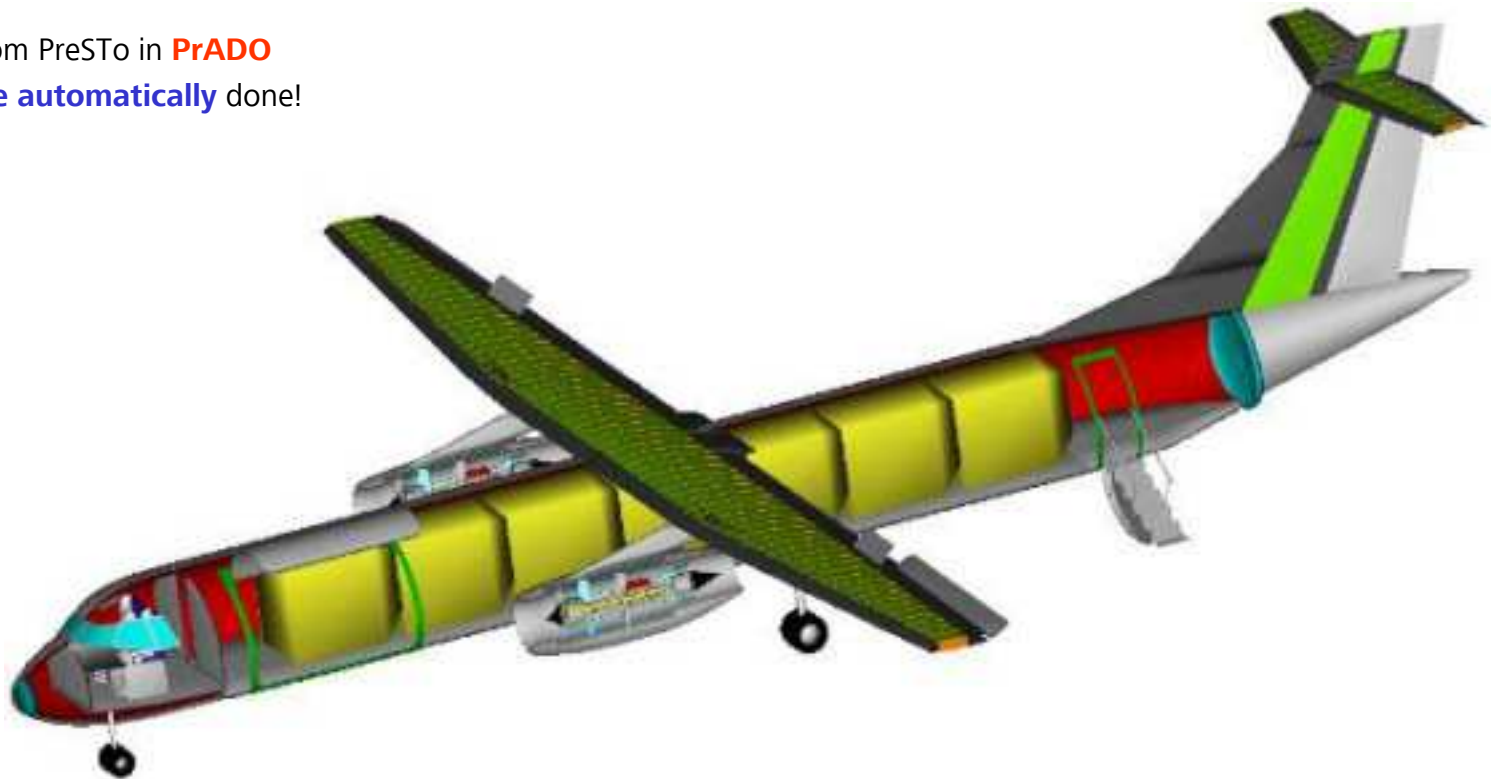
## PreSTo - Aircraft Preliminary Sizing Tool

### Data Export / Visualization

**PrADO** (Preliminary Aircraft Design and Optimization)

ATR 72 - Jet from PreSTo in **PrADO**

This is **not done automatically** done!





## PreSTo - Aircraft Preliminary Sizing Tool

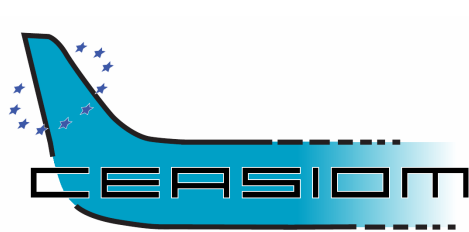
### Data Export / Visualization

#### CPACS (Common Parametric Aircraft Configuration Schema)

```
<?xml version="1.0" encoding="UTF-8" ?>
- <cpacs xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="cpacs_schema.xsd">
- <header>
  <name>FD 728</name>
  <description>Redesign</description>
  <creator>Standard</creator>
  <timestamp>2012-01-24T23:34:28</timestamp>
  <version>1.0</version>
  <cpacsVersion>1.6</cpacsVersion>
- <updates>
  - <update>
```

...

## Further Tool Chain



Computerised Environment for Aircraft Synthesis and Integrated Optimisation Methods

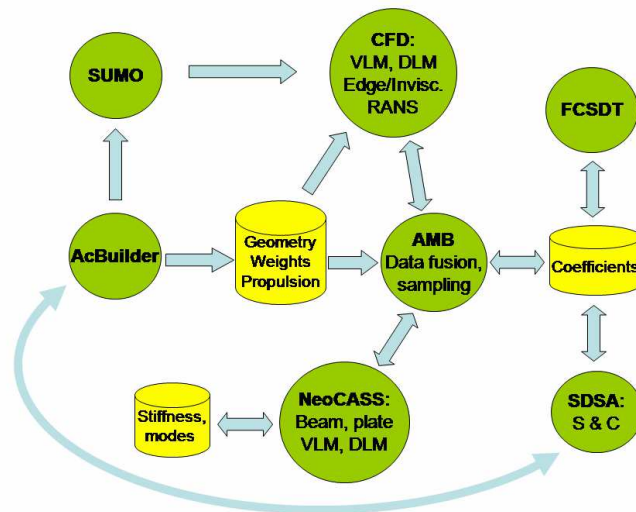
Tornado



USAF Digital DATCOM



JSBSim



## Further Tool Chain



D-SIM-42



FDM in Matlab/Simulink

## Diamond DA - 42



## Aircraft Preliminary Sizing Tool @ Aero

## PreSTo Homepage / Download

<http://PreSTo.ProfScholz.de>

**PreSTo-Cabin**

**Module 2: Cabin and Fuselage Layout** supports the sizing and the interactive step-by-step design of the cabin in some detail. Based on cabin parameters, the fuselage general dimensions are found.

PreSTo-Cabin is now available as "PreSTo-Cabin\_1.0.xls": **NEW!**

[PreSTo-Cabin\\_1.0.xls](#) Changed on: 17 January 2011, Size: 2.9M  
This file is set up for the [Airbus A320](#).

Please make sure ...

- ... to use Excel 2003 or a more recent version (unfortunately PreSTo is incompatible with Open Office),
- ... to allow Excel to use macros (you will be asked upon opening the program).

[PreSTo-Cabin\\_1.0\\_FairchildDornier728.xls](#) Changed on: 18 February 2011, Size: 2.9M  
This file is set up for the [Fairchild Dornier 728](#). Cabin data extracted from:  
[FairchildDornier728\\_3View\\_and\\_Cabin.jpg](#) Size: 963K

[PreSTo-Cabin\\_1.0\\_A330.xls](#) Changed on: 22 April 2011, Size: 2.9M  
This file is set up for the [Airbus A330](#). Compare cabin data from Airbus with the PreSTo layout:  
[A330\\_CabinLayout.jpg](#) Size: 395K

Try out PreSTo-Cabin yourself. Your feedback is welcome!

**PreSTo Documentation**

[PreSTo-Cabin\\_Documentation\\_10-11-15.pdf](#) Changed on: 17 February 2011, Size: 1.8M

**Download PreSTo-Cabin**

## Aircraft Preliminary Sizing Tools @ Aero

### Conclusions and Outlook

- **SAS, OPerA and PreSTo** support manual basic **aircraft design** and **optimization**
- **Interfaces** are provided to **higher order tools**
  - CEASIOM
  - PrADO
- **Visualization** of the aircraft is done with outside tools:
  - CEASIOM
    - **ACBuilder**
    - **SUMO**
  - Catia
- Next steps:
  - Finish SAS, OPerA and PreSTo
  - Offer for download: <http://SAS.ProfScholz.de> <http://PreSTo.ProfScholz.de>
- Further research based on „ Aircraft Preliminary Sizing Tools @ Aero“ :
  - Boxwing Aircraft
  - „Smart Turboprop“
  - Braced Wing Aircraft

## Aircraft Preliminary Sizing Tools @ Aero

### Contact

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