Aero

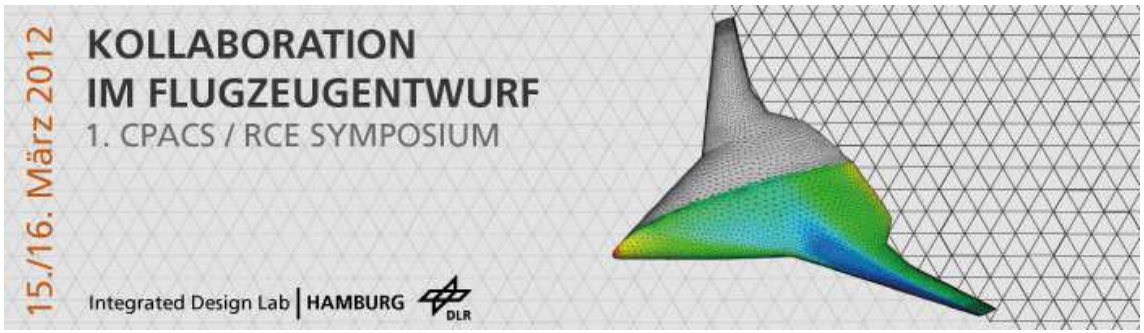
Hochschule für Angewandte Wissenschaften Hamburg
*Hamburg University of Applied Sciences*

**AERO – AIRCRAFT DESIGN AND SYSTEMS GROUP**

# Aircraft Preliminary Sizing Tools @ Aero

## SAS → OPerA → PreSTo → further Tool Chain

Dieter Scholz  Hamburg University of Applied Sciences




PreSTo

Aircraft Preliminary Sizing Tool

OPerA

Optimization in Preliminary Aircraft Design

SAS

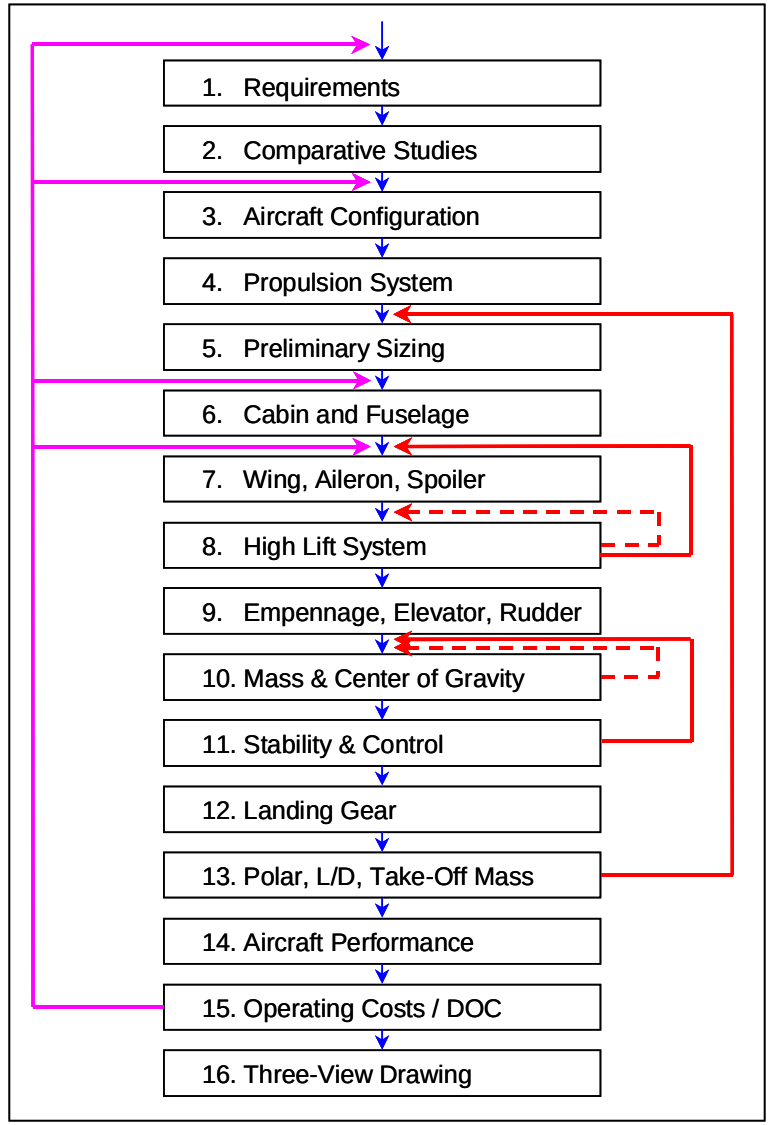
Simple Aircraft Sizing

## 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

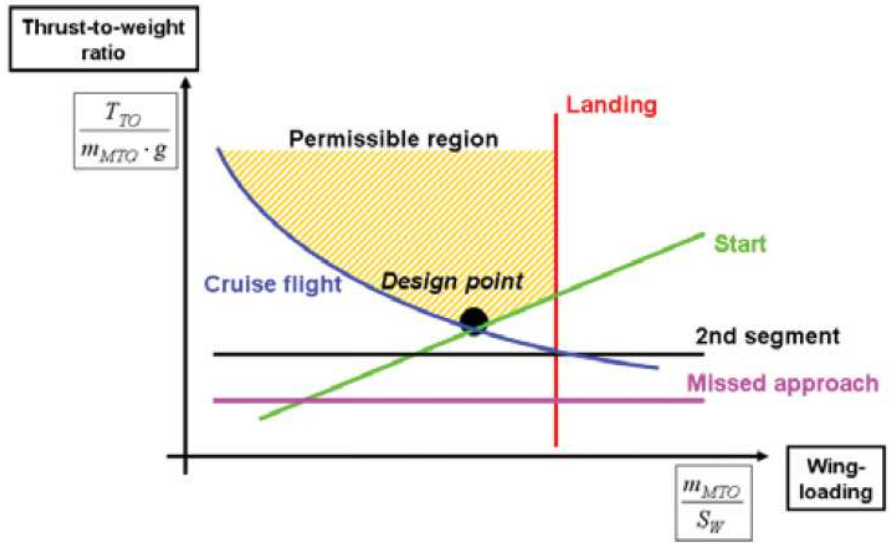
# *Aircraft Design* Lecture
## General remarks

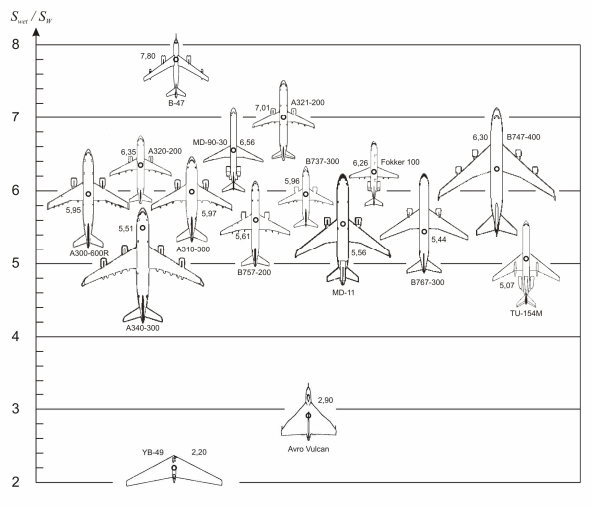
- Lecture is based on methods from:
  - Loftin, Torenbeek, Roskam, Raymer, …
  - Datcom, …
  - many own additions
- 16 design steps (see Fig.)
- Emphasis on *preliminary sizing* with *matching chart*:
  - Jet: T/W = f (m/S)
  - Prop: P/W = f (m/S)
- Lecture in this format since 1998:
  - More than 1000 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



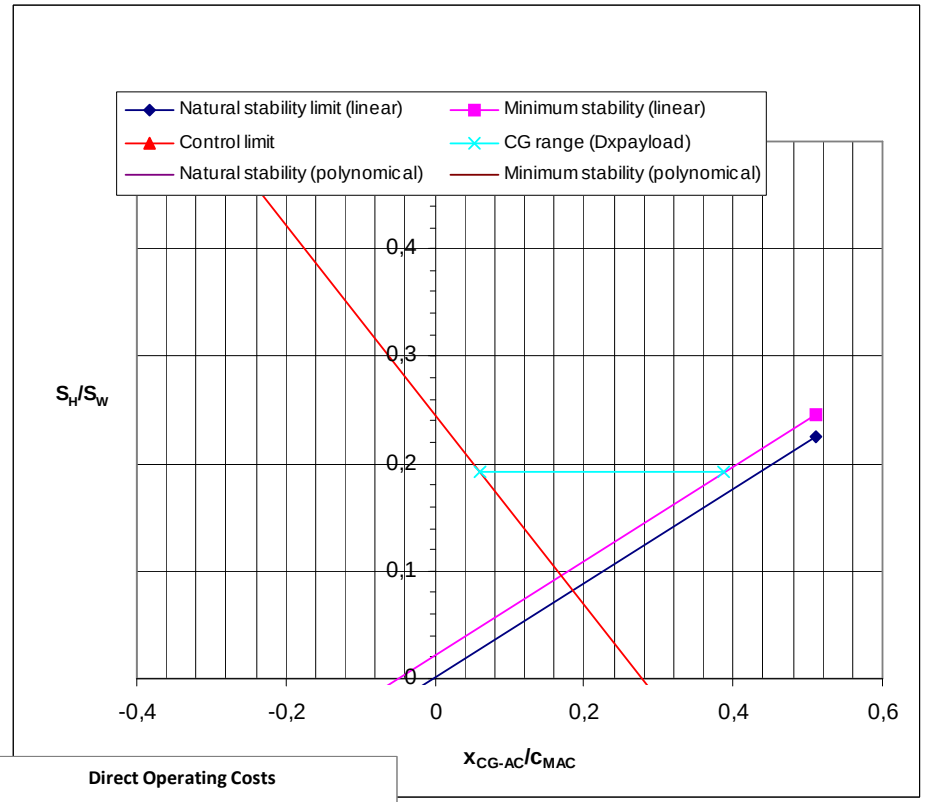



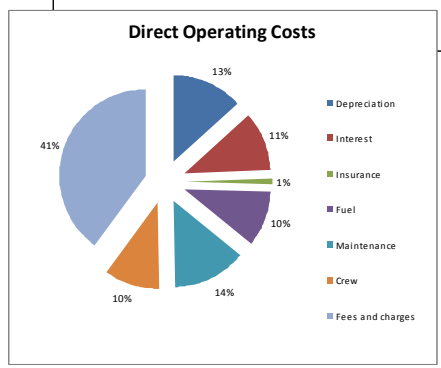
**Aircraft Design Lecture**

- 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: Asssociation 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**:

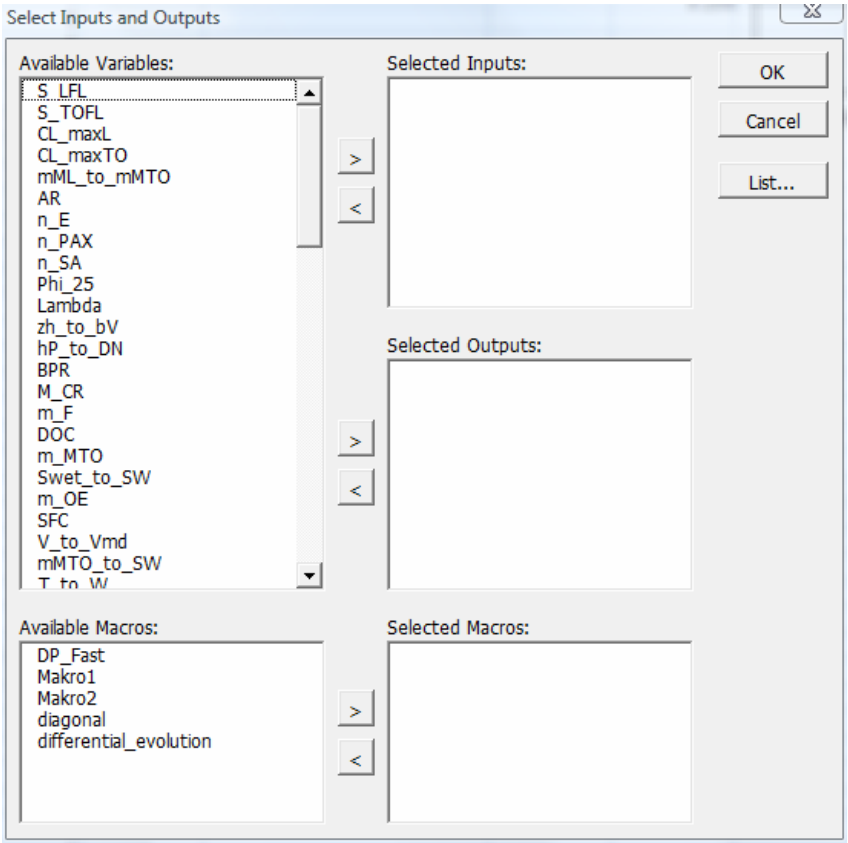
- Automatic Design: Cabin Design, Wing, Empennage, Landing Gear, …
- Mass Estimation, Drag Estimation
- SFC estimation
- DOC Calculation with Added Values

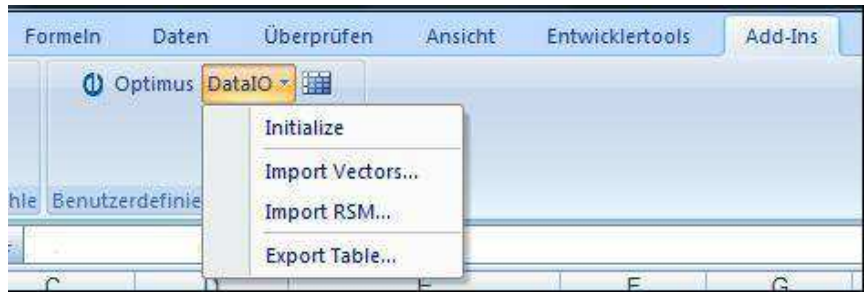

**Optimization**

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**

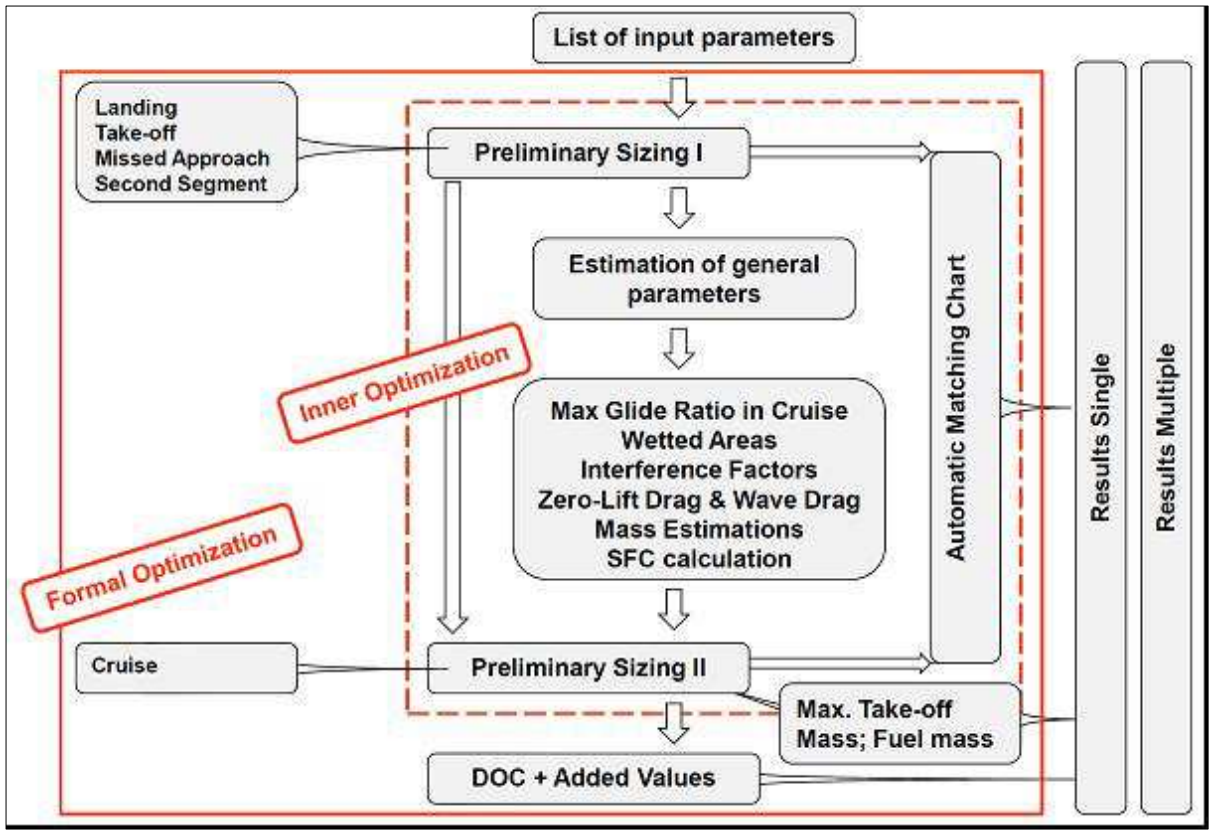
## Optimus® and Excel connected via Add-In



**OPerA – Optimization in Preliminary Aircraft Design**

## Program Structure




15 iteration loops

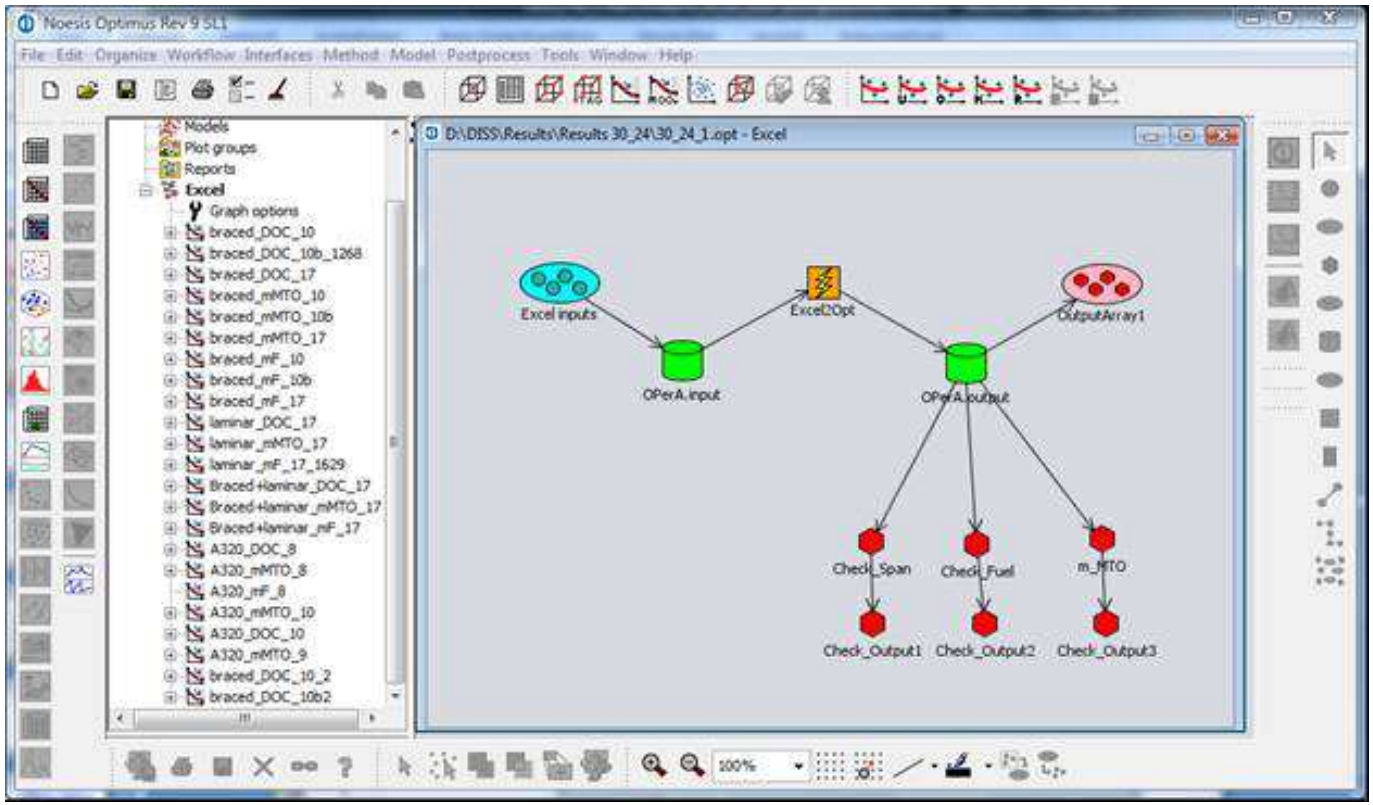
20 optimization variables

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

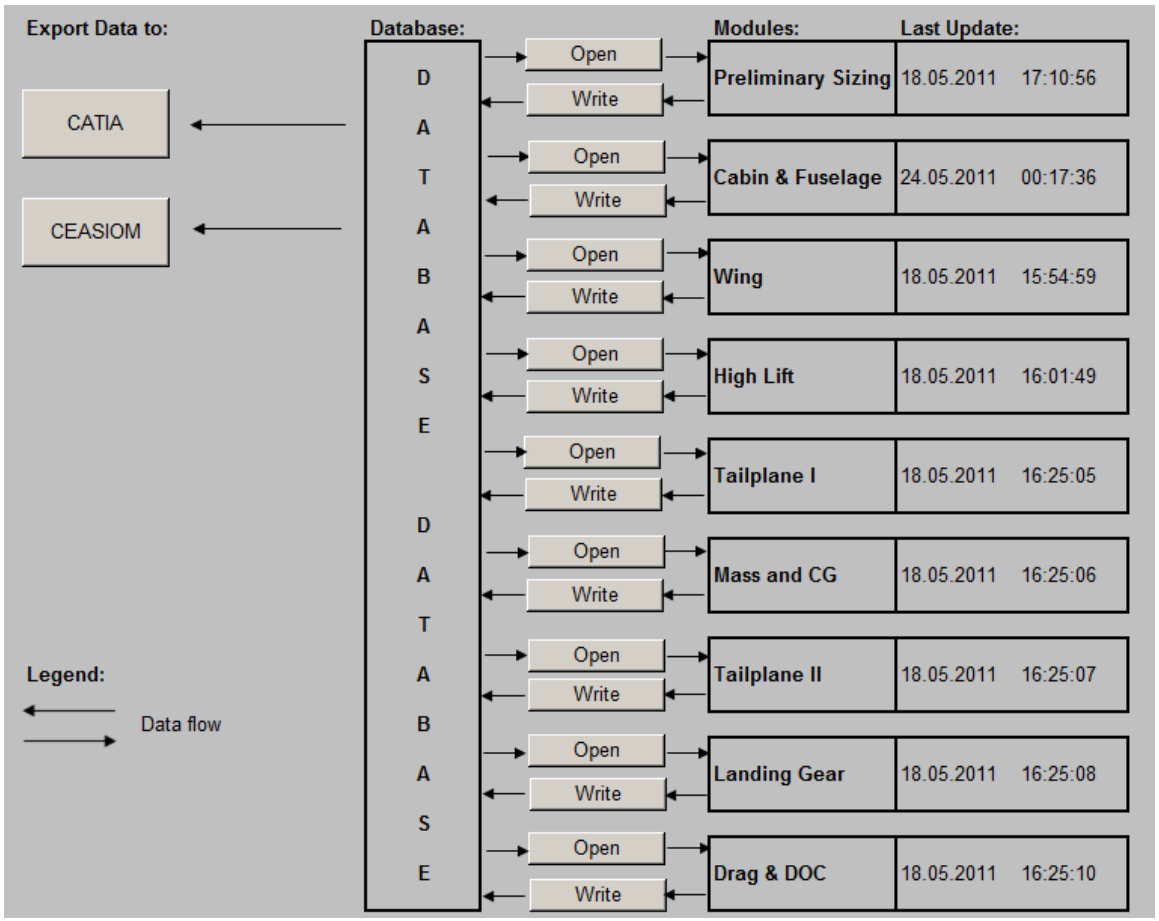
## PreSTo Control Center and Database


PreSTo Control Center – **Start page**

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots

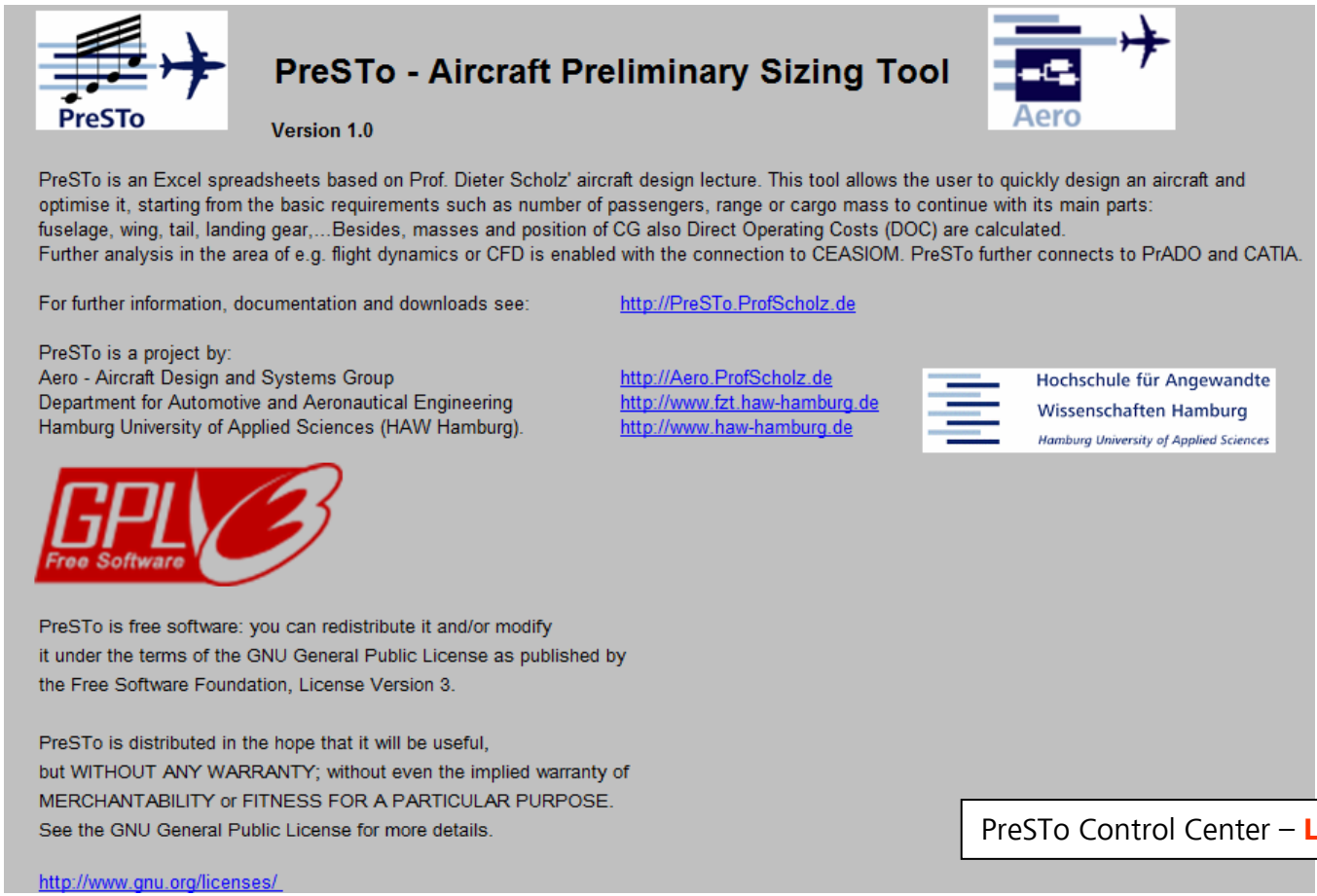
### PreSTo Control Center and Database




PreSTo Control Center – **Module page**

## PreSTo - Aircraft Preliminary Sizing Tool

### Screen Shots
### PreSTo Control Center and Database




PreSTo Control Center – **License page**

**PreSTo - Aircraft Preliminary Sizing Tool**

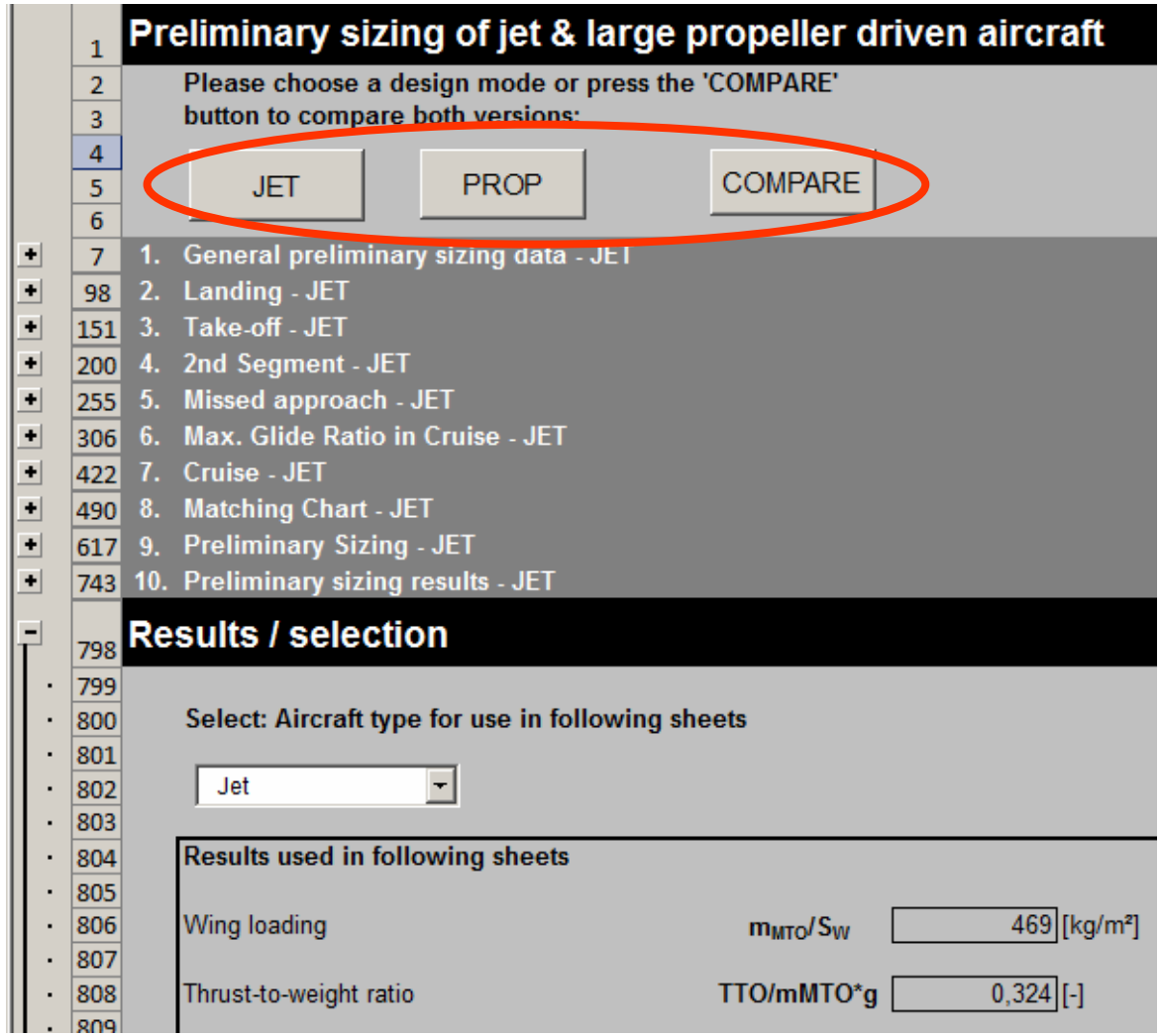
## Screen Shots
### PreSTo Control Center and Database

| | 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

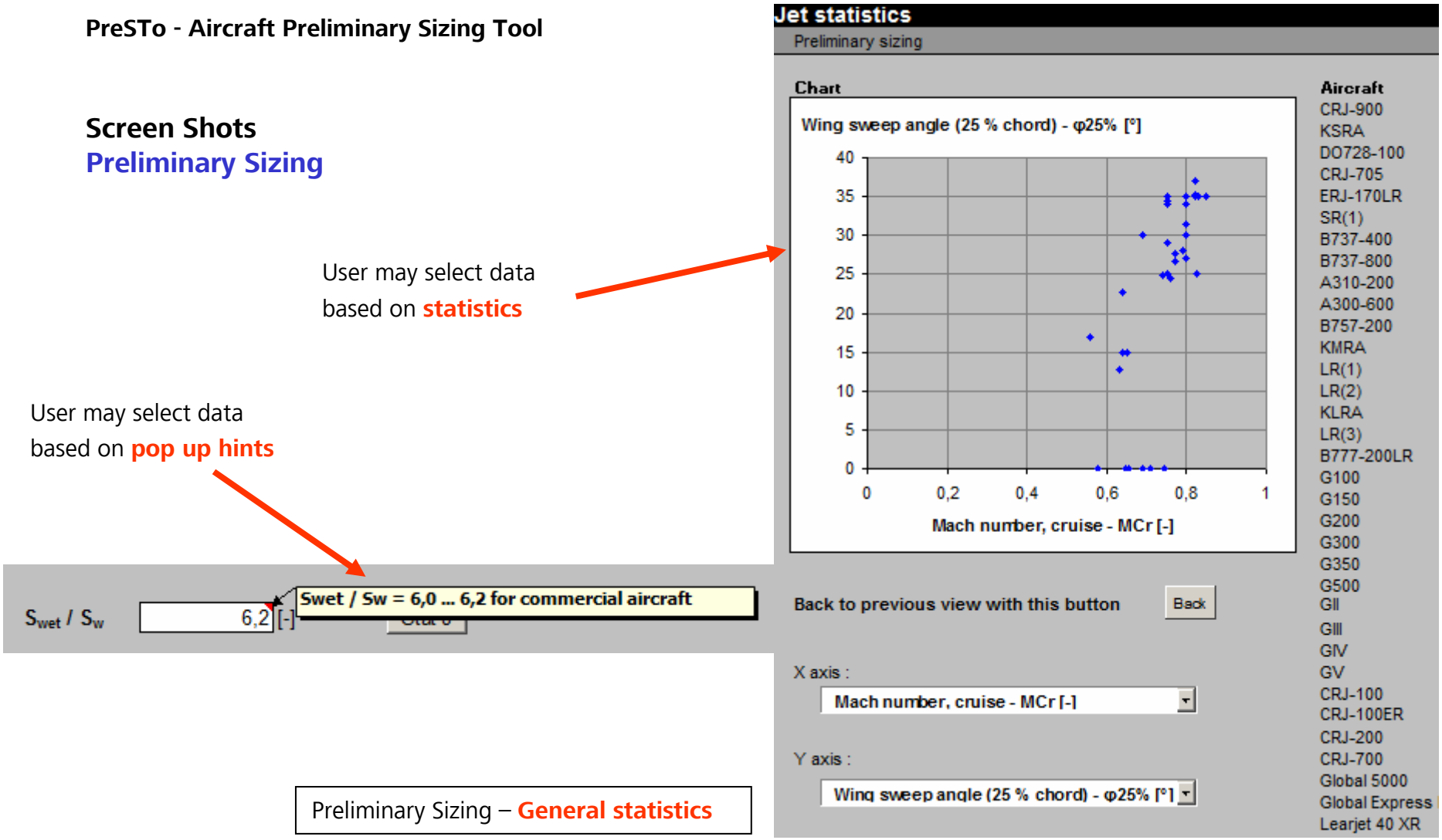
Preliminary Sizing – **Start page**

**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**



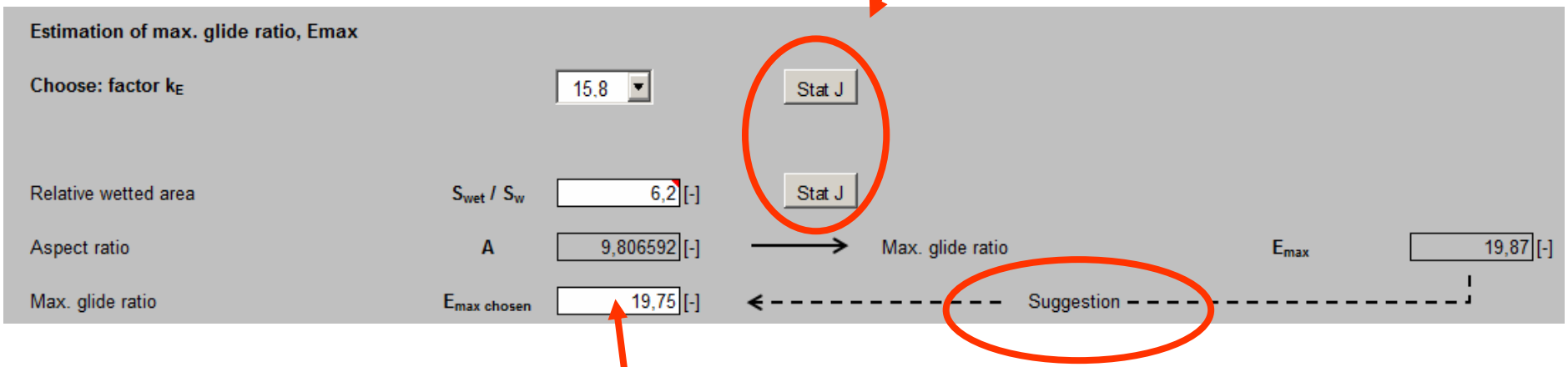

Preliminary Sizing – **General statistics**

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
## Preliminary Sizing

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

Buttons starts statistics database




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: 180 [-] > Number of passengers: 150 [-]

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 |

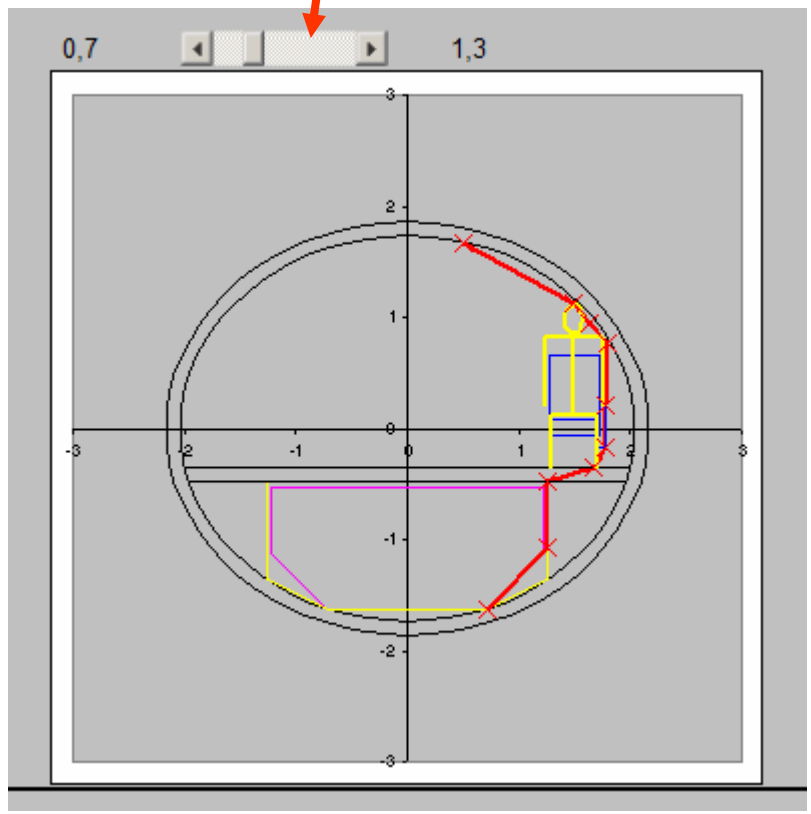
**Check of exits positions according to AC 25.807-1 (6)(b)(2)(vi)**

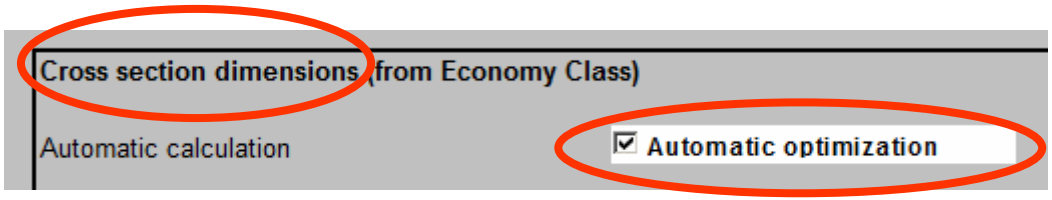
| | Position | | | Offset | | |
|---|---|---|---|---|---|---|
| Exit | Nomina | Actual | Type | [m] | [% cab. length] | Allowed PAX |
| 1 | 1,48 | 1,48 | Type C | 0,00 | 0,00 | 55 |
| 2 | 12,61 | 12,48 | Double Type III | 0,13 | 0,57 | 70 |
| 3 | 23,73 | 23,73 | Type C | 0,00 | 0,00 | 55 |

**PreSTo - Aircraft Preliminary Sizing Tool**

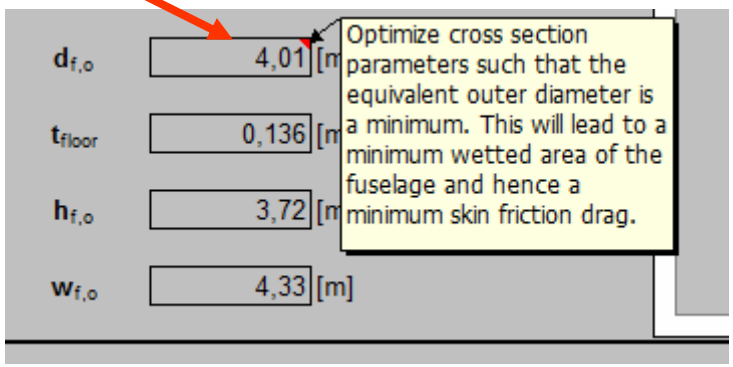
## Screen Shots
### Cabin & Fuselage

Change this …



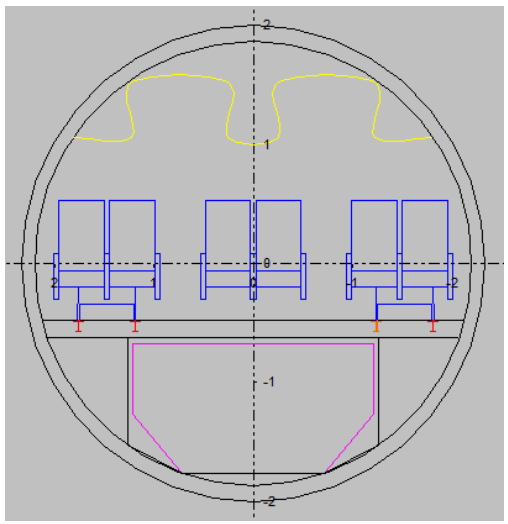

… to minimize this:

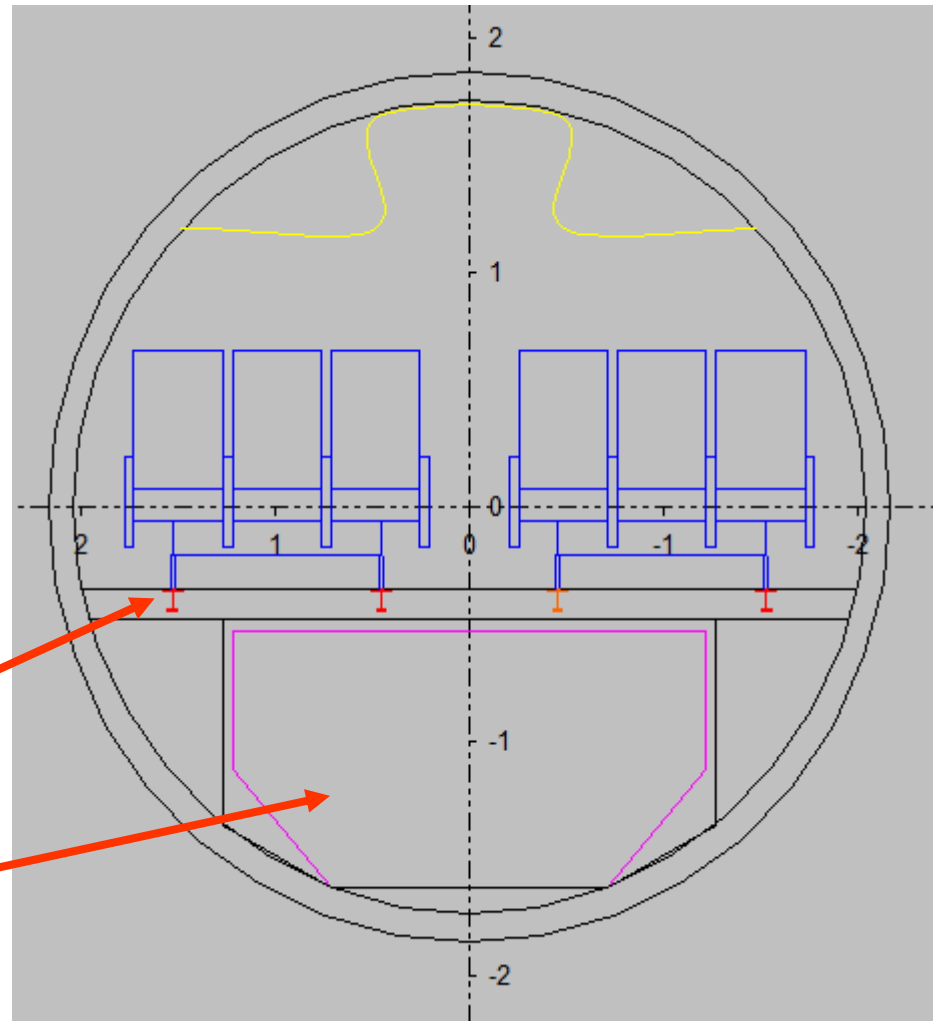


**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### Cabin & Fuselage

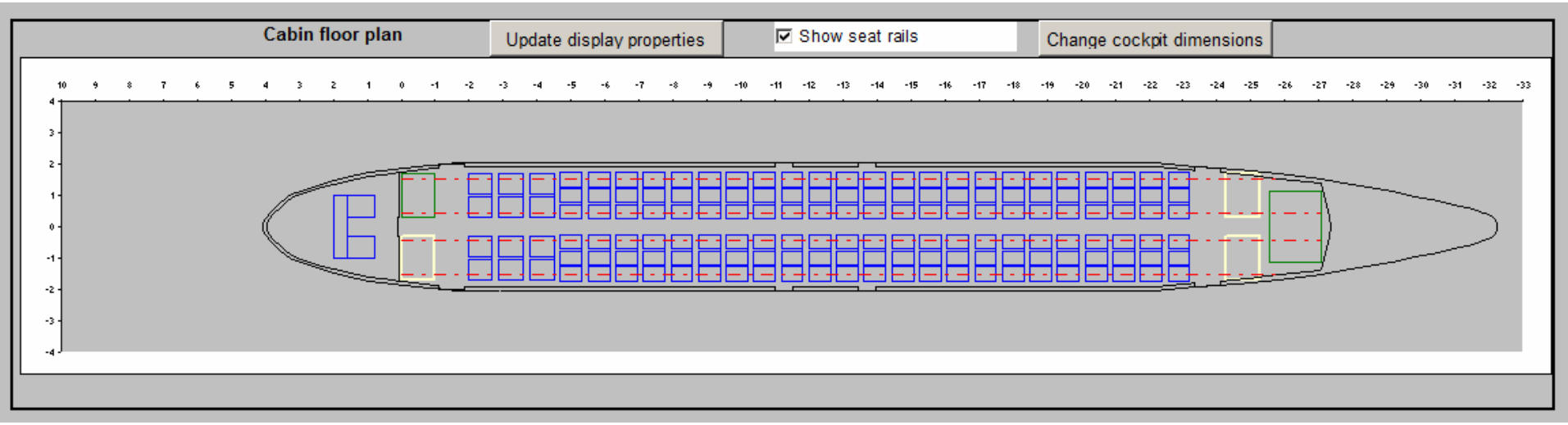
Alternative seat arrangement:





**PreSTo - Aircraft Preliminary Sizing Tool**

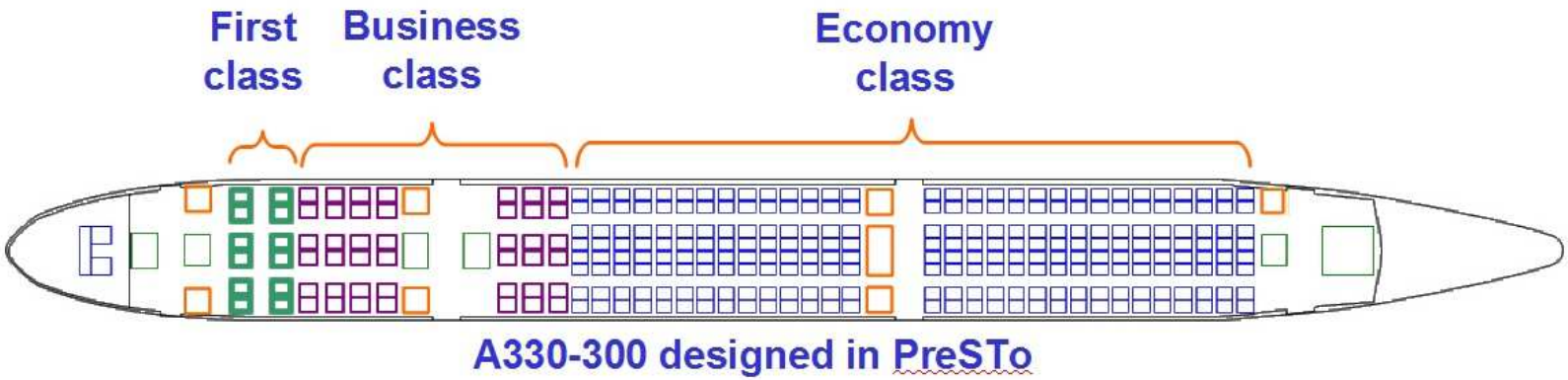
## Screen Shots
## Cabin & Fuselage



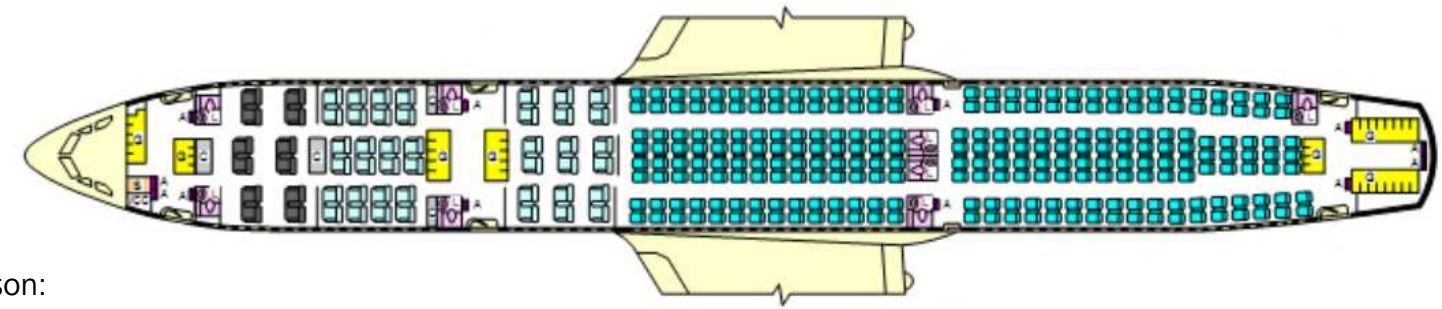

Seat layout

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### Cabin & Fuselage




A330-300 designed in PreSTo

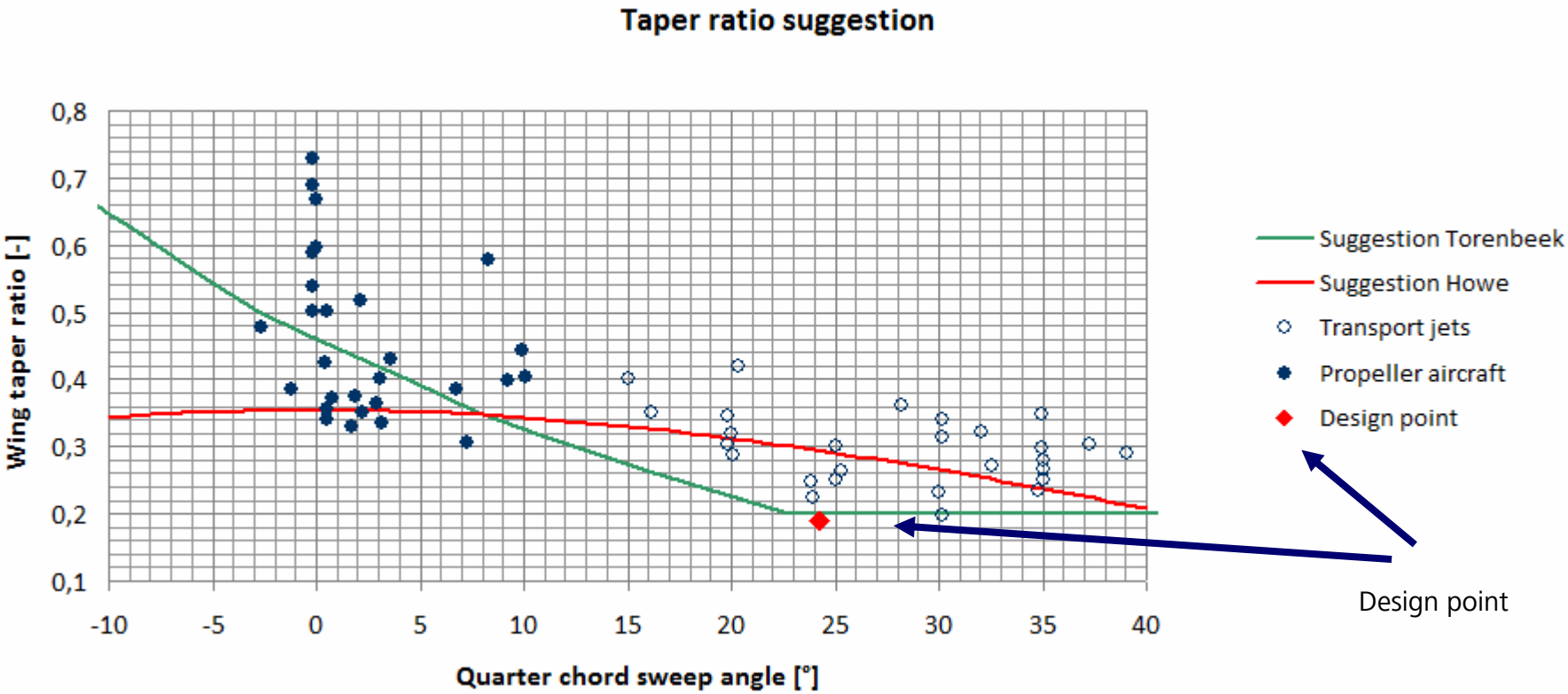


A330-300 from Airbus

Seat layout comparison:
Airbus original and PreSTo

**PreSTo - Aircraft Preliminary Sizing Tool**

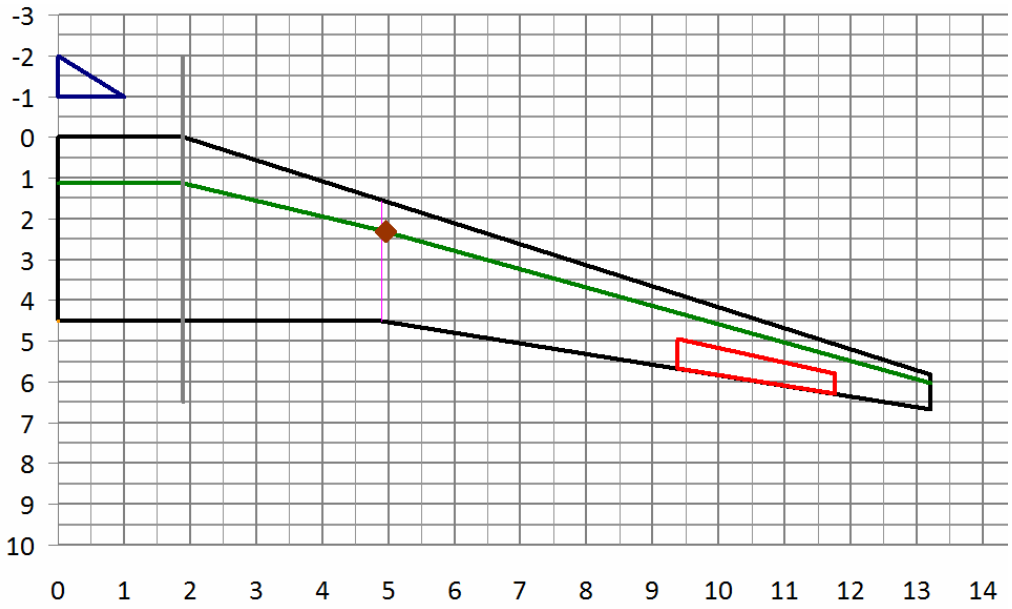
## Screen Shots
### Wing

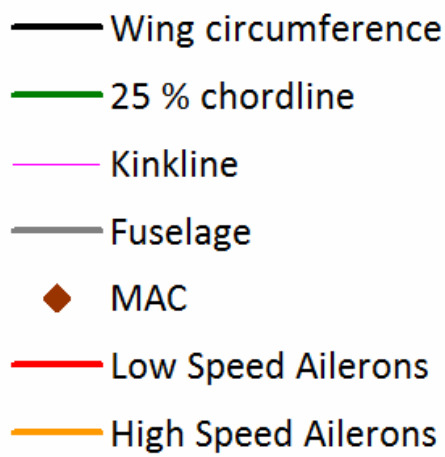



**User support** with **experience** from industry and academia **presented with respect to current design**

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### Wing




**Preview of** wing **parameters**

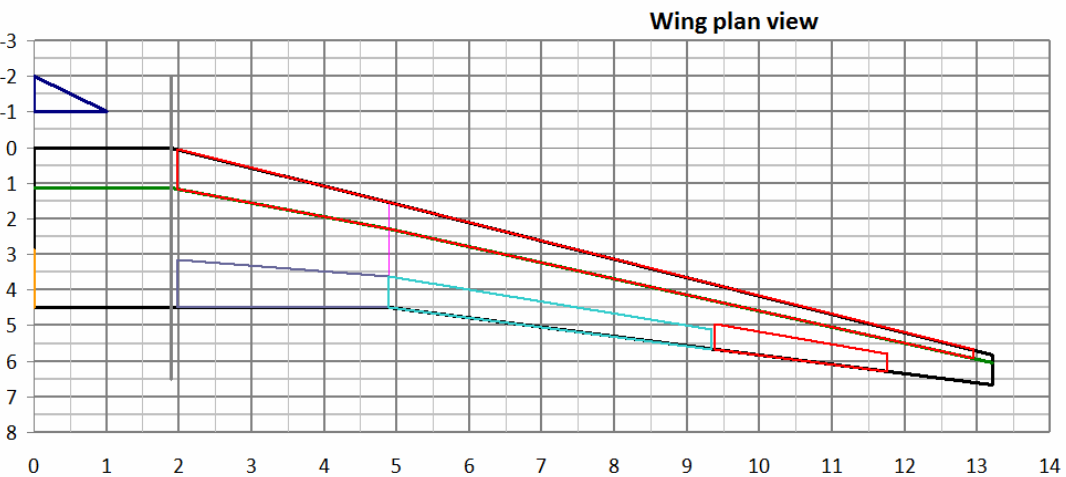
**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
## High Lift

Final statement in
high lift preliminary design

| available increase of lift coefficient due to highlift devices | | | required increase of lift coefficient | | |
|---|---|---|---|---|---|
| $\Delta C_{L,max,High\_Lift}$ | 1,985 | > | $\Delta C_{L,max,required}$ | 1,757 | |

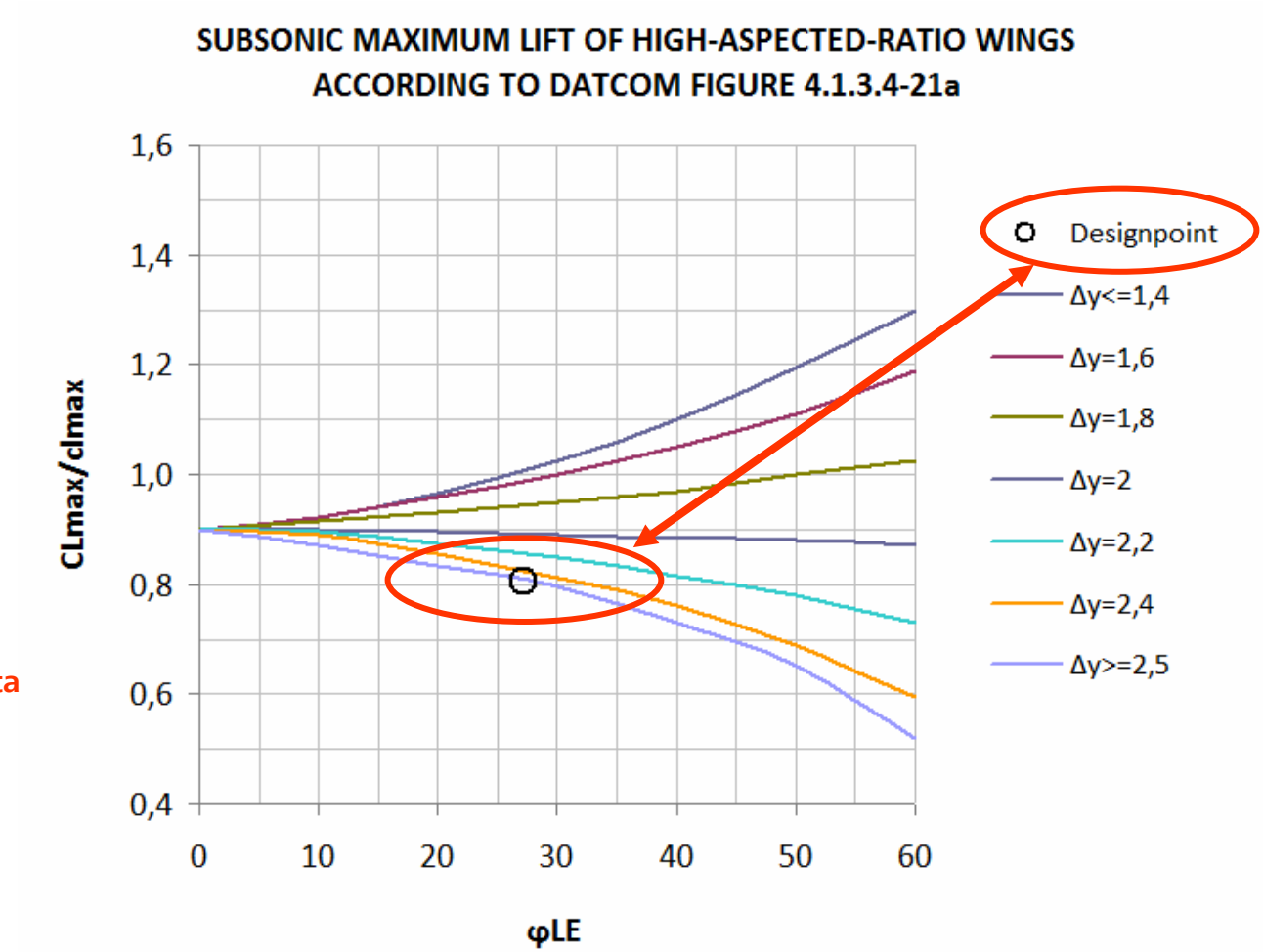
**Highlift is sufficient**




**Preview of** high lift **parameters**

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### High Lift



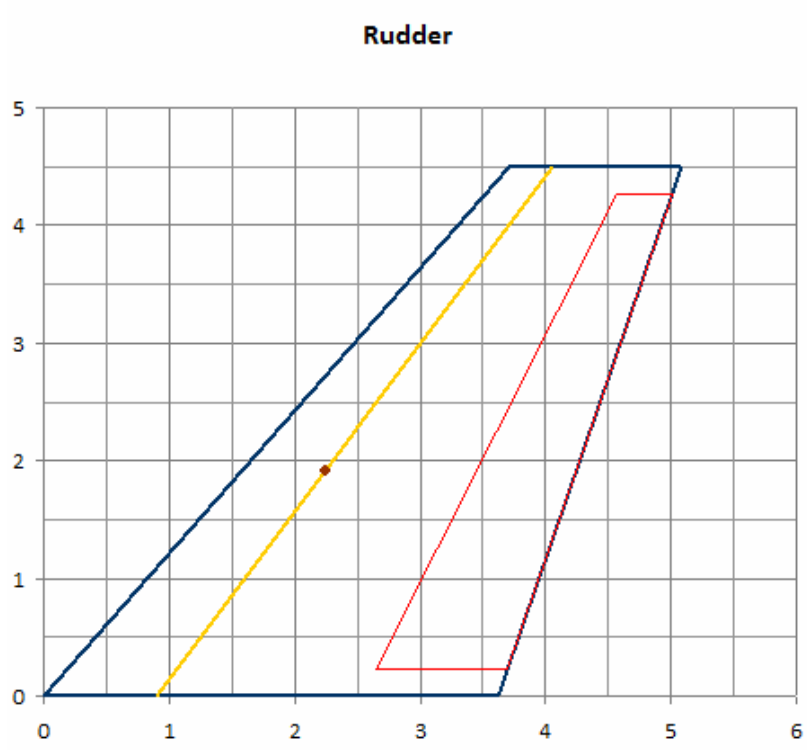

**Display of calculated Datcom data**
and
**Automatic readout** of parameters
with respect of actual **design point**

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### Tailplane I

**Preview of** tail **parameters**


Horizontal stabilizer

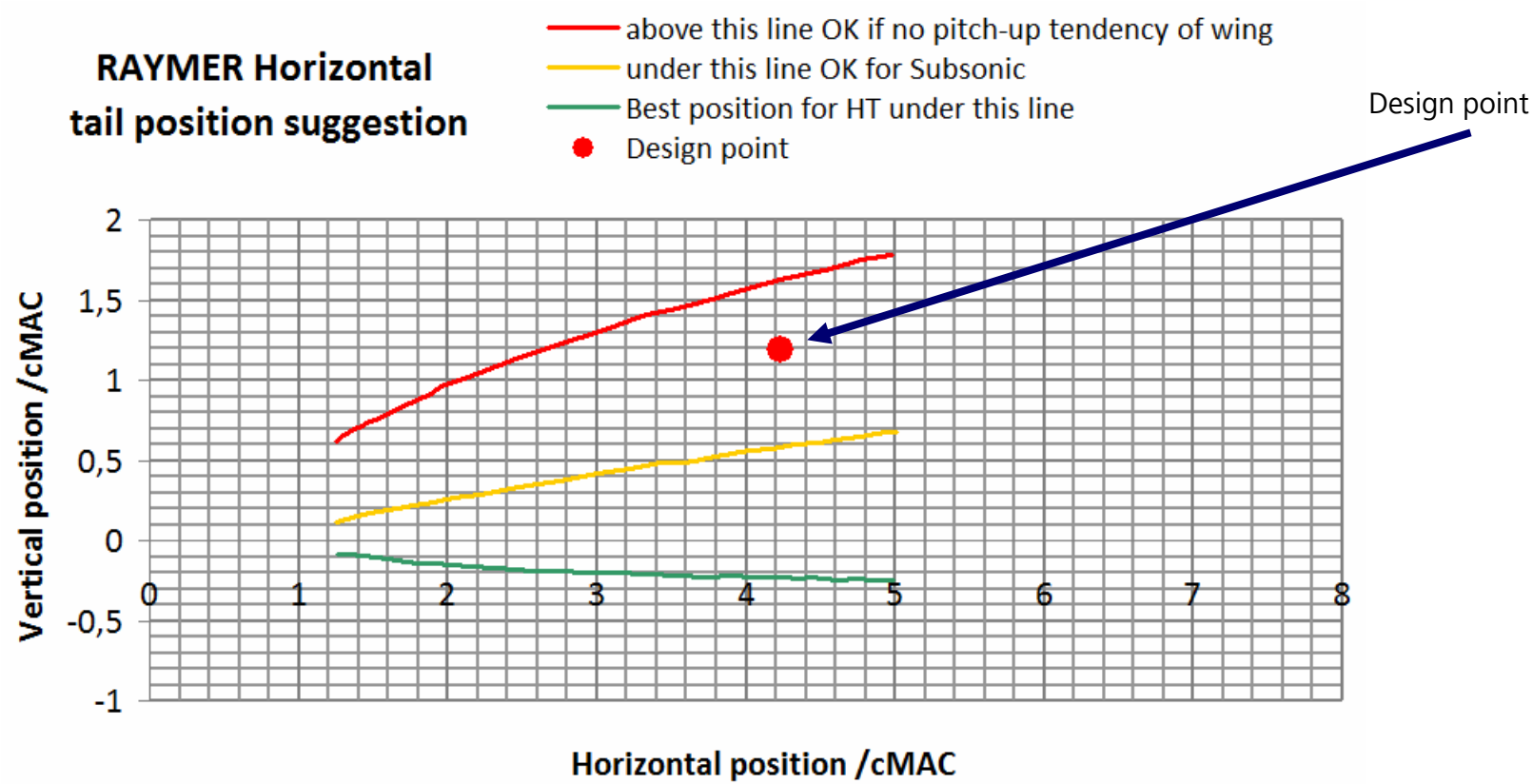



Fin

**PreSTo - Aircraft Preliminary Sizing Tool**

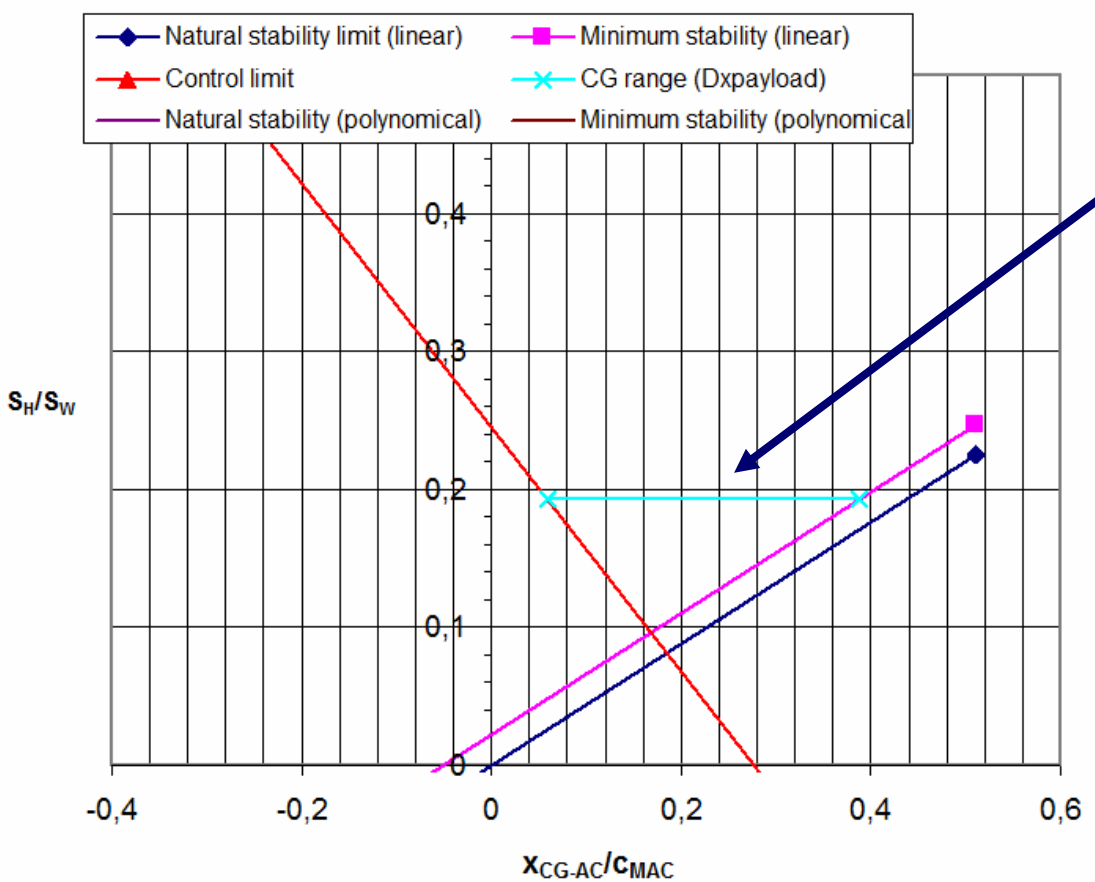
## Screen Shots
### Tailplane I

**Showing design parameters with respect to established practise**



**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### Tailplane II

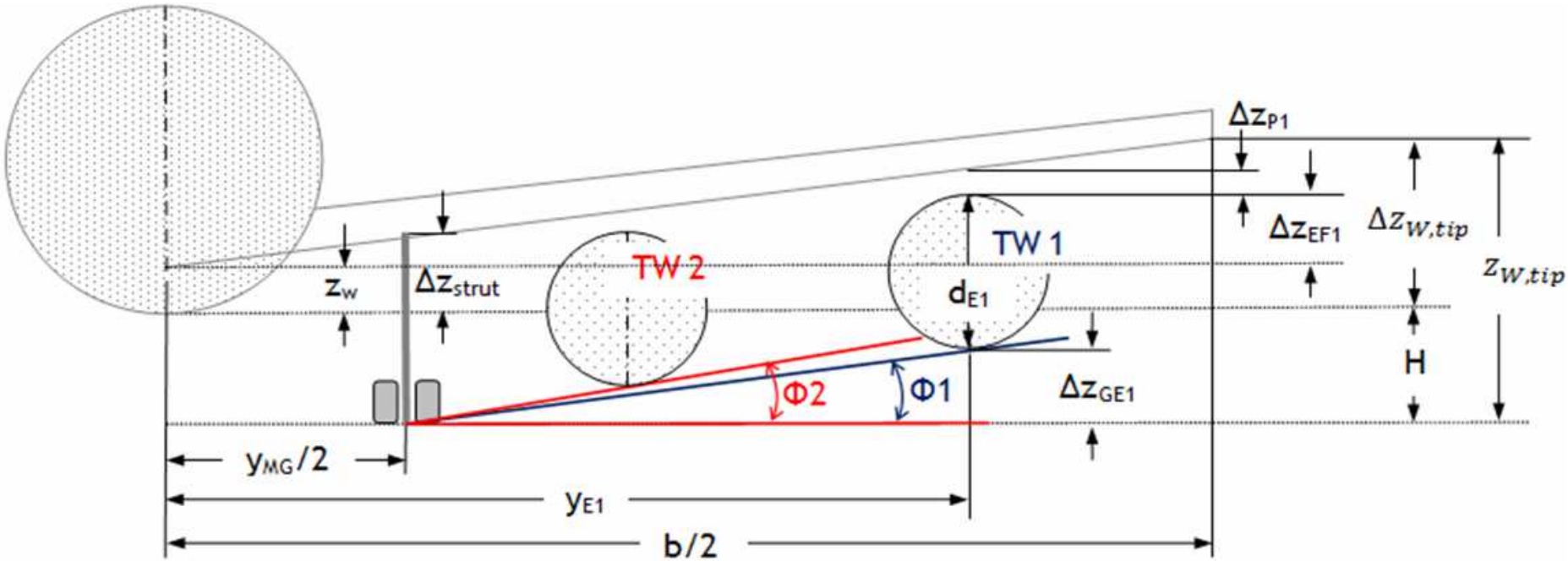



Required CG range

Horizontal tailplane sizing diagram

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
## Landing Gear

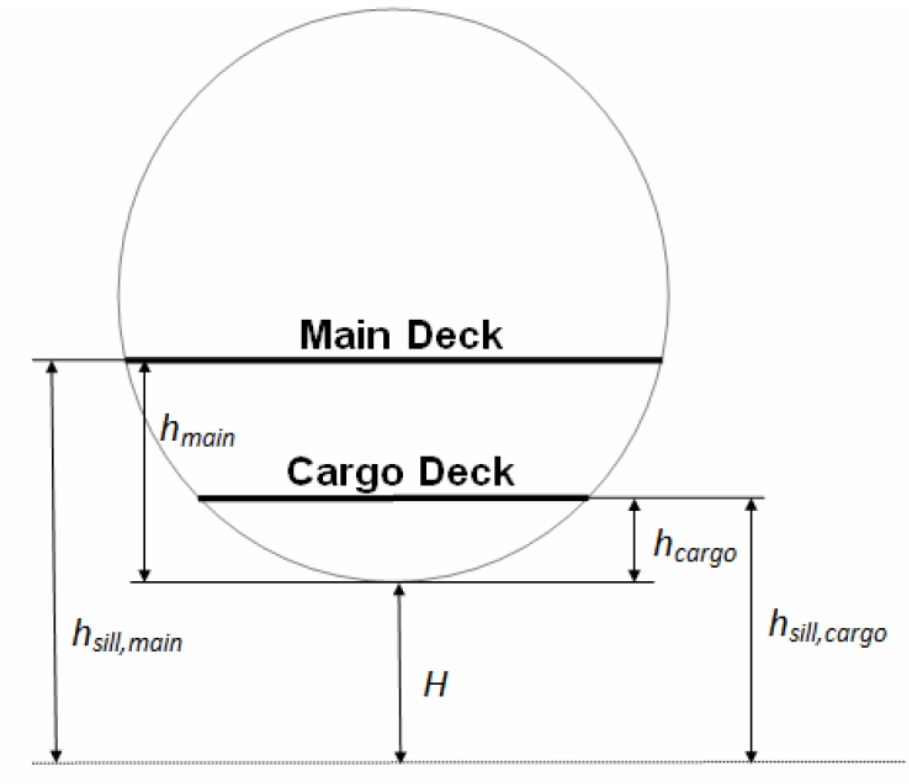



Engine ground clearance due to landing gear length

Engine 1 bank angle is OK

**PreSTo - Aircraft Preliminary Sizing Tool**

## Screen Shots
### Landing Gear




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

**PreSTo - Aircraft Preliminary Sizing Tool**

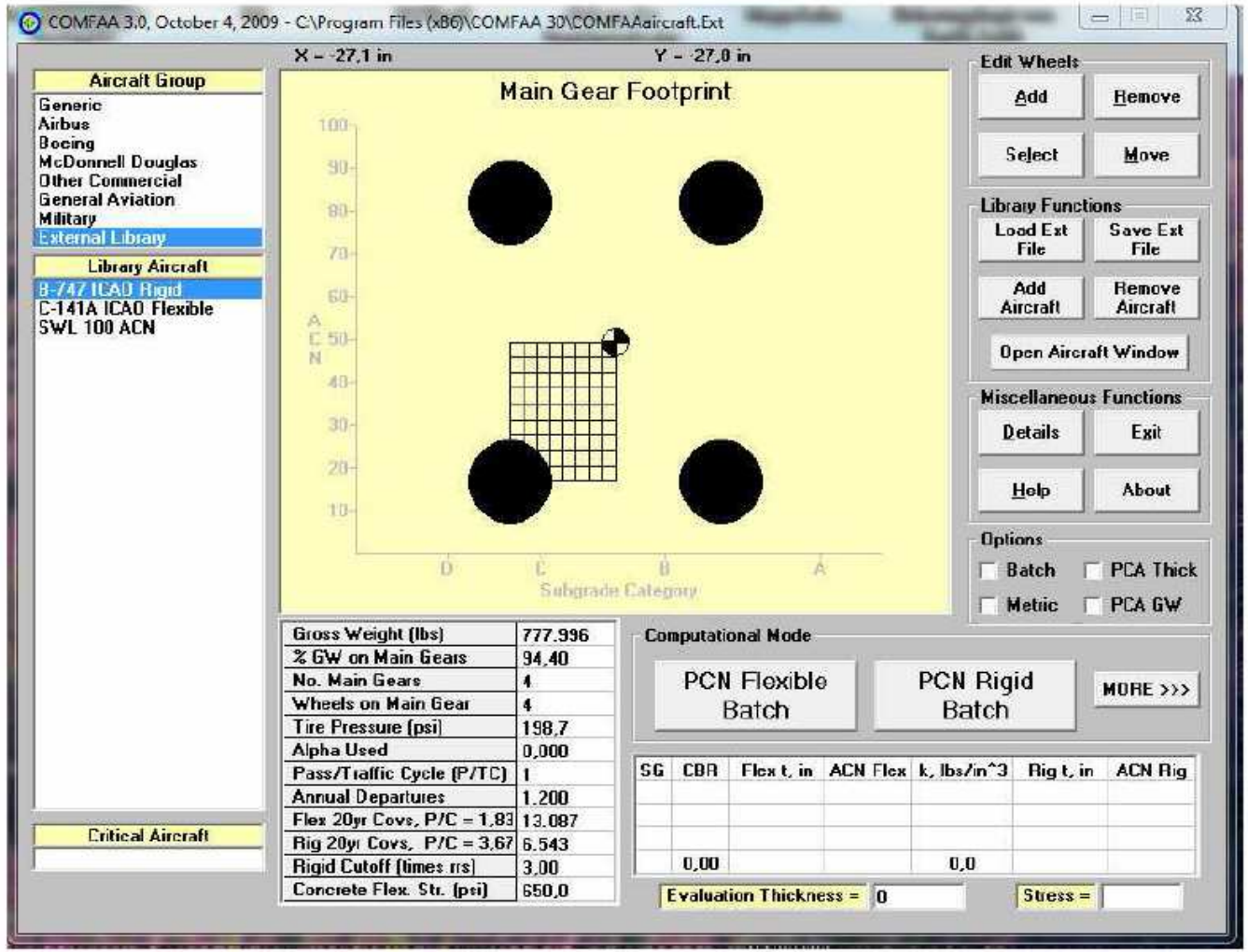
## Screen Shots
## Landing Gear

Calculation of **ACN** values
Aircraft
Classification
Number

COMFAA is integrated into PreSTo:

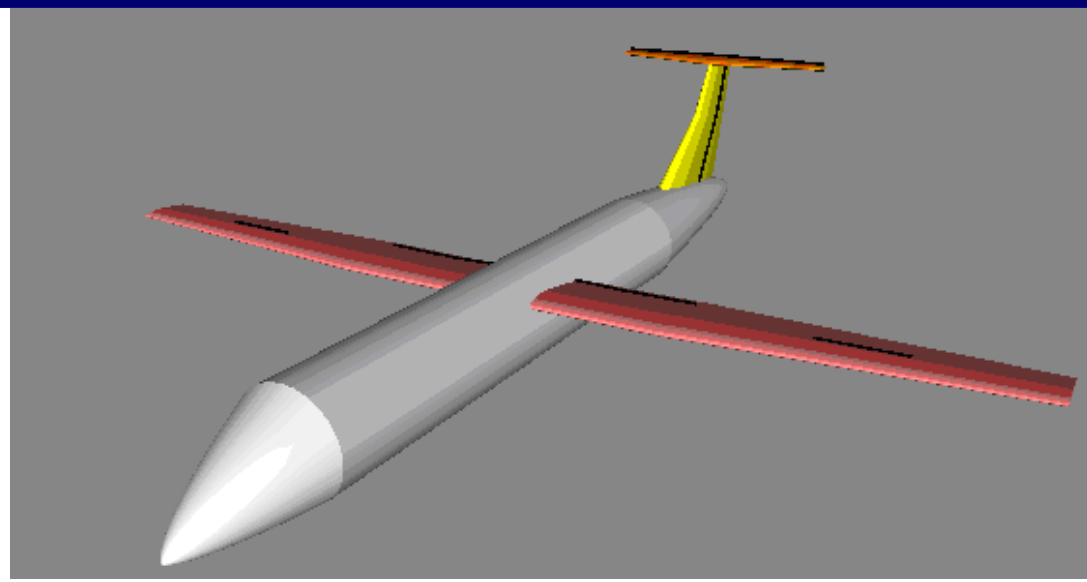
o automatic input of data

o COMFAA results stored in PreSTo

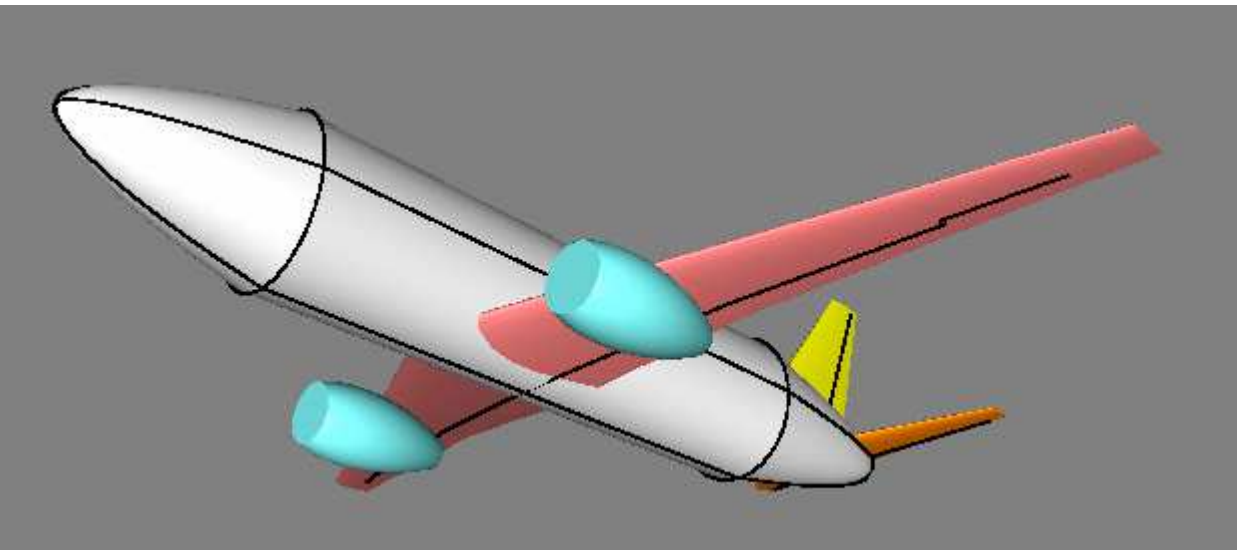


**PreSTo - Aircraft Preliminary Sizing Tool**

## Data Export / Visualization
## CEASIOM



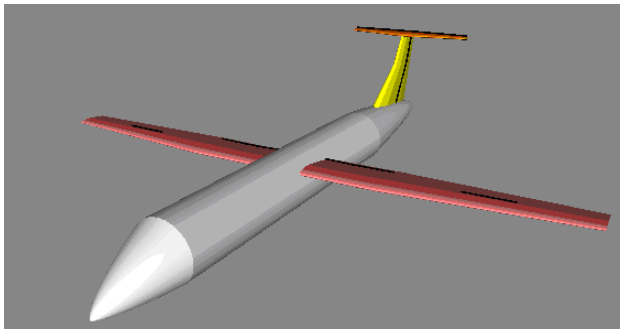
FD 728 from PreSTo in
**ACBuilder** from CEASIOM



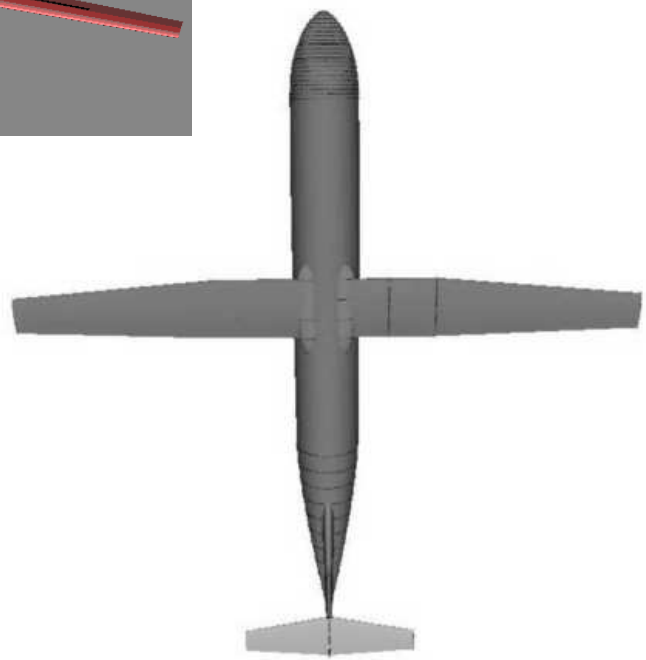
ATR 72 from PreSTo in
**ACBuilder** from CEASIOM

**PreSTo - Aircraft Preliminary Sizing Tool**

## Data Export / Visualization
## CEASIOM



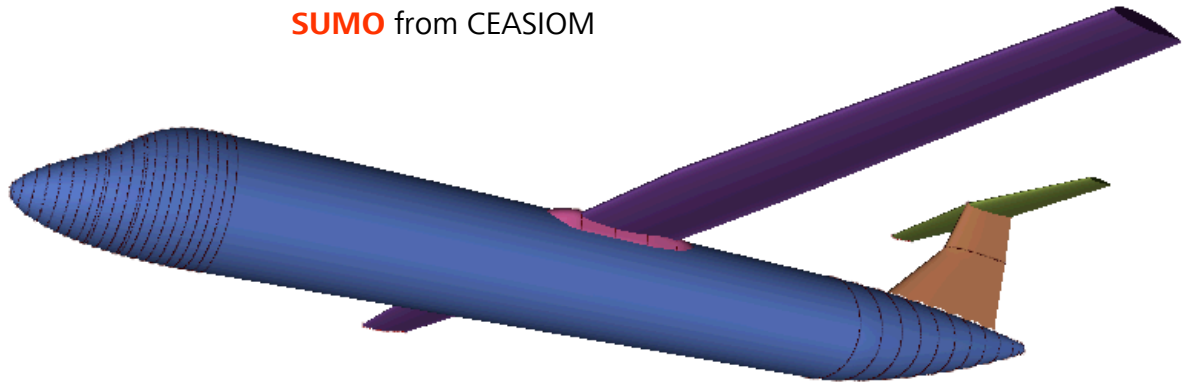
FD 728 from PreSTo in
**ACBuilder** from CEASIOM
shown in the style of a
**three-view drawing**

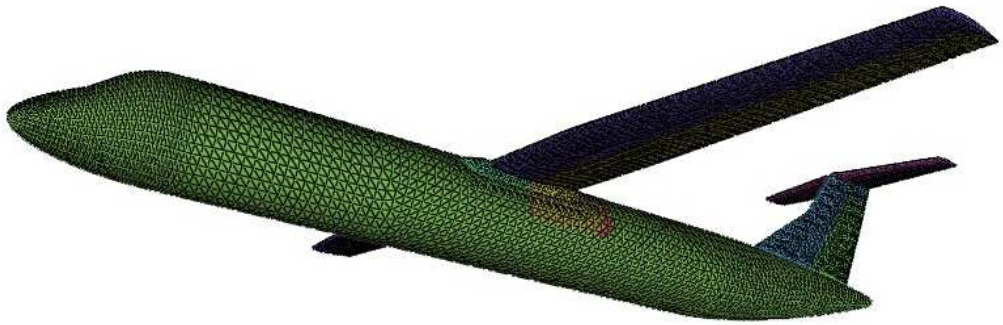


**PreSTo - Aircraft Preliminary Sizing Tool**

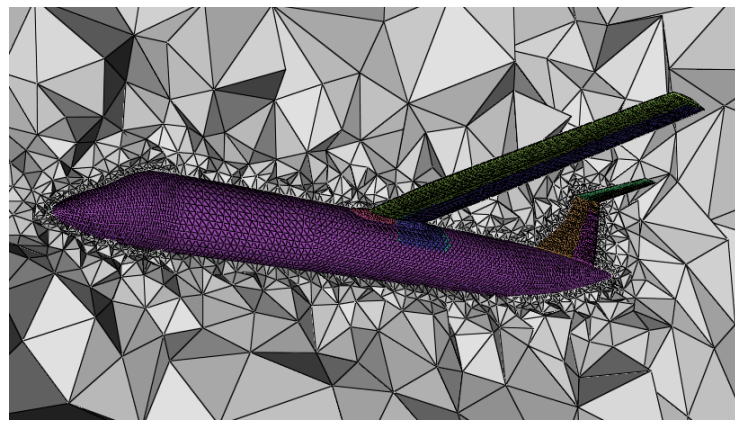
## Data Export / Visualization
## CEASIOM

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



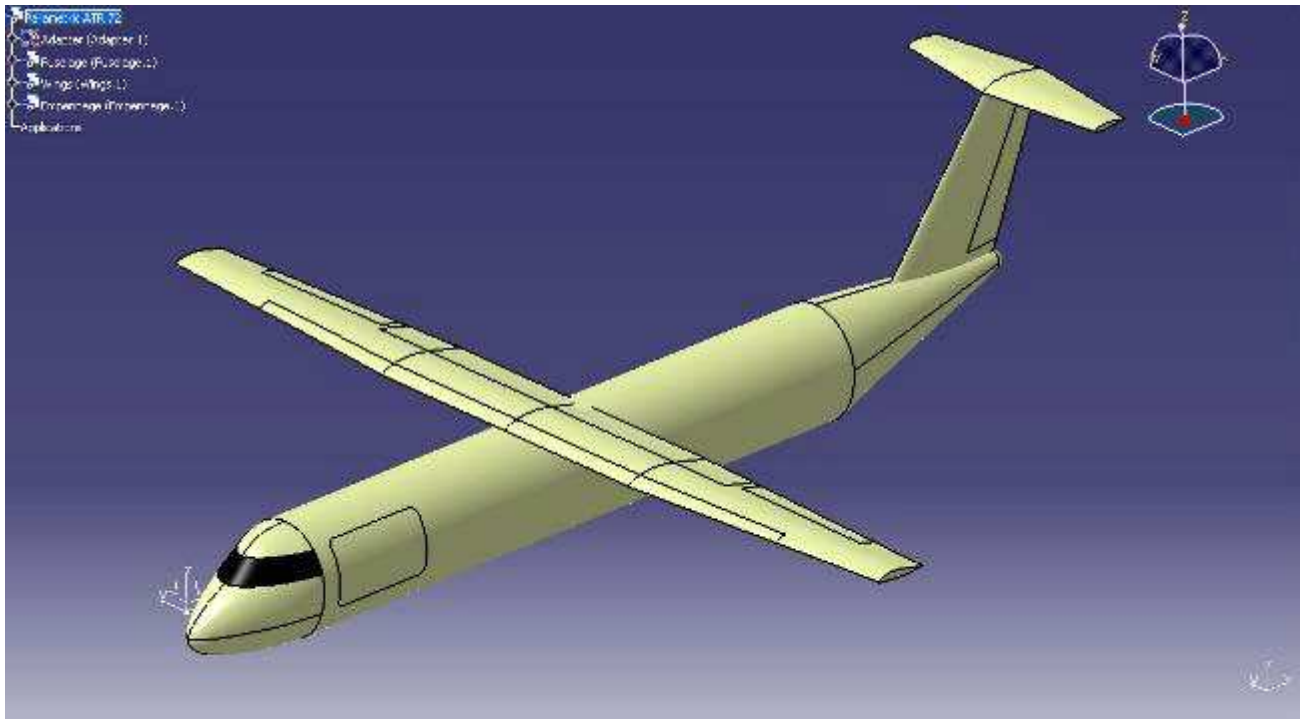


ATR 72 from PreSTo
with surface and volume mesh generated by
**SUMO** from CEASIOM



**PreSTo - Aircraft Preliminary Sizing Tool**

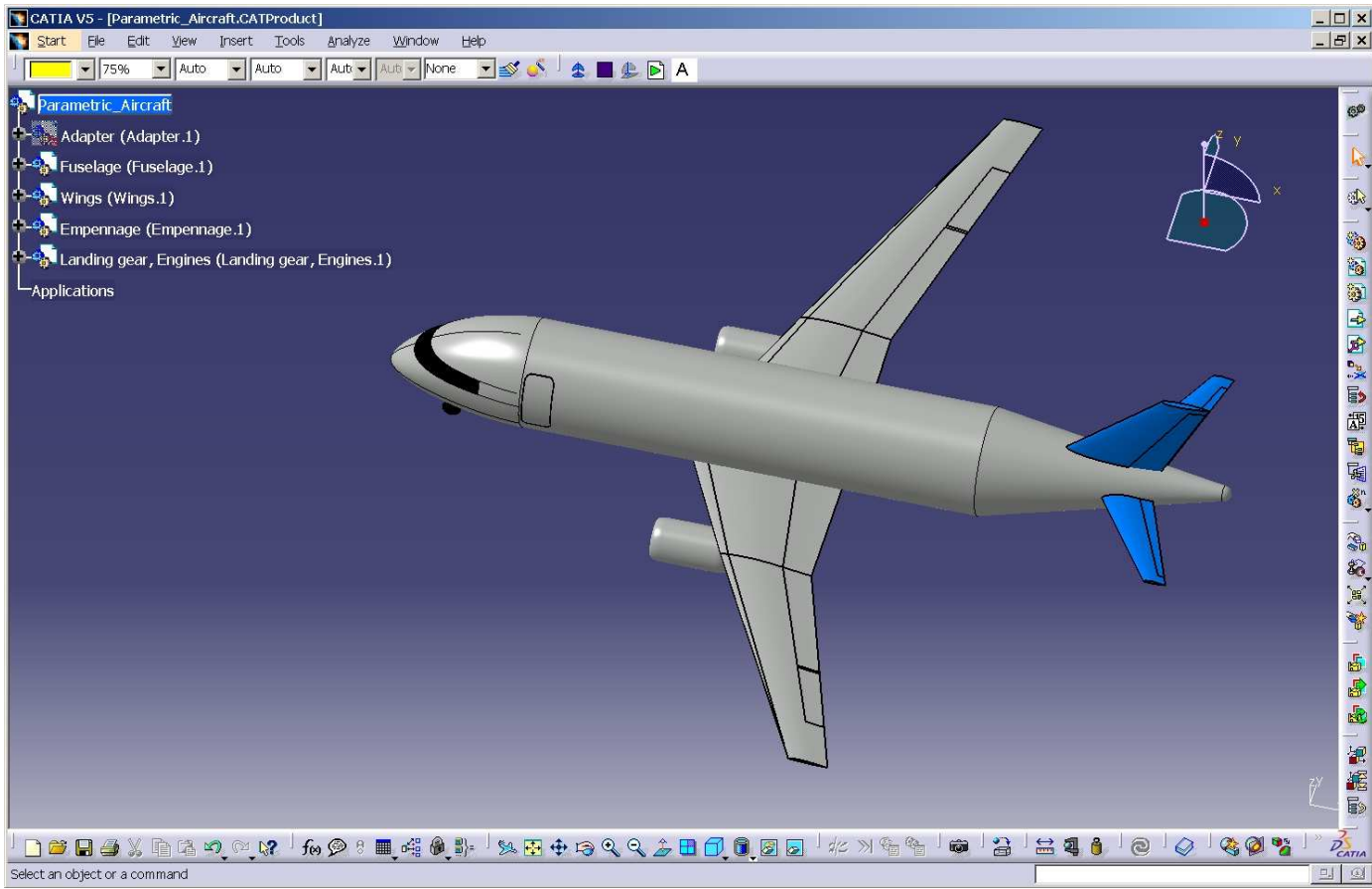
## Data Export / Visualization
## Catia



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

**PreSTo - Aircraft Preliminary Sizing Tool**

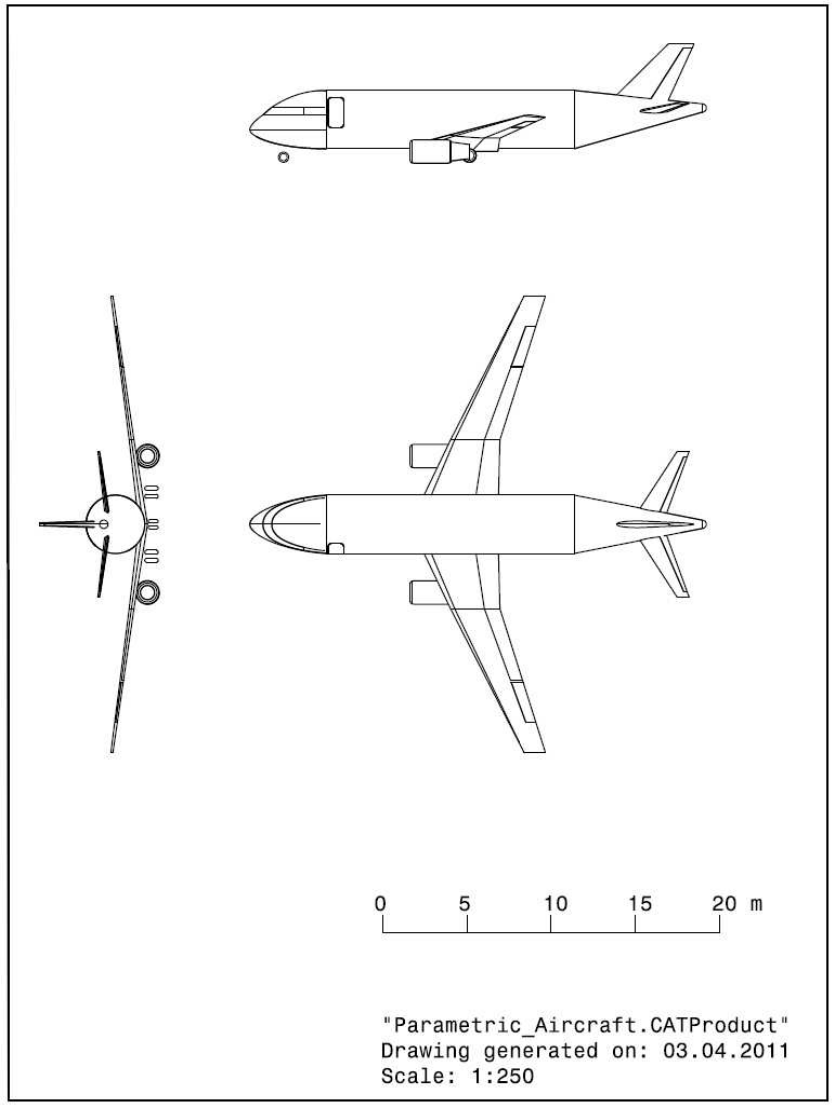
## Data Export / Visualization
### Catia




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

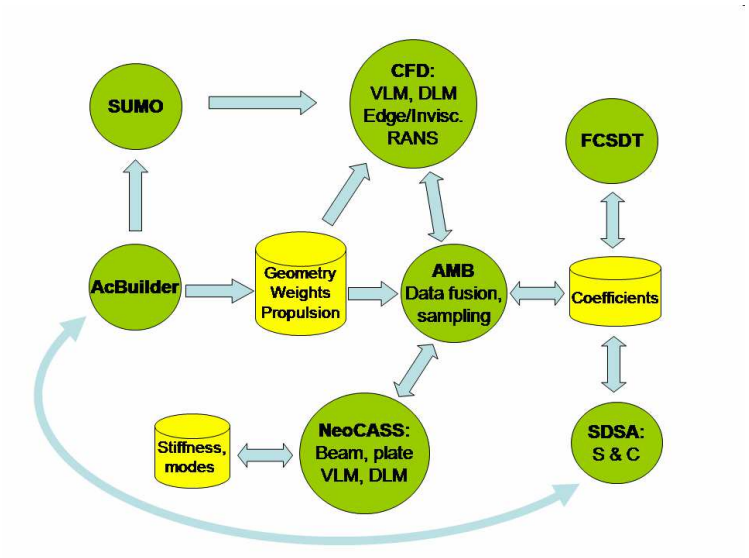
**Tornado**

TORNADO

CEASIOM

**Computerised Environment for Aircraft Synthesis and Integrated Optimisation Methods**

**USAF Digital DATCOM**




JSBSim

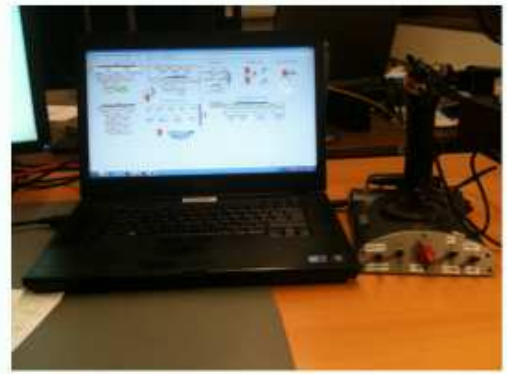
X-Plane
By Laminar Research

FLIGHTGEAR

## Further Tool Chain

Diamond SIMULATION

**D-SIM-42**



FDM in Matlab/Simulink

**Diamond DA - 42**


## Aircraft Preliminary Sizing Tool @ Aero

# PreSTo Homepage / Download

**http://PreSTo.ProfScholz.de**

## 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 donwload: 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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http://SAS.ProfScholz.de
http://OPerA.ProfScholz.de
http://PreSTo.ProfScholz.de