PreSTo - Aircraft Preliminary Sizing Tool

From Requirements to the Three-View-Drawing

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PreSTo - Aircraft Preliminary Sizing Tool

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PreSTo - Aircraft Preliminary Sizing Tool

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 aircraft data for 3D-plots and three-view-drawings
• Couple to higher order tools for further investigation
PreSTo - Aircraft Preliminary Sizing Tool

**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: \[ T/W = f \left( m/S \right) \]
  - Prop: \[ P/W = f \left( m/S \right) \]
- Lecture in this format since 1999:
  - about 1000 students taught
  - many student reports and theses produced
- Spreadsheet for preliminary sizing (only) is in service for many years: [http://FE.ProfScholz.de](http://FE.ProfScholz.de)
- Preliminary sizing spreadsheet has been used for:
  - tutorials, examinations
  - projects, theses
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Aircraft Design Lecture

Contents

- Preliminary sizing
  - Matching chart
  - \((L/D)_{\text{max}}\) 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
  - \(C_{L_{\text{max}}}\) found from Datcom

- Empennage I
  - Sizing from tail volume
Aircraft Design Lecture - Contents

- **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

![Diagram showing stability limits and direct operating costs](image-url)
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Screen Shots
PreSTo Control Center and Database

PreSTo Control Center – Start page
PreSTo Control Center and Database

**Screen Shots**

PreSTo Control Center – Module page
**PreSTo - Aircraft Preliminary Sizing Tool**

**Screen Shots**

**PreSTo Control Center and Database**

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 CEASIM. PreSTo further connects to PrADO and CATIA.

For further information, documentation and downloads see:  
[http://PreSTo.ProScholz.de](http://PreSTo.ProScholz.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).

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PreSTo - Aircraft Preliminary Sizing Tool

Screen Shots
PreSTo Control Center and Database

<p>| | | |</p>
<table>
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<td>V_APP</td>
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</tr>
<tr>
<td>8</td>
<td>n_E</td>
<td>2 [-]</td>
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</table>

PreSTo Control Center – Database
PreSTo - Aircraft Preliminary Sizing Tool

Screen Shots

Preliminary Sizing

User open und close Chapters with + / - sign

Pre-Initial 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 statistic

Jet statistics

Chart

- **Wing sweep angle (25 % chord) - \( \phi 25\% \)**

- **Mach number, cruise - MCr [-]**

- **X axis:** Mach number, cruise - MCr [-]
- **Y axis:** Wing sweep angle (25 % chord) - \( \phi 25\% \)
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Screen Shots
Preliminary Sizing

\[ E_{\text{max}} = k_E \sqrt{\frac{A}{S_{\text{wet}} / S_W}} \]

Estimation of max. glide ratio, \( E_{\text{max}} \)

Choose: factor \( k_E \) 15.8

Relative wetted area

Relative wetted area

Aspect ratio

Max. glide ratio

\( S_{\text{wet}} / S_W \) 6.2

\( A \) 9,806.592

\( E_{\text{max}} \) 19.75

Max. glide ratio

\( E_{\text{max chosen}} \) 19.75

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”.

<table>
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<tr>
<th>Zone</th>
<th>Allowed PAX</th>
<th>Effective number of PAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>125</td>
<td>96</td>
</tr>
<tr>
<td>B</td>
<td>125</td>
<td>84</td>
</tr>
</tbody>
</table>

Check of exit zones according to AC 25.807.1 (6)(b)(1)

Check of exits positions according to AC 25.807.1 (6)(b)(2)(vi)
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Screen Shots
Cabin & Fuselage

Change this ...

... to minimize this:

- Cross section dimensions (from Economy Class)
- Automatic calculation
- Automatic optimization

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.
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Screen Shots
Cabin & Fuselage

Alternative seat arrangement:

Seat rail
Container
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Screen Shots
Cabin & Fuselage

Seat layout
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Screen Shots
Cabin & Fuselage

A330-300 designed in PreSTo

Seat layout comparison:
Airbus original and PreSTo

A330-300 from Airbus
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Screen Shots

**Wing**

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

Wing

Preview of wing parameters
Screen Shots

High Lift

Final statement in high lift preliminary design

Available increase of lift coefficient due to highlift devices

\[ \Delta C_{L,\text{max,High\_Lift}} \]

\[ 1.985 \]

Required increase of lift coefficient

\[ \Delta C_{L,\text{max,required}} \]

\[ 1.757 \]

Highlift is sufficient

Wing plan view

Preview of high lift parameters
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Screen Shots

High Lift

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

Graph: Subsonic maximum lift of high-aspected-ratio wings according to DATCOM figure 4.1.3.4-21a

- Designpoint
- Δy<1.4
- Δy=1.6
- Δy=1.8
- Δy=2
- Δy=2.2
- Δy=2.4
- Δy>=2.5

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Aero - Aircraft Design and Systems Group
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Screen Shots

Tailplane I

Preview of tail parameters

- Horizontal stabilizer
- Fin

Rudder
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Screen Shots
Tailplane I

RAYMER Horizontal
tail position suggestion

Showing design parameters with respect to established practise

- above this line OK if no pitch-up tendency of wing
- under this line OK for Subsonic
- Best position for HT under this line

Design point

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Education, Naples, Italy, 24.-27.05.2011
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Screen Shots
Tailplane II

Horizontal tailplane sizing diagram

Required CG range

Horizontal tailplane sizing diagram
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Screen Shots
Landing Gear

Engine ground clearance due to landing gear length

Engine 1 bank angle is OK
Screen Shots

Landing Gear

Calculating **sill height** – an important parameter for airport compatibility
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Screen Shots
Landing Gear

Calculation of ACN values
Aircraft
Classification
Number

COMFAA is integrated into PreSTo:
- automatic input of data
- COMFAA results stored in PreSTo
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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

Initial Aircraft Design Requirements

Preliminary Sizing Tool (PreSTo)

3D Surface Model Configurator (PreSTo-Vis)

3D CAD Concept Model of Aircraft in CATIA V5

Preliminary Design Documentation

Further Geometric and Numerical Analysis & Design Optimization

Data flow from PreSTo to Catia
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!
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PreSTo Homepage

PreSTo - Aircraft Preliminary Sizing Tool

Introduction to PreSTo

Aircraft Design Spreadsheet Calculation

Aim of PreSTo is to convert the aircraft design calculation scheme from the lecture and short course of Prof. Scholz into a spreadsheet. The spreadsheet will ultimately include these modules:

1. Sizing (PreSTo-Sizing)
2. Cabin and Fuselage Layout (PreSTo-Cabin)
3. Wing Layout
4. Design for HiD Lift
5. Empennage Layout I and II
6. Mass and CG Estimation
7. Landing Gear Layout
8. Drag Estimation
9. DOC Calculation
10. Results, Interfaces to other Tools, 3D Visualization (PreSTo-3D)

Excel was selected as spreadsheet. Experience has shown that the tool will get too big (and will not run on computers with limited computing power) if all modules are put together in one file. In addition this file will be rather big (some 10 MB). So the intention is to work with separate modules that are connected via a small Excel file that provides the link between all separate modules - each in one file - and contains a database which stores user input data. In this way the modules described above are Excel files that take input data, run the design analysis and output data to a small and separated database.

Philosophy

http://PreSTo.ProfScholz.de
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PreSTo Homepage

Download PreSTo:

http://PreSTo.ProfScholz.de
Conclusions and Outlook

- **PreSTo** supports a very **basic / standard** way of **aircraft design**

- **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 PreSTo
  - Offer for download: [http://PreSTo.ProfScholz.de](http://PreSTo.ProfScholz.de)
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