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Airplane-3D-Modeling with OpenVSP-Connect

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Abstract

The first aim of this project is to analyze and improve OpenVSP-Connect, which is being designed as an interface tool between any Excel based aircraft design tool and Open Vehicle Sketch Pad (OpenVSP) from NASA. OpenVSP-Connect is also an Excel based tool which uses Visual Basic Macros. OpenVSP-Connect needs 46 core parameters in order to provide visualization of the designed aircraft. The software never asks for a parameter without suggesting one first or giving a value by default. The project describes the improvements made to OpenVSP-Connect by the author and gives detailed description of the ways OpenVSP-Connect can be used. The second objective of the project is to incorporate OpenVSP-Connect in an already existing tool chain. OpenVSP-Connect provides the missing link between another tool made by the AERO Group at Hamburg University of Applied Sciences, i.e. Aircraft Preliminary Sizing Tool (PreSTo) and NASA's tool Open Vehicle Sketch Pad. Moreover, it can be used as a mediator between any Excel based Database which contains the necessary 46 core parameters and OpenVSP. OpenVSP-Connect will support aircraft design activities and give quickly visualization of conceptual designs. It can be also used as a self-standing tool which calculates all the necessary values and pushes them into OpenVSP by a push of a button.

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a	Speed of Sound
A_H	Total aspect ratio of the horizontal tail
A_V	Total aspect ratio of the vertical tail
A_H	Total aspect ratio of the wing
b	Wing span
B_s	Briguet factor, cruise
B_t	Briguet factor, time
c	Chord
CFD	Computational fluid dynamic
c_L	Lift coefficient
c_D	Drag coefficient
C_H	Tail volume coefficient of the horizontal tail
c_{MAC}	Mean aerodynamic chord
$c_{r,df}$	Dorsal fin extension chord from VT
C_V	Tail volume coefficient of the vertical tail
$d_{e,j}$	Jet engine diameter
$d_{e,p}$	Propeller engine diameter
$d_{e,p,r}$	Proppeller rotor diameter
d_F	Fuselage diameter
$d_{F.I.}$	Fuselage inner diameter
$d_{F.O.}$	Fuselage outer diameter
DULV	Deutsche Ultraleichtflugverband (German Ultralight Association)
e	Euler's number
FEM	Finite element method
g	Earth's acceleration
h_{CR}	Cruise height
HT	Horizontal tail
$k_{A,H}$	Horizontal tail aspect ratio constant
$k_{A,V,1}$	Aspect ratio for conventional Tail
$k_{A,V,2}$	Aspect ratio for T-tail
$k_{l,cock,F}$	Cockpit length constant
$k_{l,F\backslash d,F}$	Slenderness ratio
$k_{l,tail,F}$	Fuselage tailcone constant
$k_{\eta,k,W}$	Relative kink constant
$k_{\lambda,H}$	Horizontal tail taper ratio constant
$k_{\lambda,V,1}$	Taper ratio for conventional Tail
$k_{\lambda,V,2}$	Taper ratio for T-tail
l	Length
L	Lift

L/D	Glide ratio
$L_{aft,F}$	Fuselage aft length
$L_{cock,F}$	Cockpit length
$l_{e,j}$	Jet engine length
$L_{e,p}$	Propeller engine length
L_F	Fuselage length
l_H	Horizontal tail lever arm
l_H	Vertical tail lever arm
$L_{nose,F}$	Nose length
LSA	Light Sport Aircraft
LTF-UL	Lufttüchtigkeitsforderungen für aerodynamisch gesteuerte Ultraleichtflugzeuge
m	Mass
MAC	Mean aerodynamic chord
M_{CR}	Cruise Mach number
m_F	Fuel mass
M_{ff}	Mission fuel fraction
$M_{ff,CLB}$	Fuel fraction, climb
$M_{ff,CR}$	Fuel fraction, cruise
$M_{ff,DES}$	Fuel fraction, descent
$M_{ff,L}$	Fuel fraction, landing
$M_{ff,Loiter}$	Fuel fraction, loiter
$M_{ff,RES}$	Fuel fraction, extra flight distance
$M_{ff,TO}$	Fuel fraction, take-off
$M_{ff,res}$	Fuel fraction, reserves
$M_{ff,std}$	Fuel fraction, standard
m_{MTO}	Maximum take-off mass
m_{OE}	Operating empty mass
m_{PL}	Payload mass
n_e	Number of engines
$n_{b,p}$	Number of blades
n_p	Number of passengers
n_{PAX}	Number of passengers
n_{SA}	seats abreast
NASA	National Aeronautics and Space Administration
OpenVSP	Open vehicle sketch pad
OPerA	Optimization in Preliminary Aircraft Design
P_{TO}	Total Engine Power
PreSTo	Preliminary sizing tool
R	Range
$RelPos_{H,x}$	X position of HT
$RelPos_{H,z}$	Z position of HT
$RelPos_{V,x}$	X position of VT
$RelPos_{W,x}$	X position of wing
$RelPos_{W,z}$	Z position of wing

S	Area
S_H	Total area of the horizontal tail
S_{res}	Extra flight distance
S_V	Total area of the vertical tail
S_W	Total area of the wing
SAS	Simple Aircraft Sizing
SFC	Specific fuel consumption
T_{CR}	Cruise Thrust
t_{Loiter}	Loter time
T_{TO}	Total Engine Thrust
t\c	Airfoil thickness ratio
$Type_E$	Engine Type
$Type_W$	Wing Type
$Type_{df}$	Dorsal fin
UL	Ultra Light Aircraft
V	Volume, speed
VBA	Visual Basic (Microsoft Office Excel)
VLA	Very Light Aircraft
VT	Vertical tail
W	Weight
Γ_H	Dihedral angle of the horizontal tail
$\Gamma_{W.o}$	Wing outboard dihedral angle
$\Delta\varphi_{25,H}$	Horizontal tail 25% sweep constant
Δd	fuselage wall thickness
η	preoppeler efficiency
$\eta_{k,W}$	Relative kink position of the wing
λ_H	Taper ratio of the horizontal tail
λ_V	Taper ratio of the vertical tail
λ_W	Taper ratio of the wing
μ	By-pass ratio
ρ	Density
$\varphi_{0,df}$	Dorsal fin Leading edge sweep
$\varphi_{0,W,i}$	Wing Inboard Leading edge Sweep
$\varphi_{25,H}$	25% Sweep of the horizontal tail
$\varphi_{25,V}$	25% Sweep of the vertical tail
$\varphi_{25,W,o}$	Wing outboard 25% Sweep
$\varphi_{100,W,I}$	Wing Inboard Trailing edge Sweep

1 Introduction

1.1 Motivation

The main purpose of this project is to improve and evaluate OpenVSP-Connect. OpenVSP-Connect has been developed to certain level but further improvements were needed so as the program to reach final stage. There are multiple reasons for the choice of this project. First of all, the opportunity to combine mathematics and aeronautics with 3D-designing is very interesting for me and also very useful for my further development as an aeronautical engineer. Furthermore, OpenVSP-Connect is very helpful and user friendly tool for all aircraft designers – beginners and experts as well. This program allows the user to visualize his mathematically calculated parameters into 3D-drawing or to choose just 2 key parameters and receive all the rest values necessary for an aircraft 3D-visualization as well as the 3D-model itself. Last but not least the opportunity to join the Aero Group at HAW Hamburg allows me to extend my knowledge and gain very useful experience.

1.2 Methodology

The first source for gathering information for this project was the official webpage of OpenVSP, http://www.openvsp.org/, and the software itself. The research grew into finding some other webpages related to OpneVSP and creating my firs redesign in OpenVSP. The second step for information was direct contact with my promoter at the HAW, Professor Scholz, who explained me the main idea of OpenVSP-Connect and introduced me to the work which was already done on the project. He also gave me the excel sheet of OpenVSP-Conect as well as all the other files related to it. Another very important way of gathering necessary information was joining Prof. Scholz's Aircraft Design class.

The main site of the Aero Group, http://www.fzt.hawhamburg.de/pers/Scholz/Aero.html, was the most relevance source for information for this project.

The main way of gathering the necessary database was trough a library research. "Jane's All the World's Aircrafts" series were the most used source for this purpose. Another valuable source for creating the statistical equations incorporated in OpenVSP-Connect was the database for propeller Aircrafts created by Andreas Johanning, another student of the Aero Group at the HAW Hamburg.

All the programing in OpenVSP-Connect is via VBA Editor in excel. For a self-study of this matter, YouTube was used to search for VBA tutorials as well as lecture notes from other students at HAW.

1.3 Objectives

The main objective of this project is to provide the user with very easy to use program which is able to implement pre-calculated parameters into OpenVSP by a push of a button. These pre-calculated parameter can be calculated in OpenVSP-Connect based on just two input parameters, "Number of passengers“ and "Cruise Mach number" or manually introduced by the user. The third option is to push already calculated from another preliminary design tool parameters into OpenVSP-Connect also by a push of a single button. Therefore, another objective is to provide the missing link between any excel based preliminary design tool and a 3D-modeling program, in this case OpenVSP.

Third goal of this project is to find out reliable method for calculating all the necessary values for 3D-vizualisation from the "Number of passengers" and "Cruise Mach number". Statistics as well as aeronautics are used for derivation the necessary equations.

1.4 Structure of this project

In the first part basic introduction to OpenVSP and OpenVSP-Connect will be given: the philosophy, structure and overview of the interface. Further on, the whole tool chain will be introduced, since several different programs collaborate with each other: SAS, Opera, PreSTo, OpenVSP-Connect, OpenVSP.

Furthermore, detailed "How to use" guide will be given in Chapter 6. "**3-ways to use OpenVSP-Connect**" followed by a detailed description of the structure of the program, its tabs (Main, Input and Convert) and modules (Action Buttons, Requirements, Engine, Wing, Fuselage, Horizontal Tail, Vertical Tail, Positions of Aircraft Components)

2 OpenVSP

2.1 What is OpenVSP?

According to the official webpage OpenVSP is:

„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."

OpenVSP stand for Open Vehicle Sketch Pad. Therefore, the name itself explains the main purpose of the software. This is sketch pad developed from NASA with the goal to provide the user with very light and user friendly program for 3D-drawing of aircrafts. OpenVSP is open source and thus free to download. OpenVSP can be downloaded from the official page, http://www.openvsp.org/, under the „Get Started" section. Useful tutorials and link to a database with many 3D-models is also provided. This database is called „ VSP Hangar" and has free access. After successful installing, **Figure 1** shows the interface of OpenVSP - the sketch pad on the left side and the geometry browser on the right side.

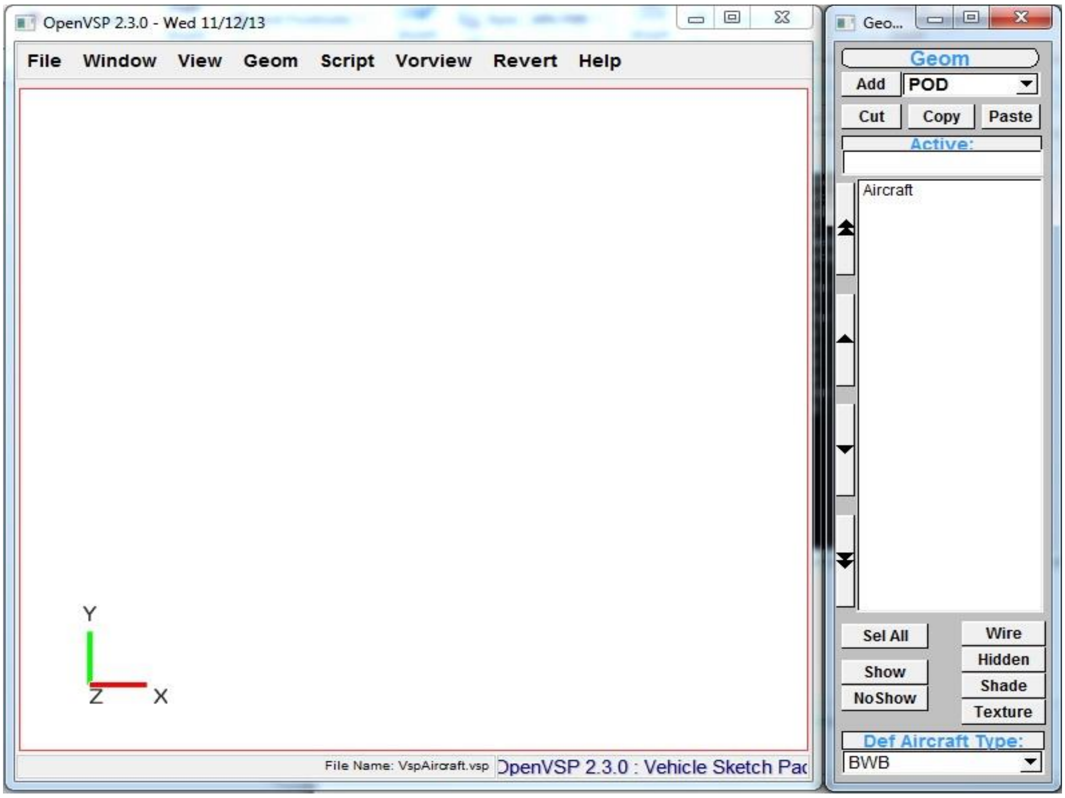


Figure 1 OpenVSP Interface

2.2 Three Approaches to Visualization with OpenVSP

„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. " (Hahn, 2013)

However, there is third approach – the "calculated" design in which all the necessary parameters are calculated in advance with the aid of a sizing tool like PreSTo, statistics or any other method. These values are then implemented into OpenVSP by hand or by another program which works as a mediator between the preliminary design program and OpenVSP, like a part of a tool chain. This is where OpenVSP-Connect is aiming.

3 What is OpenVSP-Connect?

OpenVSP-Connect is primarily intended as an joining tool between any aircraft design tool and Open Vehicle Sketch Pad (OpenVSP) from NASA. OpenVSP-Connect needs OpenVSP to display an aircraft.

In the order of 46 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 two input values "Number of passengers" and "Cruise Mach number" an aircraft can be sketched automatically based on passenger aircraft statistics. The main interface is shown on **Figure 2**.

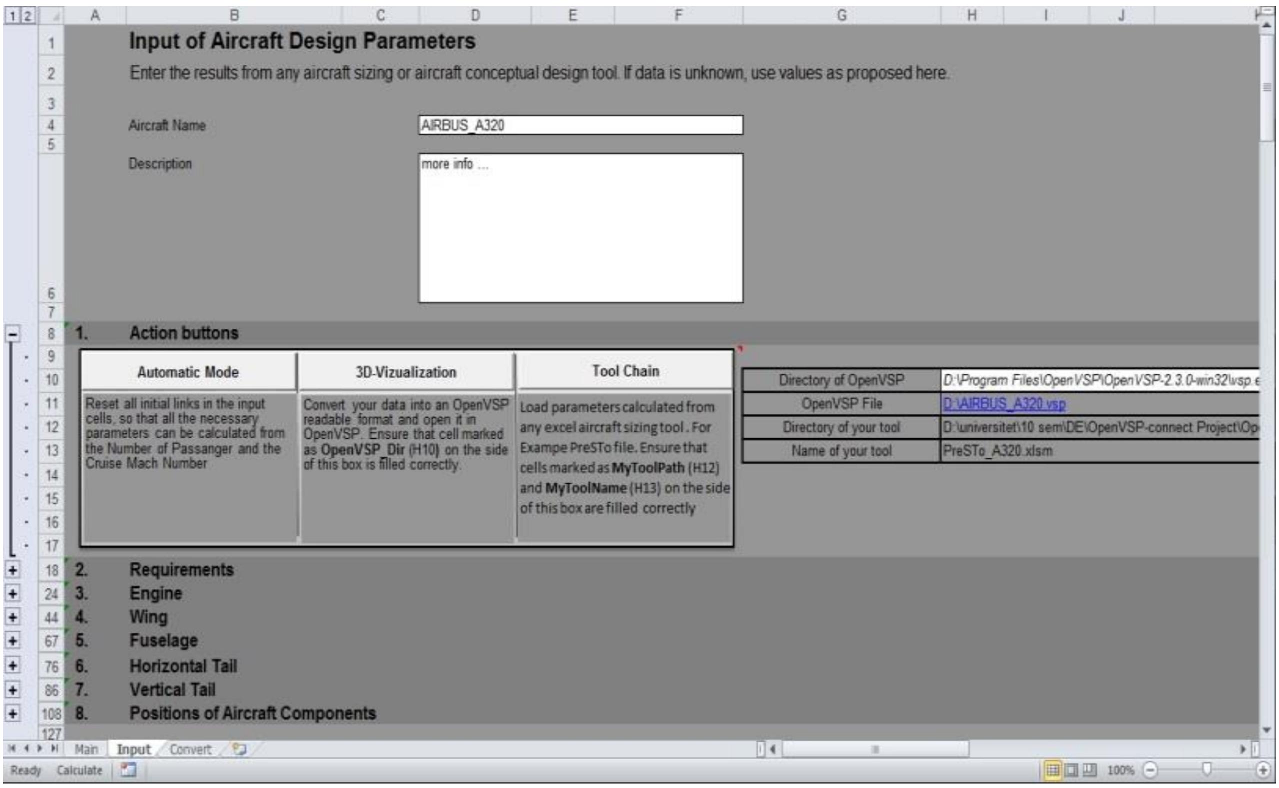


Figure 2 OpenVSO-Connect Interface.

4 Tool Chain

4.1 Simple Aircraft Sizing (SAS)

The philosophy behind SAS is to develop a web tool to convert certain mission requirements into useful aircraft parameters. These outputs may be landing field distance, take off distance, fuel calculations, the design point on matching charts and so on. To develop this Simple Aircraft Sizing tool Excel was chosen as spreadsheet because of the efficient integration of input, calculation and output, the open and easy to understand programming and because it is easy to adapt to individual needs by the user. (Scholz, 2012)

4.2 Optimization in Preliminary Aircraft Design (OPerA)

SAS is developed as an educational tool for aeronautical engineering students. Because of their inexperience in aircraft design the problem arose when it comes to giving relevant input requirements for a mission. Therefore OPerA is developed. By formal optimization algorithms, optimized values are presented to the end user when some requirements lack. In this way the designer is helped to choose more appropriate parameters that will lead to a realizable preliminary design. These algorithms are formed by Noesis Solutions (Belgium) which acts on the Optimus software platform and is able to use a huge amount of data. Nevertheless, OPerA only requires a Microsoft Excel 2007 or newer version, because the code is written in Visual Basics. (Scholz, 2012)

4.3 Aircraft Preliminary Sizing Tool (PreSTo)

PreSTo is on the other track of the bifurcation. PreSTo is abbreviated from AircraftPreliminary Sizing Tool. PreSTo, as are the other tools, is developed to aid in the lecture and short course of Prof. Scholz. As explained above, preliminary sizing is all about converting requirements into aircraft parameters. The aim is to provide PreSTo as a spread sheet and for this reason Microsoft Office Excel was chosen. For proper conversion from requirements to parameters, the philosophy of PreSTo states there should be (Scholz, 2012):

- Methods, equations and the most efficient calculation sequence,
- Statistical and best guess data,
- Reference to certification rules,
- User guidance by checks and hints,
- Worked examples.

PreSTo is divided into separate modules which are connected via a small project file which contains a control center and database to store user input data for one design. Every module is started from its own Excel file. PreSTo is still in development and should finally incorporate following ten modules.

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

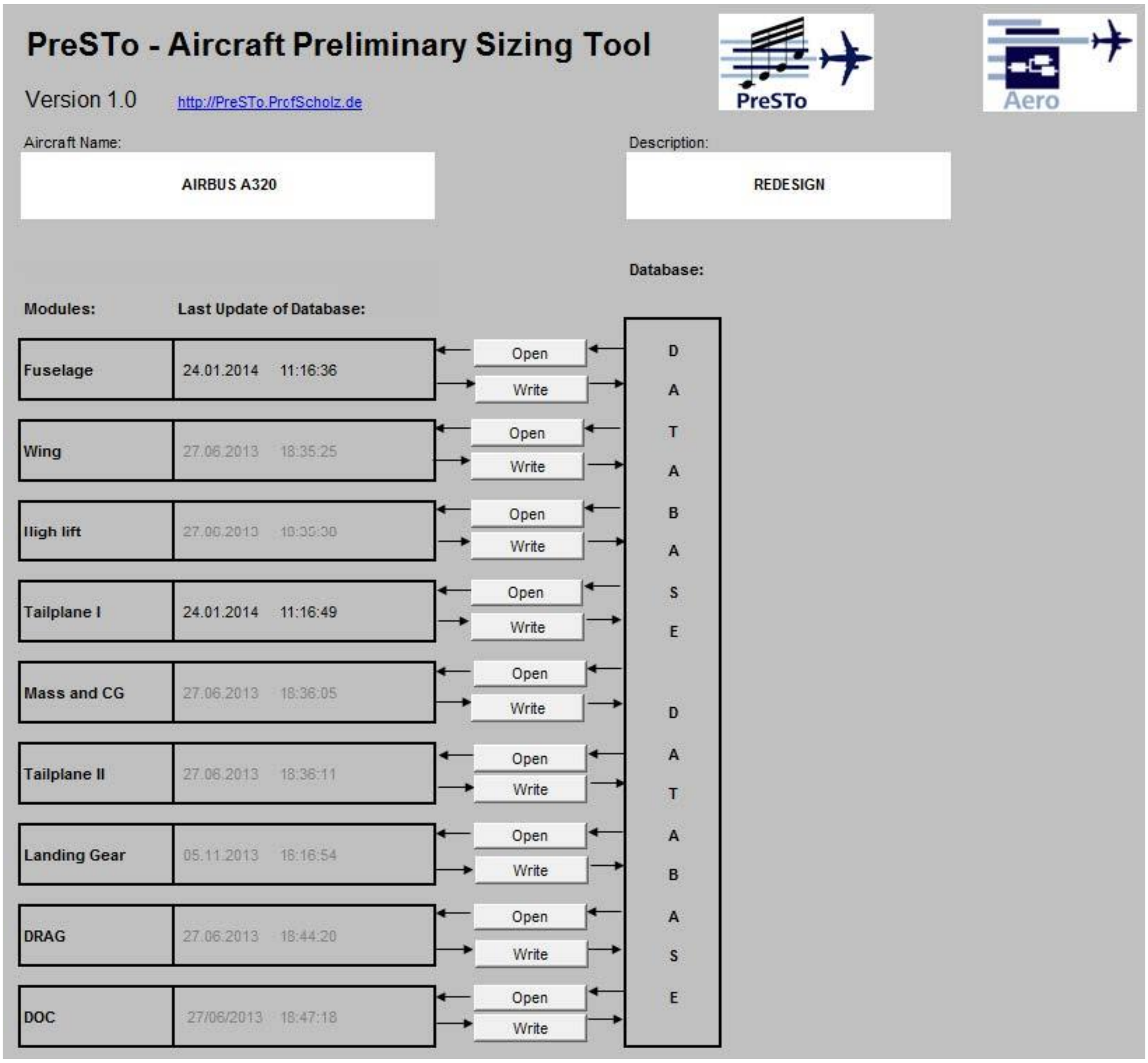


Figure 3 Graphical User Interface PreSTo

4.4 OpenVSP-Connect

OpenVSP-Connect is the mediator between PreSTo and OpenVSP from NASA. It is the focus point of this project and will be fully described within it.

4.5 OpenVSP

OpenVSP is aircraft geometry tool which provides 3D-model of an aircraft based on common design parameters. It gives the opportunity for further engineering analyses such as Finite Element Method (FEM) or Computational Fluid Dynamics (CFD), hence the tool chain can be further extended.

5 Structure of the program

The program is divided in 3 worksheets which represent the main tabs: Main, Input and Convert.

5.1 Main

This is the first tab where short description of OpenVSP-Connect is given. The logo of the Hamburg University of Applied Sciences (Hochschule für Angewandte Wissenshaften Hamburg) or HAW-Hamburg and the logo of the Aircraft Design and Systems Group (AERO) stay at the top left side, since this is where the program has been made.
The names of the authors and the license terms are also provided in this section. OpenVSP-Connect is free software, which can be redistributed and/or modified under the terms of GNU General Public License as published by the Free Software Foundation. License Version 3.

5.2 Input

This is the main tab of the program, where all the input values are introduced and the action buttons are located. On top of the worksheet an input cells for the name of the aircraft and for short description can be found. This name will later be given as a name of the OpenVSP file. Hence, it is very important that there are no spaces in the name. Otherwise an error message will appear when the "3D-Vizualization" button is pressed.

The spreadsheet consists of 8 sections:

1. Action buttons
2. Requirements
3. Engine
4. Wing
5. Fuselage
6. Horizontal tail
7. Vertical tail
8. Positions of aircraft components

Action buttons

This is where the three action buttons and the input cells for the directory of OpenVSP, directory of the newly created file, the path to the tool where the calculated parameters are extracted from and the name of this tool are located.

Requirements

Here the requirements Number of passengers and Cruse Mach number are needed to calculate suggestions for all the parameters necessary for 3D-visualization. In addition, Mach number constant can be also typed in by the user to calculate the max. operating Mach number.

Aircraft components

Sections 3 to 7 are meant for the parameters of the main aircraft components. On the left side are the input cells while on the right side are the suggestions for them based on statistics and aeronautics. Some necessary constants are introduced right of the suggestion cells. Usually they should not be changed, however more advanced users have the opportunity to choose values for these constants freely.

Positions of aircraft components

OpenVSP-Connect uses custom coordinate system to position all the aircraft components in a relation to the fuselage. Section 8 is where the relative positions of these objects are introduced. It follows the same logic as the other sections: on the left side are the input cells, on the right side are the suggestions and further right are some constants.

Positions of Aircraft Components

Component	X	Y	Z		Component	X	Y	Z				
Horizontal tail	62.464	0.000	0.751	<<<<<<	Horizontal tail	62.464	0.000	0.751				
Vertical tail	56.887	0.000	3.380	<<<<<<	Vertical tail	56.887	0.000	3.380				
Wing	23.424	0.000	-1.678	<<<<<<	Wing	23.424	0.000	-1.678				
Fuselage	0.000	0.000	0.000	<<<<<<	Fuselage	0.000	0.000	0.000				
Jet Engine 2	29.921	14.750	-4.725	<<<<<<	Jet Engine 2	29.921	14.750	-4.725	y-pos constant for 2 engines	k	32.59	[%]
Jet Engine 1	29.921	-14.750	-4.725	<<<<<<	Jet Engine 1	29.921	-14.750	-4.725				
Jet Engine 4	N/A	N/A	N/A	<<<<<<	Jet Engine 4	N/A	N/A	N/A	y-pos constant for 4 engines	k	67.27	[%]
Jet Engine 1	N/A	N/A	N/A	<<<<<<	Jet Engine 1	N/A	N/A	N/A				
Prop Engine 2	25.664	7.049	-1.969	<<<<<<	Prop Engine 2	25.664	7.049	-1.969	2 engines inter-blade distance	y	0.92	[-]
Prop Engine 1	25.664	-7.049	-1.969	<<<<<<	Prop Engine 1	25.664	-7.049	-1.969				
Prop Engine 4	N/A	N/A	N/A	<<<<<<	Prop Engine 4	N/A	N/A	N/A	4 engines inter-blade distance	y	0.26	[-]
Prop Engine 1	N/A	N/A	N/A	<<<<<<	Prop Engine 1	N/A	N/A	N/A				
Landing Gear 1	32.655	9.898	-7.042	<<<<<<	Landing Gear 1	32.655	9.898	-7.042	Rel. y-pos of LG on wing half-spar	k	0.222	[-]
Landing Gear 3	32.655	-10.198	-7.042	<<<<<<	Landing Gear 3	32.655	-10.198	-7.042				
Landing Gear 2	6.760	-0.150	-7.042	<<<<<<	Landing Gear 2	6.760	-0.150	-7.042				

Figure 4 Position of Aircraft Components section of OpenVSP-Connect

5.3 Convert

In this worksheet the geometry parameters are converted into values readable from OpenVSP. XML is used for this task. XML stand for Extensible Markup Language and represents a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. It is highly recommended that the user does not alter anything in this tab. However, advanced users can make their own improvements and if the software breaks a fresh copy of OpenVSP-Connect can be downloaded from the official webpage of the AERO Group at any time.

6 3 ways to use OpenVSP-Connect

Since OpenVSP-Connect is meant for novice users as well as advanced ones, there are 3 ways to use it which differ in their complexity.

6.1 Automatic Mode

This is the simplest mode of the program and is suitable for users who are new to the aircraft design. In this mode OpenVSP-Connect can be used as totally autonomous stand-alone tool. There are just two sections needed for this mode, i.e. "Action buttons" and "Requirements". The user shall provide the required cruse Mach number and the required Number of passengers and then press the "3D-Visualization" button. All the necessary parameters are automatically calculated and pushed into OpenVSP. OpenVSP file is created and its directory is shown in the OpenVSP file cell (cell H11). There is still the possibility some other parameters in addition to the requirements to be filled in. The user is provided with the opportunity to play around with the numbers and then to recover the default suggested values by a push of a button. The button is called "Automatic Mode" and restores all the initial links between the suggestion cells and the input cells in order the program to be able to work again in automatic mode.

6.2 Manual Mode

All the input parameters as well as the necessary constants can be freely altered by the user. This opportunity builds the essence of the manual mode. An advanced user with sufficient knowledge in the field of aircraft design can provide the necessary 46 parameters and input them manually. If it turns out that the new design is not good enough or does not fulfill the requirements 3 options for further improvement of the design are available. The 3D model can be altered directly in OpenVSP or the input parameters can be changed in OpenVSP-Connect. There is always the third option to use some of the values suggested by OpenVSP Conect in the right-hand cells. Useful comparison will be between the new design and the design suggested by OpenVSP-Connect, which is available by pressing "Automatic Mode" and "3D-Visualization" directly after one another.

6.3 As a part of a tool chain

OpenVSP-Connect can be used as a very simple and easy to use mediator between OpenVSP and any excel based preliminary design tool. There are two simple requirements which the preliminary design tool have to fulfill. First, it should provide all or at least most of the 46 core parameters in cells named exactly the same way as the input cells in OpenVSP-Connect. Full list of the core parameters and the names of the cells where they are stored is provided in **Appendix A**.

The second requirement is that all these core parameters must be stored in one and the same worksheet which must be named "Database". If the tool satisfies both requirements it can be used by a push of a single button. Before that the path to the tool and its name should be provided by the user in the corresponding cells (H12 for the path and H13 for the name).

Example:

If the tool's name is "MyTool.xls" and it is located on the drive D in folder "PreliminaryDesign", the path: D:\PreliminaryDesign must filled in cell H12 and the name: MyTool.xls must be entered in cell H13. A real example is provided in **Figure 5**

Directory of OpenVSP	D:\Program Files\OpenVSP\OpenVSP-2.3.0-win32\vsp.exe
OpenVSP File	C:\Users\Veso\Desktop\AIRBUS A320.vsp
Path of your tool	D:\PreliminaryDesign
Name of your tool	MyTool.xls

Figure 5 Example of inputs in cells H12 and H13

PreSTo fulfills both requirements and can be directly used by pressing "Tool Chain" button once when cells H12 and H13 are correctly filled. The compatibility of OpenVSP-Connect and PreSTo has been done in collaboration with Maxime van Loo, another student of the AERO Group at the HAW Hamburg.

If the aforementioned cells are not correctly filled error message will appear: "The path to your tool specified on H12 or its name specified on H13 are not correctly filled"

If there are any parameters missing in the user created tool a warning message will appear. Every time OpenVSP-Connect finds a missing parameter this message will show the number of the missing parameters already found.

7 Action buttons

OpenVSP-Connect features 3 action buttons “**Figure 6**” which help the user to easily navigate the software.

3D-Visualization

The most important button is called "3D-Visualization" and is used for visualizing the current aircraft, whose core parameters are calculated from OpenVSP-Connect, typed in by the user himself, or extracted from a design tool compatible with OpenVSP-Connect. In the order of 46 core parameters of the aircraft are used to calculate the input parameters required by OpenVSP to sketch a passenger aircraft.

Tool Chain

Another button is provided so the user can easily load these 46 core parameters calculated by a design tool compatible with OpenVSP-Connect. It is called "Tool Chain" and gives the opportunity for combination of a user created design tool or already existing one with OpenVSP-Connect, hence with OpenVSP. There are two requirements which the design tool must meet. It must be an excel table which provides all 46 necessary parameters in a worksheet called "Database" and the cells where these parameters are stored must be named the same way like the cells where OpenVSP-Connect parameters are stored. In order the button to work properly the user must type in the full name of the excel file of the design tool and the path to it.

Automatic Mode

Every time the user types in or loads new parameters in the input cells breaks the existing links between the input cells and the cells where the core parameters are calculated. That is why third button called "Automatic Mode" is provided in order to reset all the initial links.

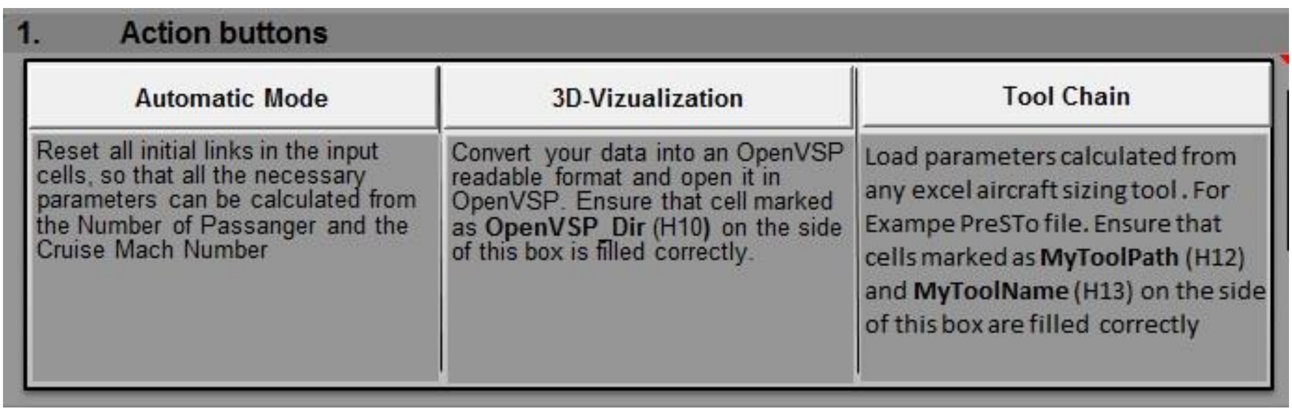


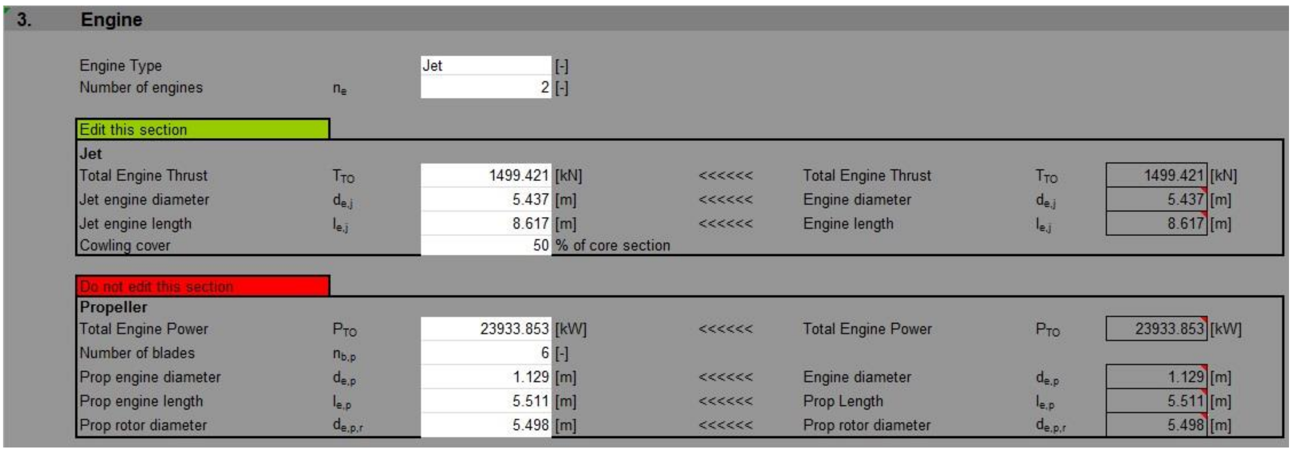
Figure 6 Action buttons

8 Engine

The engine section "**Figure 7**" provides values for two types of engines, i.e. jet and propeller. The user must choose between both types from a drop down list. The number of engines must also be provided by the user. If the selection is between 1 and 4 engines, the standard engine positions are calculated. If the desired number of engines differs from this, their positions must be manually inputted.

For a jet aircraft, the total of four parameters must be introduced: Total engine thrust, Jet engine diameter, Jet engine length and Cowling cover as a percentage of the core section. For the first three parameters values based on statistics are suggested. The cowling cover percentage is 50% by default.

The propeller engine section is activated once when a propeller engine is chosen from the drop down menu. There are five necessary parameters in this section: Total engine power, Number of blades, Prop engine diameter, Prop engine length and Prop rotor diameter. The Number of blades is 6 by default. For all the rest parameters in this section values based on statistics are suggested.



3. Engine

Engine Type		Jet	[-]					
Number of engines	n_e	2	[-]					
Edit this section								
Jet								
Total Engine Thrust	T_{TO}	1499.421	[kN]	<<<<<<	Total Engine Thrust	T_{TO}	1499.421	[kN]
Jet engine diameter	$d_{e,j}$	5.437	[m]	<<<<<<	Engine diameter	$d_{e,j}$	5.437	[m]
Jet engine length	$l_{e,j}$	8.617	[m]	<<<<<<	Engine length	$l_{e,j}$	8.617	[m]
Cowling cover		50	% of core section					
Do not edit this section								
Propeller								
Total Engine Power	P_{TO}	23933.853	[kW]	<<<<<<	Total Engine Power	P_{TO}	23933.853	[kW]
Number of blades	$n_{b,p}$	6	[-]					
Prop engine diameter	$d_{e,p}$	1.129	[m]	<<<<<<	Engine diameter	$d_{e,p}$	1.129	[m]
Prop engine length	$l_{e,p}$	5.511	[m]	<<<<<<	Prop Length	$l_{e,p}$	5.511	[m]
Prop rotor diameter	$d_{e,p,r}$	5.498	[m]	<<<<<<	Prop rotor diameter	$d_{e,p,r}$	5.498	[m]

Figure 7 Engine section

8.1 Calculation of the Maximum take-off mass

To calculate the Total Engine Thrust and the Total Engine Power two different approaches were taken. For both of them the maximum take-off mass was needed. First of them was to calculate the maximum take-off mass from the following equation:

$$m_{MTO} = \frac{m_{PL}}{1 - \frac{m_F}{m_{MTO}} - \frac{m_{OE}}{m_{MTO}}} \tag{1}$$

(Scholz, 2012, p. 5-26)

where m_{MTO} is the maximum take-off mass, m_{OE} is operating empty mass, m_{PL} is maximum payload and m_F is fuel mass.

The ratio $\frac{m_{OE}}{m_{MTO}}$ is calculated from

$$\frac{m_{OE}}{m_{MTO}} = 0{,}591.\left(\frac{R[km]}{1000}\right)^{-0{,}113}.\left(\frac{m_{MTO}[kg]}{1000}\right)^{0{,}0572}.n_E^{-0{,}206} \tag{2}$$

(Marckwardt 1998)

, where R is design range and n_E is the number of engines on the wing. As this equation contains m_{MTO} it must be solved iteratively. For the first iteration ratio of $\frac{m_{OE}}{m_{MTO}} = 0.5$ was chosen. Only 3 iterations are enough because the value of m_{MTO} does not affect the final result of the equation strongly due to the low exponent $\left(\frac{m_{MTO}[kg]}{1000}\right)^{0.0572} \approx 1$.

For calculating the relative fuel mass was used

$$\frac{m_F}{m_{MTO}} = 1 - M_{ff} \ . \tag{3}$$

(Scholz, 2012, p.5-30)

, where M_{ff} is parameter called mission fuel fraction and is equal to

$$M_{ff} = M_{ff,std}.M_{ff,res} \ . \tag{4}$$

$$M_{ff,std} = M_{ff,TO}.M_{ff,CLB}.M_{ff,CR}.M_{ff,DES}.M_{ff,L} \ . \tag{5}$$

$$M_{ff,res} = M_{ff,CLB}.M_{ff,RES}.M_{ff,DES}.M_{ff,Loiter} \ . \tag{6}$$

$M_{ff,TO} = 0.995$ – Fuel fraction, take off

$M_{ff,CLB} = 0.98$ – Fuel fraction, climb

$M_{ff,CR} = e^{-\frac{R}{B_S}}$ – Fuel fraction, cruise

$M_{ff,DES} = 0.99$ – Fuel fraction, descent

$M_{ff,L} = 0.992$ – Fuel fraction, landing

$M_{ff,RES} = e^{-\frac{S_{res}}{B_S}}$ – Fuel fraction, extra flight distance

$M_{ff,Loiter} = e^{-\frac{t_{Loiter}}{B_t}}$ – Fuel fraction, loiter

The given values are based on the table 5.9 (Scholz 2012)

B_s and B_t are respectively Breguet-Factor, cruise and Breguet-Factor, flight time, while S_{res} and t_{Loiter} are extra flight distance and loiter time and depend on the design range. . If it is up to 5500 km S_{res} is the distance to the alternate and $t_{Loiter} = 2700\ s$. Otherwise S_{res} is the distance to the alternate plus 5% of the design range and $t_{Loiter} = 1800\ s$. $B_s = \frac{\frac{L}{D}.M_{CR}.a}{SFC.g}$ for the cruise flight of jet airplane, $B_s = \frac{\frac{L}{D}.\eta}{SFC.g}$ for the cruise flight of a propeller airplane and $B_t = \frac{B_s}{M_{CR}.a}$.

m_{PL} is calculated from the number of passengers and the assumption of a single passenger and his baggage from table 3.1 (Roaskam 1989), which is 93 kg for short and medium range flights and 97.5 kg for long range flights.

Thrust to weight ratio is estimated from equation 5.27

$$\frac{T_{TO}}{m_{MTO}.g} = \frac{1}{\frac{T_{CR}}{T_{TO}}.\frac{L}{D}} \tag{7}$$

(Scholz, 2012, p. 5-17)

$\frac{T_{CR}}{T_{TO}}$ is given at the engine diagrams for a given altitude and Mach number. However, here simplified equation was used.

$$\frac{T_{CR}}{T_{TO}} = (0.0013.\mu - 0.0397).h_{CR}[km] - 0.0248.\mu + 0.7125$$

(Scholz, 2012, p. 5-17)

μ bypass ratio BPR and h_{CR} is cruise altitude.

After evaluating the maximum take-off mass and the thrust to weight ratio, the total engine thrust is calculated from equation 5.56.

$$T_{TO} = m_{MTO}.g.\frac{T_{TO}}{m_{MTO}.g}. \tag{8}$$

(Scholz, 2012, p. 5-32)

However, because of the complexity of the method which is totally opposite of the idea of Open-VSP-Connect and the need of introducing another parameters like the glide ratio $\frac{L}{D}$ and BPR another approach was taken.

The second approach uses specially created database for medium and long range aircrafts of the most popular manufacturers. Information for 22 jet and 27 propeller aircrafts was collected from „Jane's 2010-2011"

Table 1 Database of Jet Aircrafts. Max. Take-off Mass part

Manufacturer	Name	Type	n_{PAX} [-]	R with this n_PAX [nm]	R with this n_PAX [km]	M_{MO} [-]	m_{MTO} [t]	m_{MTO} [t] (calculated)	Deviation %
Airbus	A318	Medium Range	107	1462	2708	0.82	59	55	7.13%
Airbus	A320	Medium Range	150	2592	4800	0.82	74	84	14.25%
Airbus	A330-200	Long Range	253	6650	12316	0.86	230	171	25.85%
Airbus	A340-500	Long Range	313	9000	16668	0.86	372	232	37.68%
Airbus	A350-1000	Long Range	369	8000	14816	0.89	298	296	0.58%
Airbus	A380-800	Long Range	555	8000	14816	0.89	560	560	0.03%
Boeing	B737-700	Medium Range	126	1540	2852	0.82	60	67	11.35%
Boeing	727-100	Medium Range	131	2340	4334	0.9	73	71	2.76%
Boeing	757-200	Medium Range	186	2820	5223	0.86	100	112	11.79%
Boeing	767-300	Long Range	269	4890	9056	0.8	172	186	8.21%
Boeing	787-3	Long Range	317	3000	5556	0.85	165	236	43.07%
Boeing	747-100	Long Range	374	5028	9312	0.88	322	302	6.12%
Boeing	777-200	Long Range	305	3985	7380	0.84	247	223	9.63%
Boeing	747-8	Long Range	467	8000	14816	0.855	442	426	3.68%
Embraer	EMB-135BJ Legacy 600	Medium Range	16	1840	3408	0.8	20	7	67.11%
Embraer	ERJ-145XR	Medium Range	50	2000	3704	0.8	24	22	6.88%
Embraer	E-170	Medium Range	70	1800	3334	0.82	36	33	8.41%
Embraer	E-195	Medium Range	106	1400	2593	0.8	49	54	10.54%
Bombardier	CRJ-700	Medium Range	70	1649	3054	0.825	33	33	0.08%
Bombardier	CRJ-900	Medium Range	86	1350	2500	0.83	37	42	15.12%
Bombardier	CS-100	Medium Range	110	2950	5463	0.82	59	57	3.91%
Bombardier	CS-300	Medium Range	135	2950	5463	0.82	65	73	12.81%
								Average Value	14.28%
Number of Airplanes	22								

The most reliable statistical method for obtaining the maximum take-off mass for jet aircrafts is using the standard number of passenger for each aircraft and trough square function calculating m_{MTO}. The solver add-in in Excel was used to derive the best coefficients.

$$m_{MTO} = 0.0011099.\, n_{PAX}^{\;2} + 0.39333.\, n_{PAX} \quad . \tag{9}$$

Graphical representation of the function is provided on **Figure 8**

The average value of the absolute value of the deviation is 14.28% which is fully satisfactory for the purposes of OpenVSP-Connect.

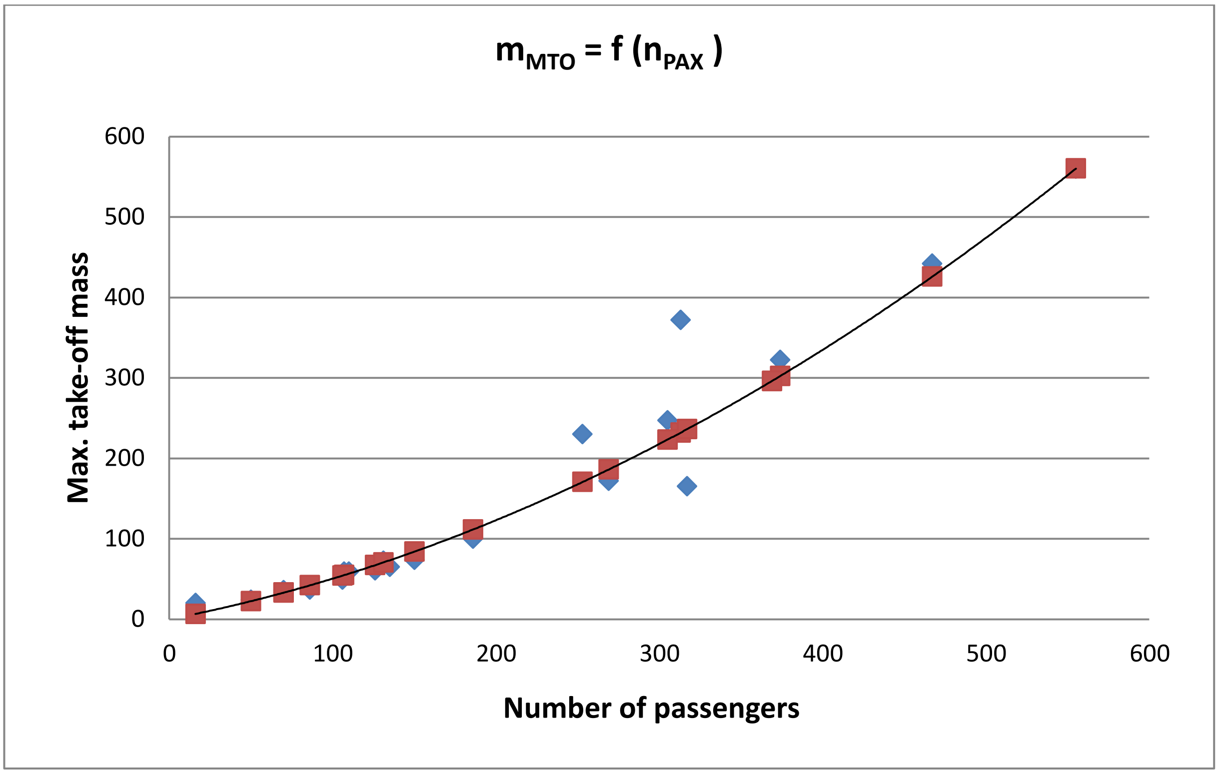


Figure 8 Maximum Take-off Mass versus Number of passengers graph for jet aircrafts

For calculating m_{MTO} of a propeller aircraft from n_{PAX} was used simple line function.

$$m_{MTO} = 0.36286.n_{PAX} \quad . \tag{10}$$

Graphical representation of the function is provided on **Figure 9**

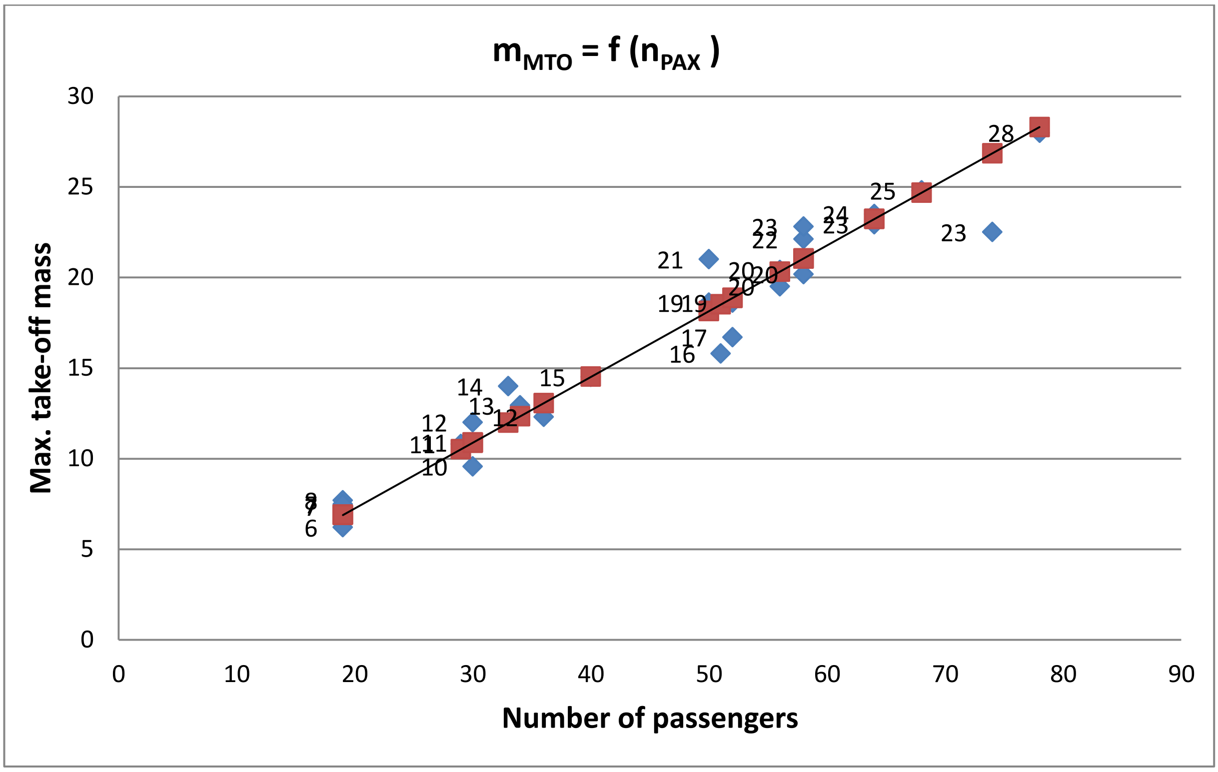


Figure 9 Maximum Take-off Mass versus Number of passengers graph for propeller aircrafts

The average value of the deviation this time is even smaller, 6.87%.

Part of both databases are provided on **Table 1** for jet aircrafts and **Table 2** for propeller aircrafts

Table 2 Database of Propeller Aircrafts. Max. Take-off Mass part

Database					
	Name	n_{PAX} [-]	m_{MTO} [t]	m_{MTO} [t] (calculated)	Deviation %
	Fokker-VFW F.27 200/400/600 Friendship	56	20	20	0.44%
	Hawker Siddeley HS.748 Srs 2A	58	20	21	4.28%
	Antonov An-24V Series II	50	21	18	13.60%
	Aerospatiale (Nord) 262C Frégate	29	11	11	2.56%
	Short SD3-30	30	10	11	13.75%
	de Havilland Canada Dash 7	50	19	18	2.46%
	Fairchild Dornier 228	19	6	7	11.20%
	BAe Jetstream-Super 31	19	7	7	6.20%
	Saab 340B	34	13	12	4.56%
	ATR-42-300	52	17	19	12.99%
	EMB-120ER	30	12	11	9.28%
	Fokker 50-300	58	22	21	4.81%
	Shorts 360	36	12	13	6.27%
	Casa/IPTN CN-235	51	16	19	17.13%
	BAe ATP	64	23	23	1.28%
	Q300	56	20	20	4.18%
	ATR-72-500	74	23	27	19.34%
	LET L-610	40	15	15	0.10%
	Raytheon Beech 1900D	19	8	7	10.32%
	Bae Jetstream 41	30	11	11	0.00%
	Fairchild METRO 23	19	7	7	7.87%
	Fairchild Dornier 328	33	14	12	14.41%
	Saab 2000	58	23	21	7.69%
	ATR-42-500	52	19	19	1.45%
	Ilyushin IL-114	64	24	23	1.18%
	IPTN N-250	68	25	25	0.50%
	Q400	78	28	28	1.13%
				Average Value	6.87%
Number of Aircrafts	27				

It is logical that a zero mass aircraft will have zero thrust or power. Hence, in both equations used for calculating m_{MTO} for jet and propeller aircrafts a function which goes through the beginning of the coordinate system is chosen.

8.2 Calculation of the Thrust and Power

One more time a statistical approach based on the gathered database was taken. The best equation for obtaining the Total Engine Thrust from the Max Take-off Mass is:

$$T_{TO} = 2.63967.m_{MTO} + 20.76239 \quad . \tag{11}$$

Graphical representation of the function is provided on **Figure 10**

The average deviation from the real values of the Total engine Thrust of the aircrafts in the database is 13.24%

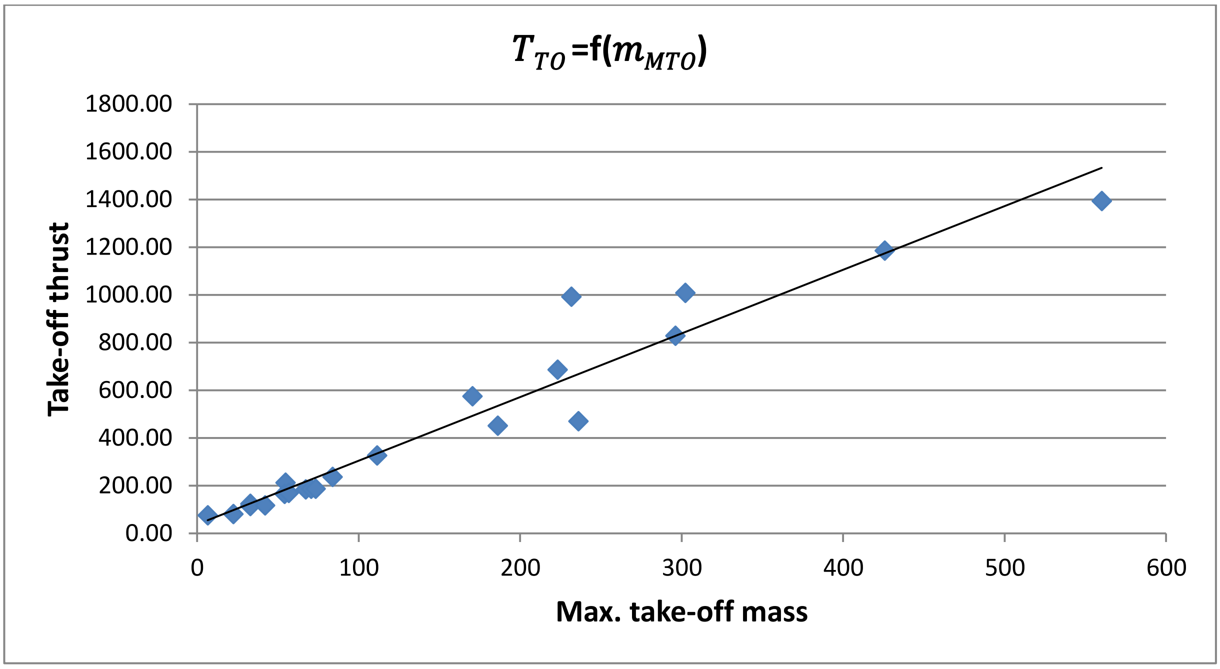


Figure 10 Thrust versus Maximum Take-off mass graph for jet aircrafts

The equation for calculating the Total Engine Power of a propeller aircraft is a power function of the Max Take-off Mass:

$$P_{TO} = 274.2572. m_{MTO}{}^{0.8422} \quad . \tag{12}$$

Graphical representation of the function is provided on **Figure 11**

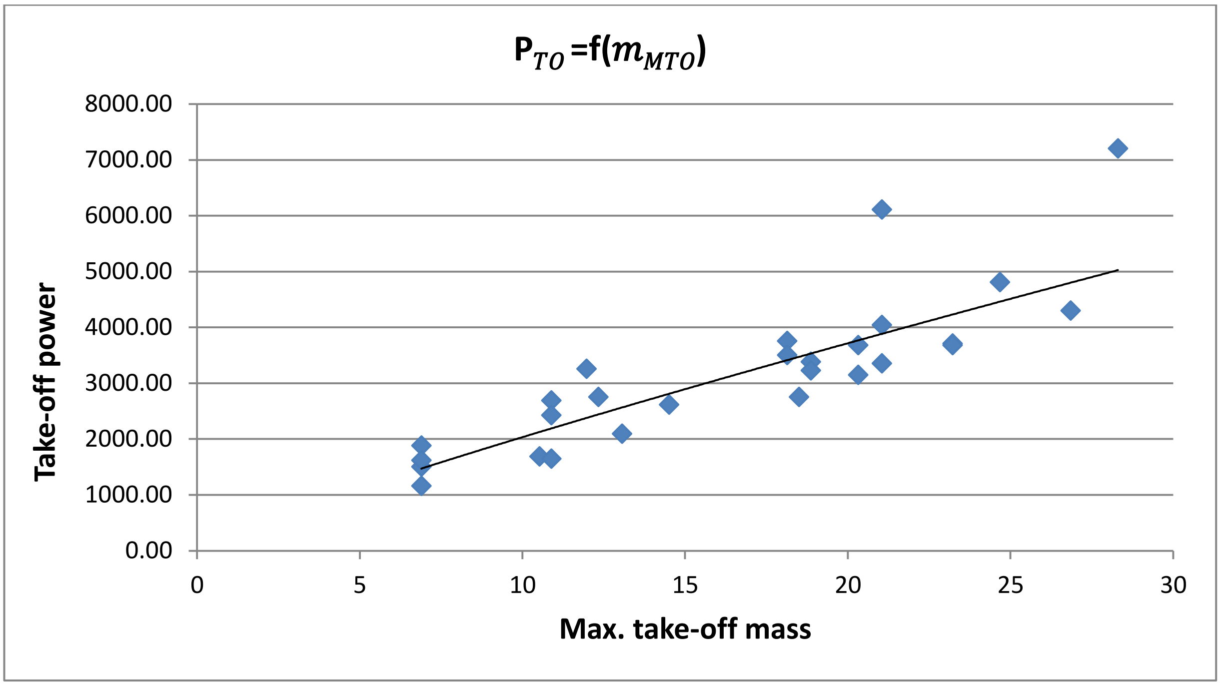


Figure 11 Thrust versus Maximum Take-off mass graph for propeller aircrafts

9 Wing

Wing is a fundamental component of the aircraft. The Wing section in OpenVSP-Connect "**Figure 12**" is represented by 11 core parameters for a single-tapered wing and another 4 parameters in addition for a double-tapered wing.

Wing

Wing Type	$Type_W$	double-trapezoidal	[-]					
Total Area	S_W	835.567	[m^2]	<<<<<<	Toral Area Suggestion	S_W	835.567	[m^2]
Total Aspect ratio	A_W	9.806592	[-]					
					Total Span	b_w	90.521	[m]
Outboard 25% Sweep	$\varphi_{25,W,o}$	24.417	[°]	<<<<<<	25% Wing sweep suggestion	$\varphi_{25,W,o}$	24.417	[°]
Taper Ratio	λ_W	0.180	[-]	<<<<<<	Taper Ratio Suggestion	λ_W	0.180	[-]
					Root Chord	$c_{r,w}$	17.951	[m]
					Tip Chord	$c_{t,w}$	3.233	[m]
					Outboard Leading edge Sweep	$\varphi_{0,W,o}$	27.165	[°]
					Outboard Trailing edge sweep	$\varphi_{100,W,o}$	15.454	[m]
Airfoil thickness ratio	(t\c)	0.112	[-]	<<<<<<	Thickness ratio	(t\c)	0.112	[-]
X position of wing	$RelPos_{W,x}$	31.500	% of fuselage	<<<<<<	X position of wing		31.500	% o
Z position of wing	$RelPos_{W,z}$	25.18	% of fuselage diameter					
Outboard dihedral angle	$\Gamma_{W,o}$	2.220	[°]	<<<<<<	Outboard dihedral angle	$\Gamma_{W,o}$	2.220	[°]
Edit this section								
Relative kink position	$\eta_{k,W}$	0.320	[-]	<<<<<<	Relative kink position	$\eta_{k,W}$	0.320	[-]
Inboard Leading edge Sweep	$\varphi_{0,W,i}$	27.165	[°]	<<<<<<	Inboard Leading edge Sweep	$\varphi_{0,W,i}$	27.165	[°]
Inboard Trailing edge Sweep	$\varphi_{100,W,i}$	0.000	[°]	<<<<<<	Inboard Trailing edge Sweep	$\varphi_{100,W,i}$	0.000	[°]
Inboard dihedral angle	$\Gamma_{W,i}$	2.220	[°]	<<<<<<	Inboard dihedral angle	$\Gamma_{W,i}$	2.220	[°]

Figure 12 Wing section of OpenVSP-Connect

There are 5 more parameters necessary for the calculations hidden from the user. These are: Wing MAC, Outer Aspect Ratio, Outer Taper Ration, Inboard Half-Span and Kick chord "**Figure 13**".

Wing MAC	10.438	[-]
Outer Aspect Ratio	4.476	[-]
Outer Taper Ratio	0.307	[-]
Inboard Half-Span	14.483	[m]
Kink chord	10.518	[m]

Figure 13 Constants necessary for visualization of the wing

First, the wing type should be chosen trough a drop down list at the top the wing section. Since double-trapezoidal wings are more common this type is chose by default. If a single-trapezoidal wing is chosen the double-trapezoidal wing section at the bottom becomes inactive. The Aspect ratio and the Relative kink constant must be chosen by the user, since no suggestion value is calculated for them by OpenVSP-Connect. A value of 9.5 for the aspect ratio and 0.320 for the Relative kink constant are recommended, since these are the most typical values for civil transport aircrafts.

An algorithm loop is used in order some of the suggested values to be calculated. Therefore, the settings of Office Excel have to allow iterations "**Figure 14**".

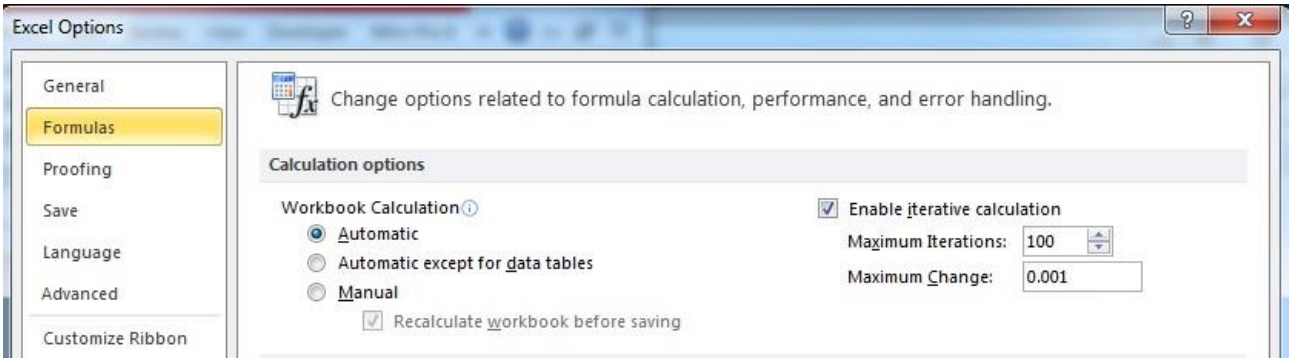


Figure 14 Excel Formulas Options tab

9.1 The square-cub law

The square-cube law can be stated as follows:

When an object undergoes a proportional increase in size, its new surface area is proportional to the square of the multiplier and its new volume is proportional to the cube of the multiplier.

Represented mathematically:

$$\frac{S_2}{S_1} = \left(\frac{l_2}{l_1}\right)^2 \tag{13}$$

Where S_1 is the original surface area and S_2 is the new surface area.

$$\frac{V_2}{V_1} = \left(\frac{l_2}{l_1}\right)^2 \tag{14}$$

Where V_1 is the original volume, V_2 is the new volume, l_1 is the original length and l_2 is the new length.

For example, a cube with a side length of 1 meter has a surface area of 6 m^2 and a volume of 1 m^3. If the dimensions of the cube were doubled, its surface area would be increased to 24 m^2 and its volume would be increased to 8 m^3. This principle applies to all solids.

Importance for the Aircraft Engineering

When a physical object maintains the same density and is scaled up, its mass is increased by the cube of the multiplier while its surface area only increases by the square of said multiplier.

Let us consider a simplified example of an airplane, with mass m and wing area S. The weight,

$$W = m.g = \rho.V.g \tag{15}$$

,lift,

$$L = c_L.\frac{\rho.V^2}{2}.S. \tag{16}$$

For cruise flight the weight must be equal to the lift,

$$W = \rho.V.gL = c_L.\frac{\rho.V^2}{2}.S \tag{17}$$

Now, let us consider the airplane be exaggerated by a multiplier factor = x so that it has a new mass,$m^` = x^3.m$, and the surface of the wing has a new surface area, $S^` = x^2.S$.

The new weight is

$$W^` = m.x^3.g = W.x^3 \tag{18}$$

and the new lift,

$$L^` = c_L.\frac{\rho.V^2}{2}.Sx^2 = L.x^2 \tag{19}$$

Now the lift is not enough to balance the weight of the airplane

$$\frac{W^`}{L^`} = \frac{W.x^3}{L.x^2} = \frac{W}{L}.x \tag{20}$$

This only means that the wing must be bigger.

Thus, just scaling up the size of the airplane, keeping the same material of construction (density), would increase the wing area by the same scaling factor. This would indicate that the airplane wing would be 'unproportional' to its fuselage.

This is why the lift and control surfaces (wings, rudders and elevators) of Airbus A380 are relatively big compared to the fuselage of the airplane. In, for example, an Airbus A320 these relationships seem much more 'proportional', but designing an A380 sized aircraft by merely magnifying the design dimensions of a A380 would result in wings that are too small for the aircraft weight, because of the square-cube rule "**Figure 15**".

Figure 15 Comparison between the wing and the tail of A320 (left) and A380 (right) –real top view drawing

9.2 Calculation of the Wing Area

Since the Lift is proportional to the Wing Area, it is one of the most fundamental parameters of the wing and in the aircraft design. Equation (21) was used to calculate the wing area of a jet aircraft.

$$S_W = 1.45463.\, m_{MTO} + 20.67308 \qquad (21)$$

As it can be seen at **Table 3** the average deviation from the real values for the wing area is 12%.

Table 3 Database of Jet Aircrafts. Wing Area part

Database

Manufacturer	Name	Wing Area[m^2]	Wing Area[m^2] calculated	Deviation %
Airbus	A318	122.40	100.38	17.99%
Airbus	A320	122.40	142.83	16.69%
Airbus	A330-200	361.60	268.78	25.67%
Airbus	A340-500	437.40	357.95	18.16%
Airbus	A350-1000	453.00	451.65	0.30%
Airbus	A380-800	845.00	835.57	1.12%
Boeing	B737-700	125.00	118.40	5.28%
Boeing	727-100	153.00	123.34	19.39%
Boeing	757-200	181.25	182.96	0.94%
Boeing	767-300	283.30	291.42	2.87%
Boeing	787-3	325.00	364.30	12.09%
Boeing	747-100	510.00	460.51	9.70%
Boeing	777-200	427.80	345.39	19.26%
Boeing	747-8	554.00	640.01	15.52%
Embraer	EMB-135BJ Legacy 600	51.18	30.24	40.91%
Embraer	ERJ-145XR	51.20	53.32	4.14%
Embraer	E-170	72.70	68.64	5.59%
Embraer	E-195	92.50	99.47	7.53%
Bombardier	CRJ-700	68.63	68.64	0.01%
Bombardier	CRJ-900	68.63	81.82	19.22%
Bombardier	CS-100	112.30	103.15	8.15%
Bombardier	CS-300	112.30	127.34	13.40%
				12.00%
Number of Airplanes	22			

Another equation based on statistics was used to calculate the Wing Area of a propeller aircraft:

$$S_W = 8.9222.m_{MTO} \quad (22)$$

The average deviation is a bit bigger this time : 12.35% "**Table 4**".

Table 4 Database of Propeller Aircrafts. Wing Area part

Database				
Name	n_{PAX} [-]	Wing Area[m²]	Wing Area[m²] calculated	Deviation %
Fokker-VFW F.27 200/400/600 Friendship	56	70.00	57.62	17.68%
Hawker Siddeley HS.748 Srs 2A	58	75.40	58.89	21.90%
Antonov An-24V Series II	50	72.50	53.71	25.91%
Aerospatiale (Nord) 262C Frégate	29	55.70	38.33	31.18%
Short SD3-30	30	42.14	39.15	7.10%
de Havilland Canada Dash 7	50	79.90	53.71	32.77%
Fairchild Dornier 228	19	32.00	29.50	7.81%
BAe Jetstream-Super 31	19	25.20	29.50	17.06%
Saab 340B	34	41.81	42.30	1.18%
ATR-42-300	52	54.50	55.04	0.98%
EMB-120ER	30	54.50	39.15	28.17%
Fokker 50-300	58	70.00	58.89	15.88%
Shorts 360	36	42.18	43.83	3.90%
Casa/IPTN CN-235	51	59.10	54.38	7.99%
BAe ATP	64	78.30	62.59	20.06%
Q300	56	56.20	57.62	2.53%
ATR-72-500	74	61.00	68.48	12.26%
LET L-610	40	56.00	46.78	16.46%
Raytheon Beech 1900D	19	29.50	29.50	0.00%
Bae Jetstream 41	30	32.55	39.15	20.26%
Fairchild METRO 23	19	29.70	29.50	0.67%
Fairchild Dornier 328	33	39.50	41.53	5.13%
Saab 2000	58	55.70	58.89	5.72%
ATR-42-500	52	54.50	55.04	0.98%
Ilyushin IL-114	64	76.00	62.59	17.65%
IPTN N-250	68	65.00	64.98	0.02%
Q400	78	63.08	70.75	12.16%
				12.35%

10 Fuselage

The fuselage section in OpenVSP-Connect represents 5 core parameters: Fuselage diameter, Fuselage length, Nose length, Cockpit length and Fuselage aft length "**Figure 16**".

Fuselage									
Fuselage diameter	d_F	6.7602	[m]	<<<<<<	Fuselage diameter	d_F	6.7602	[m]
Fuselage length	L_F	74.362	[m]	<<<<<<	Fuselage length	L_F	74.362	[m]
Nose length	$L_{nose,F}$	11.103	[m]	<<<<<<	Nose length	$L_{nose,F}$	11.103	[m]
Cockpit length	$L_{cock,F}$	4.394	[m]	<<<<<<	Cockpit length	$L_{cock,F}$	4.394	[m]
Fuselage aft length	$L_{aft,F}$	22.309	[m]	<<<<<<	Fuselage tail length	$L_{tail,F}$	22.309	[m]
					Cylinder length	$L_{c,F}$	40.951	[m]

Figure 16 Fuselage section of OpenVSP-Connect

3 additional constants are introduced: Slenderness ration, Cockpit length constant and Fuselage tailcone constant. Typical values for these parameters are 9, 0.650 and 3.3 respectively "**Figure 17**".

Number of seats per row	n_{SA}	11	
Slenderness ratio	$k_{l,F\backslash d,F}$	11.000	[-]
Cockpit length constant	$k_{l,cock,F}$	0.650	[-]
Fuselage tailcone constant	$k_{l,tail,F}$	3.300	[-]

Figure 17 Constants necessary for visualization of the fuselage

Typically, users have defined a certain range and number of passengers in the very beginning. This defines the fuselage length and the fuselage diameter. First, the number of seats abreast should be calculated. Equation (23) Provides simple method for calculating n_{SA}

$$n_{SA} = 0.45.\sqrt{n_{PAX}} \tag{23}$$

(Scholz, 2012, p. 6-1)

With n_{SA} known, the inner fuselage diameter can be calculated. It consists of the width of a single seat multiplied by the n_{SA} , the width of each aisle, and some more space between the fuselage wall and the armrest of the outer seats which is necessary for the comfort of the passengers. The certification regulations define minimum for the width and number of aisles.

According to JAR 25.817:

$n_{SA} \leq 6$: one isle

$6 < n_{SA} \leq 12$: two aisles

When the fuselage inner diameter is calculated the fuselage outer diameter can be easily deduced. According to Scholz, (2012, p.6-5) the fuselage is:

$$\Delta d = d_{F.O.} - d_{F.I.} = 0.084 + 0.045.\, d_{F.I.} \tag{24}$$

Typical values for the width of a single seat, the width of an aisle and the width of the space between the armrest of the outer seat and the fuselage wall were chosen, 0.495 m, 0.4826 m and 0.025m respectively.

Then the fuselage outer diameter is:

$$d_{F.O.} = d_{F.I.} + 0.084\, m + 0.045.\, d_{F.I.} \tag{25}$$

$$\begin{aligned} d_{F.O.} = (\mathrm{n}_{SA} \cdot 0.495 + 2 \cdot 0.025 + 0.4826) + 0.084 + \\ +0.045 \cdot (\mathrm{n}_{SA} \cdot 0.495 + 2 \cdot 0.025 + 0.4826) \end{aligned} \tag{26}$$

,

for $\mathrm{n}_{SA} \leq 6$ and

$$\begin{aligned} d_{F.O.} = (\mathrm{n}_{SA} \cdot 0.495 + 2 \cdot 0.025 + 2 \cdot 0.4826) + 0.084 + \\ +0.045 \cdot (\mathrm{n}_{SA} \cdot 0.495 + 2 \cdot 0.025 + 2 \cdot 0.4826) \end{aligned} \tag{27}$$

,for $6 < \mathrm{n}_{SA} \leq 12$.

From the fuselage outer diameter and the fuselage slenderness ratio the fuselage length can be deduced.

$$L_F = k_{\frac{L_F}{d_{O.F.}}} \cdot d_{O.F.} \tag{28}$$

Slenderness ratio of 11 was chosen for better visual outputs.

11 Horizontal tail

In order the horizontal tail of the designed aircraft to be correctly represented 7 core parameters should be introduced in the horizontal tail section: Total aspect ratio of the HT, Taper ratio of the HT, Total area of the HT, Sweep of HT, Dihedral angle of HT, X and Z position of HT "**Figure 18**".

Horizontal Tail								
Total aspect ratio	A_H	5.43	[-]	<<<<<<	Aspect Ratio	A_H	5.428	[-]
Taper ratio	λ_H	0.22	[-]	<<<<<<	Taper Ratio	λ_H	0.216	[-]
Total area	S_H	209.37	[m²]	<<<<<<	Area	S_H	209.370	[m²]
Sweep	$\varphi_{25,H}$	29.42	[°]	<<<<<<	Sweep	$\varphi_{25,H}$	29.417	[°]
Dihedral angle	Γ_H	0.00	[°]	<<<<<<	Dihedral angle	Γ_H	0.000	[°]
X position of HT	$RelPos_{H,x}$	84.000	% of fuselage	<<<<<<	X position of HT	$RelPos_{H,x}$	84.000	% of fuselage length
Z position of HT	$RelPos_{H,z}$	-15.000	% of VT span	<<<<<<	Z position of HT	$RelPos_{H,z}$	-15.000	% of VT span

Figure 18 Horizontal Tail section of OpenVSP-Connect

Suggested values are given by OpenVSP-Connect based on the HT Aspect ratio constant, HT Taper ratio constant, Tail volume coefficient and HT 25% sweep constant "**Figure 19**".

HT Aspect ratio constant	$k_{A,H}$	0.554	[-]
HT taper ratio constant	$k_{\lambda,H}$	1.200	[-]
Tail volume coefficient of HT	C_H	0.991	[-]
HT 25% sweep constant	$\Delta\varphi_{25,H}$	5.000	[-]

Figure 19 Constants necessary for visualization of the horizontal tail

Typical values for the HT Aspect Ratio Constant and the HT taper ratio Constant are 0.554 and 1.2 respectively. The sweep of the horizontal tail should be approximately 5° more than the sweep of the wing so as the horizontal tail to be able to achieve higher critical Mach number. Otherwise, a loss in efficiency due to shock waves may occur. Due to increased sweep the lift gradient of the horizontal tail can be less than the lift gradient of the wing, so that the horizontal tail reaches stall state at higher angles of attach than the wing. Therefore a value around 5 should be chosen for the HT 25% sweep constant.

The Tail volume coefficient of the HT C_H is used to calculate the Total area of the horizontal tail from the Total area of the wing.

$$C_H = \frac{S_H \cdot l_H}{S_W \cdot c_{MAC}} \quad (29)$$

(Scholz, 2012, p. 9-13)

l_H is the lever arm of the horizontal tail and is defined as the distance between the aerodynamic center of the wing and the horizontal tail.

Table 5 shows typical values for the tail volume coefficient of the HT of different types aircrafts. The same table is provided in the input cell of the Tail volume coefficient of the HT as a comment.

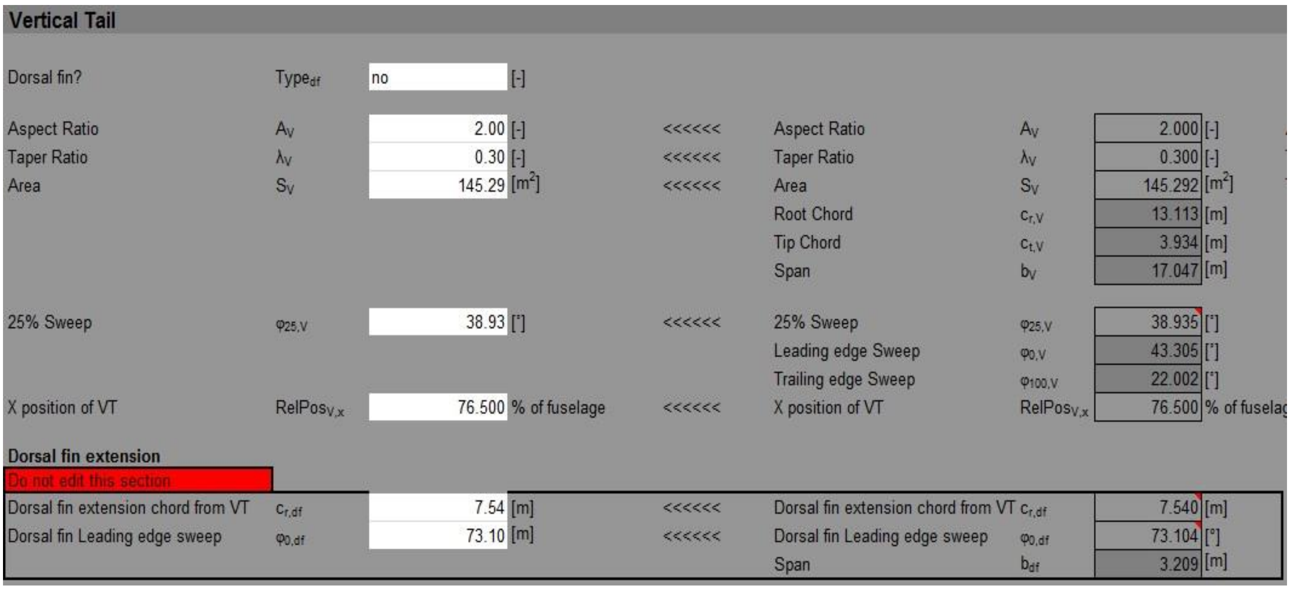
Table 5 Typical values of the tail volume coefficient

Aircraft Type	Average
Sailplane	0.5
Civil Props	
Homebuilt	0.484
Personal	0.593
GA - Single engine	0.672
GA - twin engine	0.812
Commuter	0.93
Regional Turboprop	1.004
Jet	
Business Jets	0.694
Jet transport	0.991
Supersonic Cruise Airplanes	0.535
Military	
Jet Trainer	0.663
Jet Fighter	0.356
Military Transport	0.859
Special purpose	
Flying Boat	0.671
Agricultural	0.513

12 Vertical Tail

First, it should be chosen if the vertical tail has a dorsal fin. This is possible through a drop-down list which is locatedat the top of this section. In OpenVSP-Connect a dorsal fin is considered as an addition to the vertical tail. Hence, the user is advised to first design a good vertical tail and then to proceed with the defining of an appropriate dorsal fin for it. Through the dorsal fin the efficiency of the vertical tail by high angles of yaw is improved. Moreover, the stall state of the vertical tail is moved to higher angles of yaw.

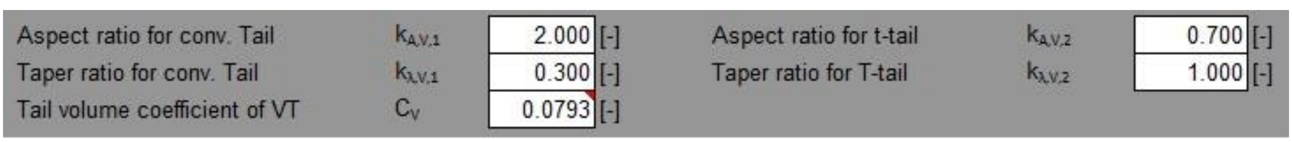
5 more parameters are necessary for the 3D-vizualization of an airplane without dorsal fin. Additional 2 parameters should be introduced once when the dorsal fin section is activated "**Figure 20**".



Vertical Tail								
Dorsal fin?	$Type_{df}$	no	[-]					
Aspect Ratio	A_V	2.00	[-]	<<<<<<	Aspect Ratio	A_V	2.000	[-]
Taper Ratio	λ_V	0.30	[-]	<<<<<<	Taper Ratio	λ_V	0.300	[-]
Area	S_V	145.29	[m²]	<<<<<<	Area	S_V	145.292	[m²]
					Root Chord	$c_{r,V}$	13.113	[m]
					Tip Chord	$c_{t,V}$	3.934	[m]
					Span	b_V	17.047	[m]
25% Sweep	$\varphi_{25,V}$	38.93	[°]	<<<<<<	25% Sweep	$\varphi_{25,V}$	38.935	[°]
					Leading edge Sweep	$\varphi_{0,V}$	43.305	[°]
					Trailing edge Sweep	$\varphi_{100,V}$	22.002	[°]
X position of VT	$RelPos_{V,x}$	76.500	% of fuselage	<<<<<<	X position of VT	$RelPos_{V,x}$	76.500	% of fuselag
Dorsal fin extension								
Do not edit this section								
Dorsal fin extension chord from VT	$c_{r,df}$	7.54	[m]	<<<<<<	Dorsal fin extension chord from VT	$c_{r,df}$	7.540	[m]
Dorsal fin Leading edge sweep	$\varphi_{0,df}$	73.10	[m]	<<<<<<	Dorsal fin Leading edge sweep	$\varphi_{0,df}$	73.104	[°]
					Span	b_{df}	3.209	[m]

Figure 20 Vertical Tail section of OpenVSP-Connect

Constant analogical to these used for the horizontal tail are used here. Again the Aspect ratio constant, the Taper ratio constant and the Tail volume coefficient of the VT are used. The difference is that for the vertical tail 2 Aspect ratio constants and 2 Taper ratio constants instead of just one are introduced. The reason this is necessary is because OpenVSP-Connect gives the opportunity for visualization of airplanes with conventional tail and T-tail as well "**Figure 21**".



Aspect ratio for conv. Tail	$k_{A,V,1}$	2.000	[-]	Aspect ratio for t-tail	$k_{A,V,2}$	0.700	[-]
Taper ratio for conv. Tail	$k_{\lambda,V,1}$	0.300	[-]	Taper ratio for T-tail	$k_{\lambda,V,2}$	1.000	[-]
Tail volume coefficient of VT	C_V	0.0793	[-]				

Figure 21 Constants necessary for visualization of the vertical tail

The tail volume coefficient of the VT has similar to the Tail Volume Coefficient of the HT definition:

$$C_V = \frac{S_V \cdot l_V}{S_W \cdot b} \quad (30)$$

(Scholz, 2012, p. 9-13)

l_V is the lever arm of the vertical tail and is defined as the distance between the aerodynamic center of the wing and the vertical tail.

Table 6 shows typical values for the tail volume coefficient of the VT of different types aircrafts. The same table is provided in the input cell of the Tail volume coefficient of the VT as a comment.

Table 6 Typical values of the tail volume coefficient

Aircraft Type	Average
Sailplane	0.019
Civil Props	
Homebuilt	0.038
Personal	0.0601
GA - Single engine	0.0443
GA - twin engine	0.0657
Commuter	0.0707
Regional Turboprop	0.079
Jet	
Business Jets	0.0722
Jet transport	0.0793
Supersonic Cruise Airplanes	0.0635
Military	
Jet Trainer	0.062
Jet Fighter	0.071
Military Transport	0.0742
Special purpose	
Flying Boat	0.055
Agricultural	0.036

13 Results

3 examples of OpenVSP-Connect outputs are given: Airbus A320 "**Figure 22**", Airbus A380 "**Figure 23**" and ATR 72 "**Figure 24**".

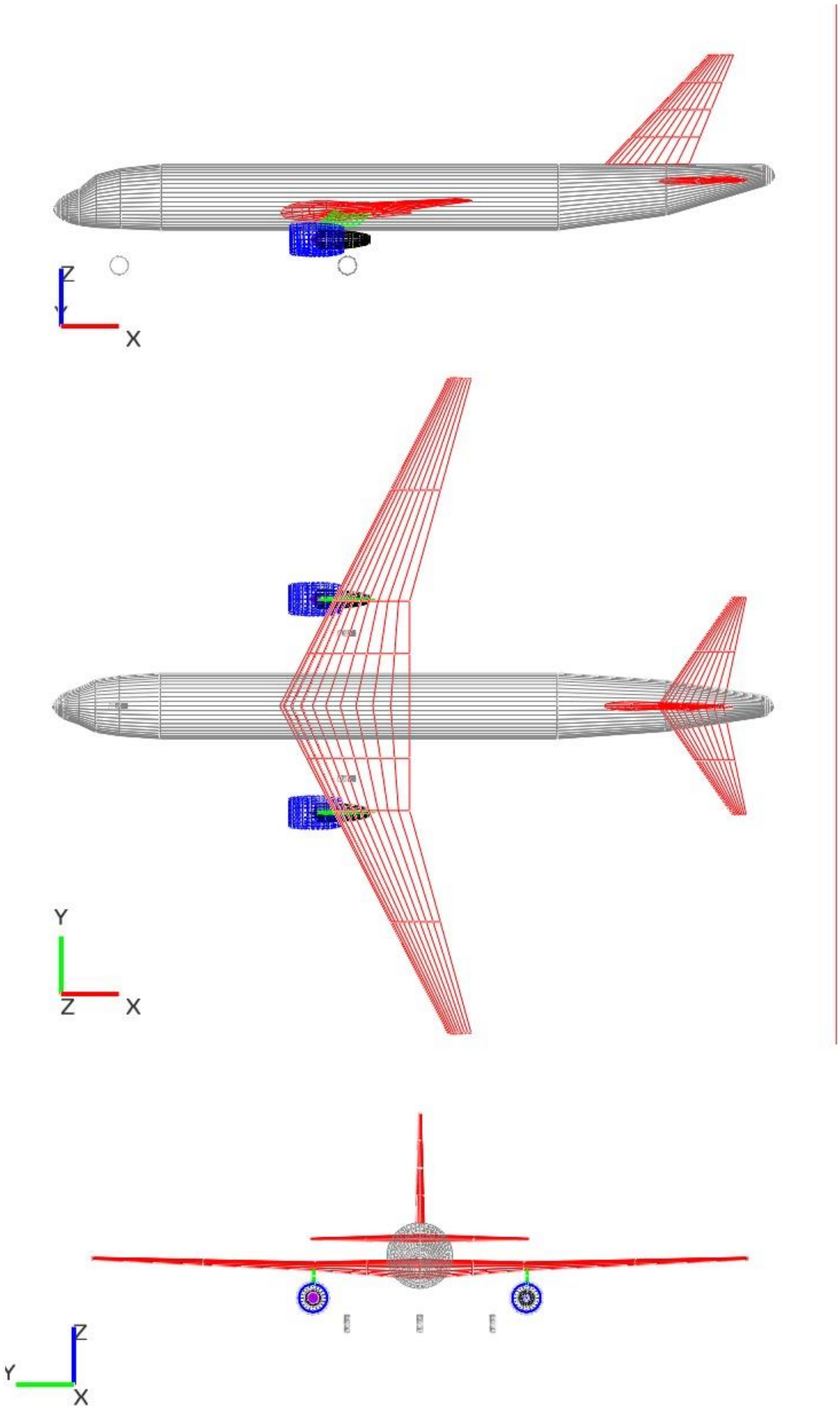


Figure 22 Airbus A320 3-view drawing from OpenVSP-Connect

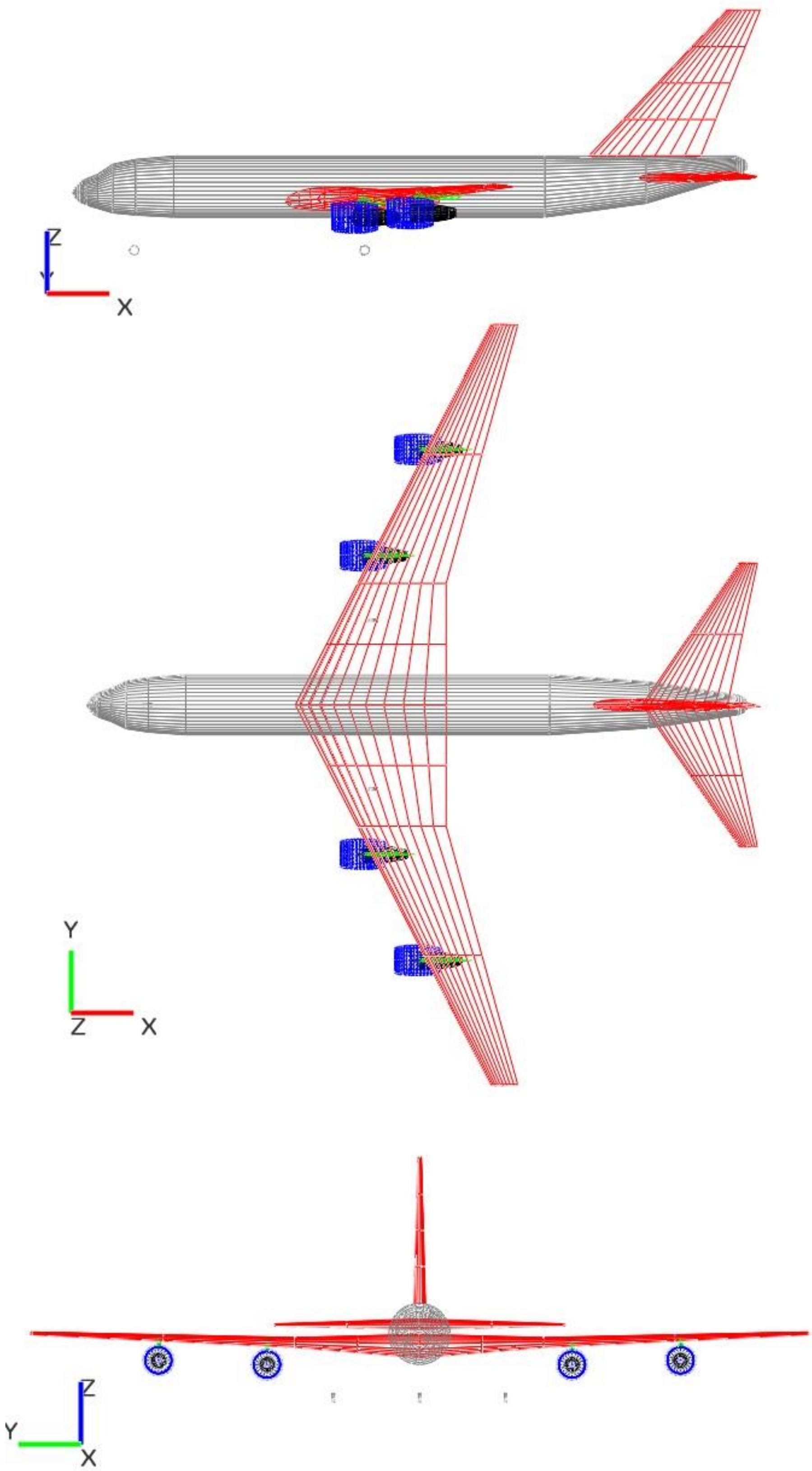


Figure 23 Airbus A380 3-view drawing from OpenVSP-Connect

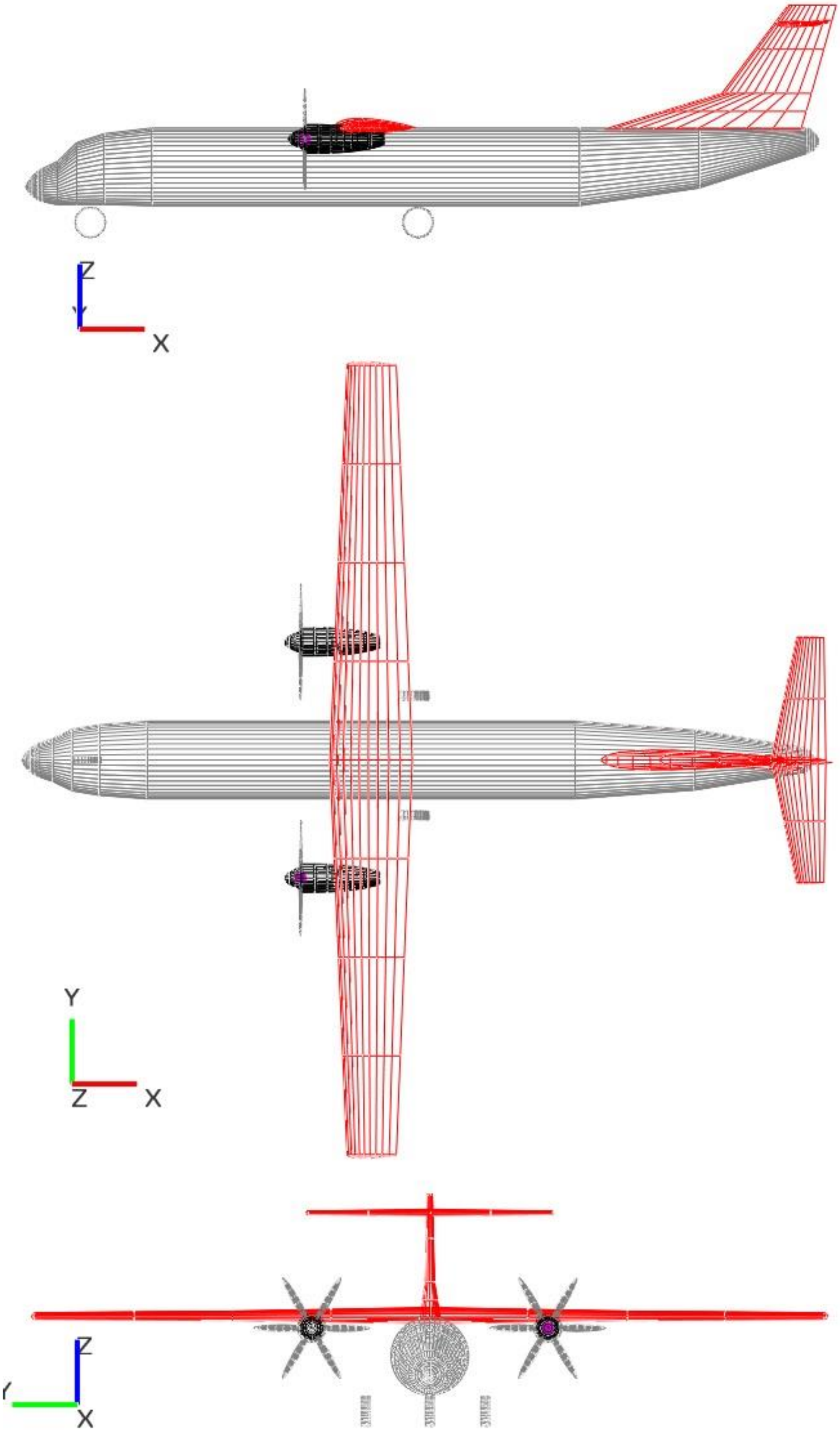


Figure 24 ATR 72 3-view drawing from OpenVSP-Connect

On Figure 25 the difference in the size of the wing and the tail of A380 and A320 due to the square-cub rule is obvious. Hence, OpenVSP-Connect represents the square-cub rule well.

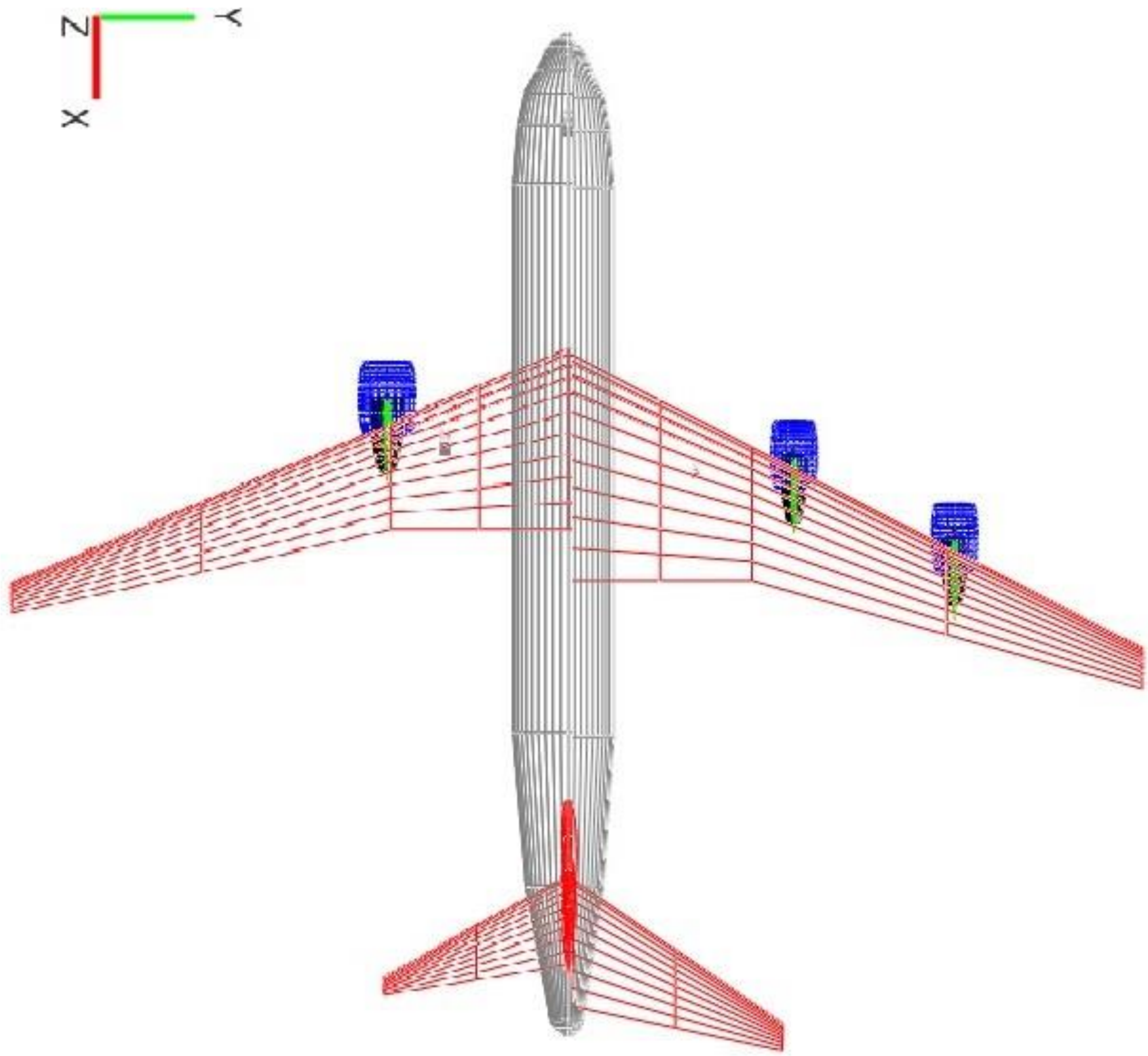


Figure 25 Comparison between the wing and the tail of A320 (left) and A380 (right) – top view drawing from OpenVSP-Connect

14 Tips and Suggestions for OpenVSP-Connect

OpenVSP-Connect is a tool that is being improved constantly. Although it is very close to its final stage, suggestions for further improvement can be given. First of all, the tool should be beta-tested by users. This is very important stage in the development of the tool, since the user feedback gives very important data for the not noticed mistakes and the errors in the code writing. Thereafter, the user feedback should be carefully evaluated and the reported bugs should be corrected.

Secondly, OpenVSP-Connect can be improved in the direction of visualizing not only passenger transport aircrafts but Very Light Aircrafts (VLA), Ultra Light Aircrafts (UL) and Light Sport Aircrafts (LSA). Since these 3 categories take big part of the aviation sector, the visualization of parameters calculated by preliminary design tool is important and necessary objective.

Least but not last, further extension in the tool chain should be made. Since aircraft design is the first step in the creation process of a new airplane, the 3D-model should be able to be pushed into another program for CFD or FEM analysis for example.

15 Summary

Two new buttons have been implemented in OpenVSP-Connect, i.e. "Tool Chain" and "Automatic Mode". "Tool Chain" button provides fast and easy use of any excel-based preliminary sizing tool and PreSTo as well. "Automatic Mode" button gives the opportunity for further use of OpenVSP-Connect after the user has broken the initial links between the input and the suggestion cells by in-putting values manually or with the aid of another preliminary sizing tool.

Furthermore, new statistical equations for calculating the Total take-off thrust, the Total take-off power and the Wing area have been found and implemented in OpenVSP-Connect. This makes the use of the Automatic mode possible. The users who are new in the aeronautics can draw their 3D-modell only by inputting 2 parameters (the Number of passenger and the Cruse Mach number) and pressing a single button.

Moreover, the method from the Aircraft Design lecture notes of Prof. Scholz for calculating the fuselage outer diameter from the Number of passengers has also been implemented in OpenVSP-Connect. This method has gratefully improved the Automatic mode of the tool and gives very good results for the output 3D-models.

Detailed description of the possible ways of using OpenVSP-Connect has been made. It can be later used as a quick "How to use guide" of OpenVSP-Connect and implemented in the official web page of this software.

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About the Author

Veselin Pavlov has bachelor degree with first-class honors from Technical University of Sofia, Bulgaria and has finished the last semester of the master degree program of TU-Sofia in Hamburg University of Applied Sciences, Germany as an Erasmus-student.

The author gained the most of his practical experience in Aeroplanes DAR, Sofia where he worked as 3D-designer and has main influence in the creation of the 3D-model of the newest company's product, i.e. DAR Solo. The 3D-model and the drawing based on it are currently revised by the German Ultralight Association (Deutschen Ultraleichtflugverbandes - DULV) as a part of the documentation for certification of DAR Solo in class LTF-UL

Appendix A

In this appendix all 46 core parameters necessary of OpenVSP-Connect for a proper 3D-Vizualisation and the names of the cells where they are stored are provided as a table.

Table 7 46 core parameters

46 core parameters			
Name	**Abbreviation**	**Unit**	**Name of the Cell**
Number of Passangers	n_p	[-]	n_p
Cruise Mach Number	M_{CR}	[-]	M_CR
Engine Type		[-]	Type_e
Number of engines	n_e	[-]	n_e
Total Engine Thrust	T_{TO}	[kN]	T_TO
Jet engine diameter	$d_{e,j}$	[m]	d_e.j
Jet engine length	$l_{e,j}$	[m]	l_e.j
Cowling cover		% of core section	cowl_cover
Total Engine Power	P_{TO}	[kW]	P_TO
Number of blades	$n_{b,p}$	[-]	n_b.p
Prop engine diameter	$d_{e,p}$	[m]	d_e.p
Prop engine length	$l_{e,p}$	[m]	l_e.p
Prop rotor diameter	$d_{e,p,r}$	[m]	d_e.p.r
Wing Type	$Type_W$	[-]	Type_W
Total Area	S_W	[m^2]	S_W
Total Aspect ratio	A_W	[-]	A_W
Outboard 25% Sweep	$\varphi_{25,W,o}$	[˚]	phi_25.o.W
Taper Ratio	λ_W	[-]	lam_W
Airfoil thickness ratio	(t\c)	[-]	t\c
X position of wing	$RelPos_{W,x}$	% of fuselage length	RelPos_W.x
Z position of wing	$RelPos_{W,z}$	% of fuselage diameter	RelPos_W.z
Outboard dihedral angle	$\Gamma_{W.o}$	[˚]	ggam_W.o
Relative kink position	$\eta_{k,W}$	[-]	eta_k.W
Inboard Leading edge Sweep	$\varphi_{0,W,i}$	[˚]	phi_0.W.i
Inboard Trailing edge Sweep	$\varphi_{100,W,i}$	[˚]	phi_100.W.i
Inboard dihedral angle	$\Gamma_{W.i}$	[˚]	ggam_W.i
Fuselage diameter	d_F	[m]	d_F
Fuselage length	L_F	[m]	l_F
Nose length	$L_{nose,F}$	[m]	l_nose.F
Cockpit length	$L_{cock,F}$	[m]	l_cock.F
Fuselage aft length	$L_{aft,F}$	[m]	l_aft.F

Total aspect ratio	A_H	[-]	A_H
Taper ratio	λ_H	[-]	lam_H
Total area	S_H	[m^2]	S_H
Sweep	$\varphi_{25,H}$	[˚]	phi_25.H
Dihedral angle	Γ_H	[˚]	ggam_H
X position of HT	$RelPos_{H,x}$	% of fuselage length	RelPos_H.x
Z position of HT	$RelPos_{H,z}$	% of VT span	RelPos_H.z
Dorsal fin?	$Type_{df}$	[-]	Type_df
Aspect Ratio	A_V	[-]	A_V
Taper Ratio	λ_V	[-]	lam_V
Area	S_V	[m^2]	S_V
25% Sweep	$\varphi_{25,V}$	[˚]	phi_25.V
X position of VT	$RelPos_{V,x}$	% of fuselage length	RelPos_V.x
Dorsal fin extension chord from VT	$c_{r,df}$	[m]	c_r.df
Dorsal fin Leading edge sweep	$\varphi_{0,df}$	[m]	phi_0.df

Appendix B

In Appendix B all necessary constants are provided as a table. It is recommended that the user uses the default values of these constants. However, advanced users can alter them, since they are input parameters.

Table 8 Necessary constants

Constants	
Name	**Abbreviation**
Mach number constant	$k_{M,MO}$
Relative kink constant	$k_{\eta,k,W}$
Slenderness ratio	$k_{l,F\backslash d,F}$
Cockpit length constant	$k_{l,cock,F}$
Fuselage tailcone constant	$k_{l,tail,F}$
HT Aspect ratio constant	$k_{A,H}$
HT taper ratio constant	$k_{\lambda,H}$
Tail volume coefficient of HT	C_H
HT 25% sweep constant	$\Delta\varphi_{25,H}$
Aspect ratio for conv. Tail	$k_{A,V,1}$
Taper ratio for conv. Tail	$k_{\lambda,V,1}$
Tail volume coefficient of VT	C_V
Aspect ratio for t-tail	$k_{A,V,2}$
Taper ratio for T-tail	$k_{\lambda,V,2}$

Appendix C

Code of the Tool Chain button. This button loads parameters calculated by any tool compatible with OpenVSP-Connect.

```
'
'*************************************************************************
''   PreSTo convert
'This macro is to be used to load a PreSTo calculated parameters into OpenVSP-Connect.
'Last modified: 18 Jun 2014
'Author:      Veselin Pavlov, Hamburg University of Applied Sciences
'Contact:     veselin.g.pavlov@gmail.com
'*************************************************************************
   Application.ScreenUpdating = False

    Dim FileName As String
    Dim PathName As String
    Dim i As Long

    FileName = Range("MyToolName").Value
    PathName = Range("MyToolPath").Value & "\"
    i = 0

    On Error GoTo ErrorHandler
    Workbooks.Open FileName:=PathName & FileName

      Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("Name_aircraft").Value =
Workbooks(FileName).Worksheets("Database").Range("Name_aircraft").Value

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("M_CR").Value = Work-
books(FileName).Worksheets("Database").Range("M_CR").Value

    On Error GoTo ErrorHandler2
'**********
'Engine
'**********

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("Type_e").Value = Work-
books(FileName).Worksheets("Database").Range("Type_e").Value
```

```
    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("n_e").Value = Workbooks(FileName).Worksheets("Database").Range("n_e").Value

    If Range("Type_e").Value = "Propeller" Or Range("Type_e").Value = "propeller" Then

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("P_TO").Value = Workbooks(FileName).Worksheets("Database").Range("P_TO").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("n_b.p").Value = Workbooks(FileName).Worksheets("Database").Range("n_b.p").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("d_e.p").Value = Workbooks(FileName).Worksheets("Database").Range("d_e.p").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("l_e.p").Value = Workbooks(FileName).Worksheets("Database").Range("l_e.p").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("d_e.p.r").Value = Workbooks(FileName).Worksheets("Database").Range("d_e.p.r").Value
   Else

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("T_TO").Value = Workbooks(FileName).Worksheets("Database").Range("T_TO").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("d_e.j").Value = Workbooks(FileName).Worksheets("Database").Range("d_e.j").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("l_e.j").Value = Workbooks(FileName).Worksheets("Database").Range("l_e.j").Value

        Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("cowl_cover").Value = Workbooks(FileName).Worksheets("Database").Range("cowl_cover").Value

    End If
'**********
'Wing
'**********
```

```
Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("Type_W").Value = Workbooks(FileName).Worksheets("Database").Range("Type_W").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("S_W").Value = Workbooks(FileName).Worksheets("Database").Range("S_W").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("A_W").Value = Workbooks(FileName).Worksheets("Database").Range("A_W").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("phi_25.o.W").Value = Workbooks(FileName).Worksheets("Database").Range("phi_25.o.W").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("lam_W").Value = Workbooks(FileName).Worksheets("Database").Range("lam_W").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("t\c").Value = Workbooks(FileName).Worksheets("Database").Range("t\c").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("RelPos_W.x").Value = Workbooks(FileName).Worksheets("Database").Range("RelPos_W.x").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("RelPos_W.z").Value = Workbooks(FileName).Worksheets("Database").Range("RelPos_W.z").Value

Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("ggam_W.o").Value = Workbooks(FileName).Worksheets("Database").Range("ggam_W.o").Value

If Range("Type_W").Value = "double-trapezoidal" Or Range("Type_W").Value = "Double-trapezoidal" Or Range("Type_W").Value = "Double-Trapezoidal" Or Range("Type_W").Value = "double trapezoidal" Or Range("Type_W").Value = "Double Trapezoidal" Or Range("Type_W").Value = "Double trapezoidal" Then

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("eta_k.W").Value = Workbooks(FileName).Worksheets("Database").Range("eta_k.W").Value

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("phi_0.W.i").Value = Workbooks(FileName).Worksheets("Database").Range("phi_0.W.i").Value
```

```
    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("phi_100.W.i").Value = Workbooks(FileName).Worksheets("Database").Range("phi_100.W.i").Value

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("ggam_W.i").Value = Workbooks(FileName).Worksheets("Database").Range("ggam_W.i").Value
  End If
'**********
'Fuselage
'**********

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("d_F").Value = Workbooks(FileName).Worksheets("Database").Range("d_F").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("l_F").Value = Workbooks(FileName).Worksheets("Database").Range("l_F").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("l_nose.F").Value = Workbooks(FileName).Worksheets("Database").Range("l_nose.F").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("l_cock.F").Value = Workbooks(FileName).Worksheets("Database").Range("l_cock.F").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("l_aft.F").Value = Workbooks(FileName).Worksheets("Database").Range("l_aft.F").Value
'**********
'Horizontal Tail
'**********

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("A_H").Value = Workbooks(FileName).Worksheets("Database").Range("A_H").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("lam_H").Value = Workbooks(FileName).Worksheets("Database").Range("lam_H").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("S_H").Value = Workbooks(FileName).Worksheets("Database").Range("S_H").Value
```

```
  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("phi_25.H").Value = Workbooks(FileName).Worksheets("Database").Range("phi_25.H").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("ggam_H").Value = Workbooks(FileName).Worksheets("Database").Range("ggam_H").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("RelPos_H.x").Value = Workbooks(FileName).Worksheets("Database").Range("RelPos_H.x").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("RelPos_H.z").Value = Workbooks(FileName).Worksheets("Database").Range("RelPos_H.z").Value
'**********
'Vertical Tail
'**********

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("A_V").Value = Workbooks(FileName).Worksheets("Database").Range("A_V").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("lam_V").Value = Workbooks(FileName).Worksheets("Database").Range("lam_V").Value

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("S_V").Value = Workbooks(FileName).Worksheets("Database").Range("S_V").Value

  Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("phi_25.V").Value = Workbooks(FileName).Worksheets("Database").Range("phi_25.V").Value

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("RelPos_V.x").Value = Workbooks(FileName).Worksheets("Database").Range("RelPos_V.x").Value
      If Range("Type_df").Value = "yes" Or Range("Type_df").Value = "Yes" Then

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("c_r.df").Value = Workbooks(FileName).Worksheets("Database").Range("c_r.df").Value

    Workbooks("OpenVSP-Connect.xls").Worksheets("input").Range("phi_0.df").Value = Workbooks(FileName).Worksheets("Database").Range("phi_0.df").Value
  End If
```

```
    Workbooks(FileName).Close SaveChanges:=False
    Application.ScreenUpdating = True

    Exit Sub

ErrorHandler:
    Select Case Err

        Case 1004
        MsgBox " The path to your tool specified on H12 or its name specified on H13 are not correct-
ly filled"

        Exit Sub

                Case Else
        MsgBox "An error has occurred while loading the PreSTo file into OpenVSP-Connect."

    End Select

    Exit Sub

ErrorHandler2:
    Select Case Err

        Case 1004
        i = i + 1
        MsgBox i & " missing input parameter/s"

        Resume Next

        Case Else
        MsgBox "An error has occurred while loading the PreSTo file into OpenVSP-Connect."

    End Select

End Sub
```

Appendix D

Code of Automatic Mode button. This button resets all the initial links between the input cells and the suggestion cells.

```
Sub reset()
'
'**********************************************************************
'
'   Reset
'
'This macro is to be used to reset all the initial links for the Automatic Mode in OpenVSP-Connect.
'
'Last modified: 18 Jun 2014
'Author:      Veselin Pavlov, Hamburg University of Applied Sciences
'Contact:     veselin.g.pavlov@gmail.com
'**********************************************************************


    '**********
    'Engine
    '**********
    Worksheets("Input").Range("T_TO").Value = "=I31"
    Worksheets("Input").Range("d_e.j").Value = "=I32"
    Worksheets("Input").Range("l_e.j").Value = "=I33"
    Worksheets("Input").Range("P_TO").Value = "=I38"
    Worksheets("Input").Range("d_e.p").Value = "=I40"
    Worksheets("Input").Range("l_e.p").Value = "=I41"
    Worksheets("Input").Range("d_e.p.r").Value = "=I42"

    '**********
    'Wing
    '**********
    Worksheets("Input").Range("S_W").Value = "=I46"
    Worksheets("Input").Range("phi_25.o.W").Value = "=I50"
    Worksheets("Input").Range("lam_W").Value = "=I51"
    Worksheets("Input").Range("t\c").Value = "=I56"
    Worksheets("Input").Range("RelPos_W.x").Value = "=I57"
    Worksheets("Input").Range("ggam_W.o").Value = "=I59"
```

```
    Worksheets("Input").Range("eta_k.W").Value = "=I62"
    Worksheets("Input").Range("phi_0.W.i").Value = "=I63"
    Worksheets("Input").Range("phi_100.W.i").Value = "=I64"
    Worksheets("Input").Range("ggam_W.i").Value = "=I65"
    '**********
    'Fuselage
    '**********
    Worksheets("Input").Range("d_F").Value = "=I69"
    Worksheets("Input").Range("l_F").Value = "=I70"
    Worksheets("Input").Range("l_nose.F").Value = "=I71"
    Worksheets("Input").Range("l_cock.F").Value = "=I72"
    Worksheets("Input").Range("l_aft.F").Value = "=I73"
    '**********
    'Horizontal Tail
    '**********
    Worksheets("Input").Range("A_H").Value = "=I78"
    Worksheets("Input").Range("lam_H").Value = "=I79"
    Worksheets("Input").Range("S_H").Value = "=I80"
    Worksheets("Input").Range("phi_25.H").Value = "=I81"
    Worksheets("Input").Range("ggam_H").Value = "=I82"
    Worksheets("Input").Range("RelPos_H.x").Value = "=I83"
    Worksheets("Input").Range("RelPos_H.z").Value = "=I84"
    '**********
'Vertical Tail
'**********

    Worksheets("Input").Range("A_V").Value = "=I90"
    Worksheets("Input").Range("lam_V").Value = "=I91"
    Worksheets("Input").Range("S_V").Value = "=I92"
    Worksheets("Input").Range("phi_25.V").Value = "=I97"
    Worksheets("Input").Range("RelPos_V.x").Value = "=I100"
    Worksheets("Input").Range("c_r.df").Value = "=I104"
    Worksheets("Input").Range("phi_0.df").Value = "=I105"
End Sub
```