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INTEGRATED SYSTEM FOR UNIFICATION OF AIRCRAFT CONCEPTUAL DESIGN APPLICATIONS

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Abstract

Unification of several tools in conceptual design process helps for a better communication and enhances the investigation of the aircraft under consideration. A collaboration is needed so that the data can be exchanged for collaboration within the framework and partners. The work presented aims at fulfilling the need of the aeronautical engineers to exchange their data with ease between tools. The awareness of this demand leads to the inspiration of this project and its aim to introduce a way for easier data sharing where it is applicable, not only for the included aircraft conceptual design applications in this project but for further applications created by other aeronautical engineers. The tools used in this work are BeX, PreSTo-Cabin, OpenVSP, RAPID, and CPACS. BeX is used for initial geometry design and sizing. PreSTo-Cabin for designing the cabin of the initial design. OpenVSP is used to obtain initial 3D geometry and RAPID for a more detailed geometry and cabin interiors. Finally, all the data is saved in CPACS data format and used for communicating between the tools and exchange of data with partners.

1 Introduction

This work aims at improving the data exchange between various aircraft conceptual design applications, using the CPACS (Common Parametric Aircraft Configuration Schema) [1] data definition. Since all the available aircraft conceptual design applications have connections to VBA-based Excel® sheets the collaboration platform is also implemented in Microsoft Excel®. This also enables easy management and exchange of data for the creation of geometry of various aircraft configuration.

2 Objectives/Designing Studies

The fundamental objective of this investigation is the creation of the base geometry of an aircraft using a particular aircraft conceptual design application and share the data with various applications such as Bex [2], PreSTo-Cabin [3], OpenVSP [4], RAPID [5, 6] and for further analysis using CPACS schema as a communication channel.

The other objectives are: creation of the outer geometry and the interior configuration of the aircraft, user-friendly data exchange, integrity of the geometry must remain intact during the exchange of data, and testing the reliability of CPACS for the exchange of data.

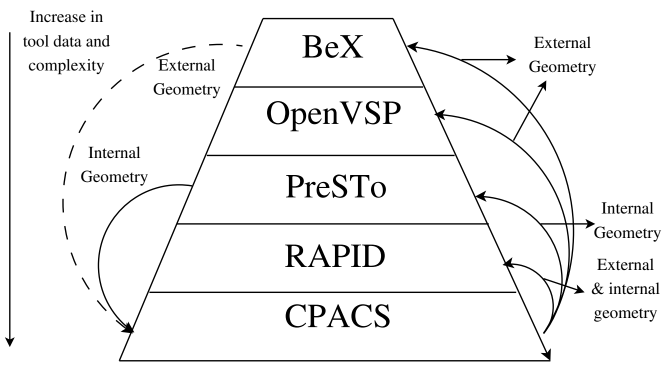


Fig. 1 : Flow chart

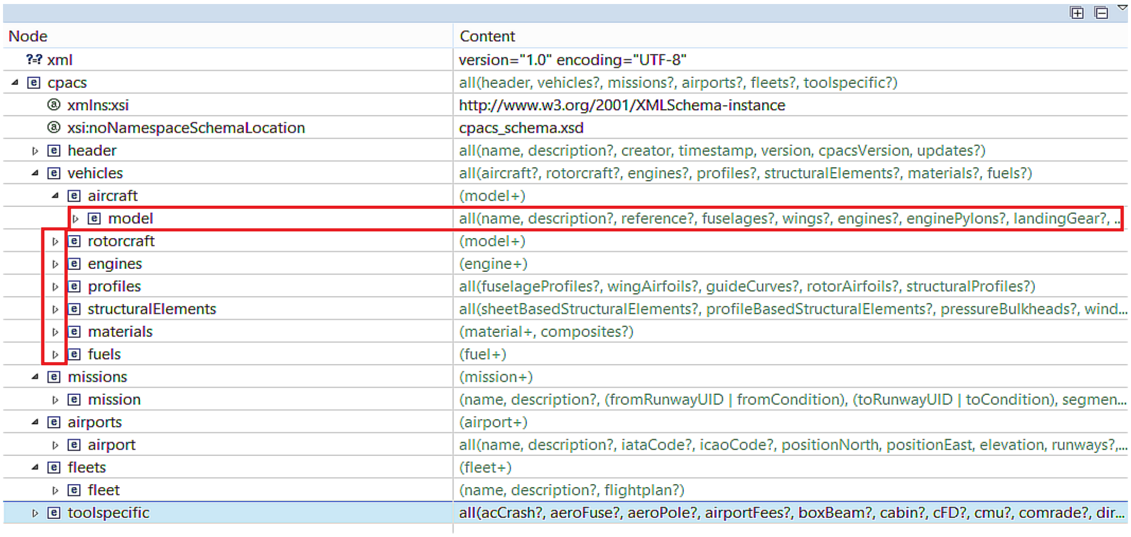


Fig. 2 : CPACS XML structure overview [1].

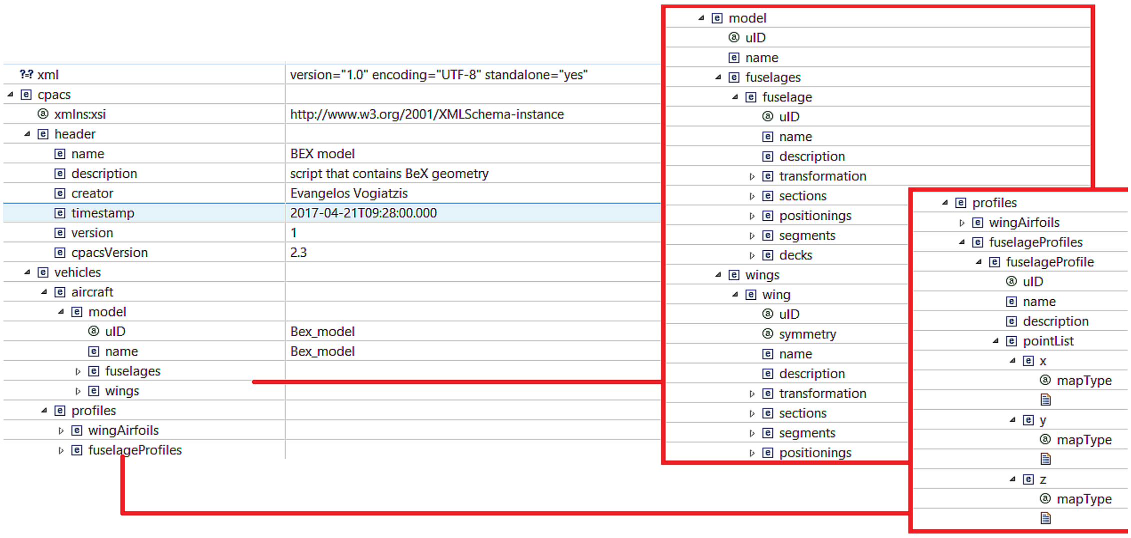


Fig. 3 : CPACS structure overview [1].

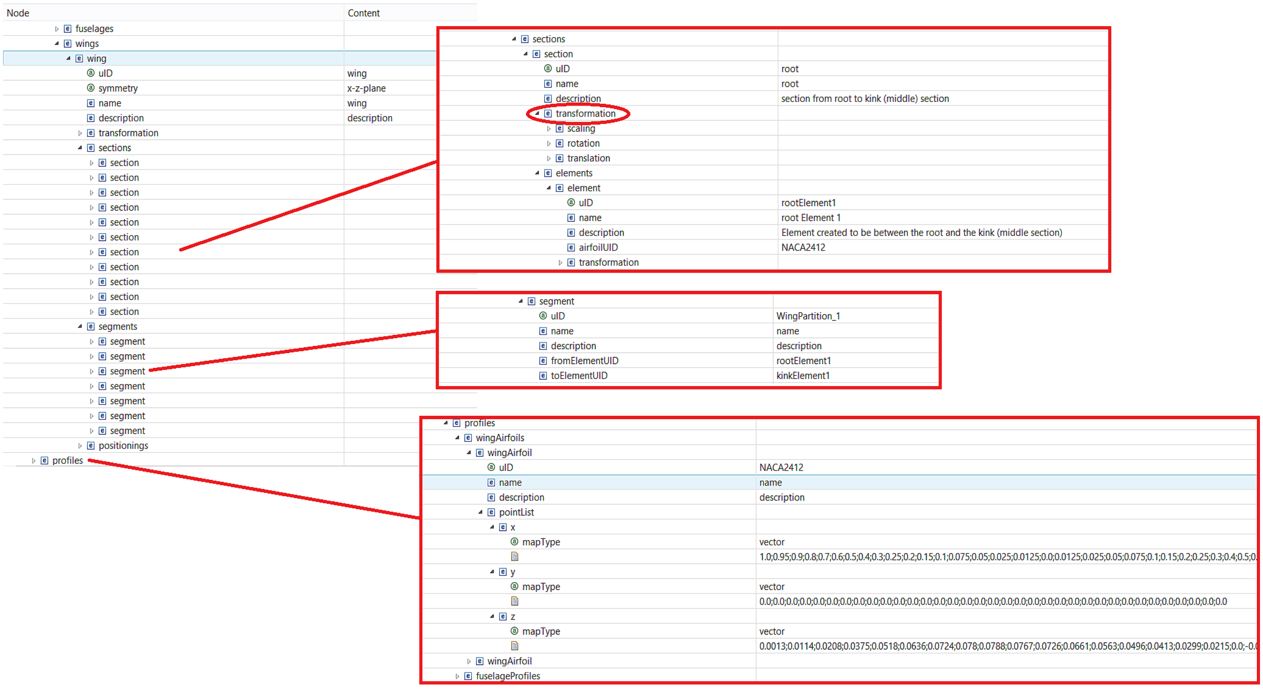


Fig. 4 : CPACS sections and segments and airfoils profile overview [1].

3 Methodology

The work-flow and the use of CPACS to exchange the information needed among the available applications is shown in Figure 1. The geometrical and interiors data can be imported and exported from CPACS to BeX and PreSTo. Furthermore, the outer geometry can be exported to the TiGL viewer and both the outer geometry and interior configuration can be exported to RAPID. Import and export of data can occur between BeX and PreSTo through CPACS and the data from BeX can be exchanged independently with RAPID. An interface in Excel® which is called Data Exchange Interface (DxI), has been created, this acts as the main data integrator of all above mentioned tools and used to import and export information.

3.1 CPACS Data Structure

CPACS XML file is divided into several parts. Figure 2 shows the CPACS XML structure as it is implemented in the XML editor Eclipse [7]. The CPACS XML structure starts with the header, which contains general information about the project, such as the creator's name, the creation date, and a general description. After the header, the structure of CPACS is divided into sections which are highlighted with red color in Figure 2. The vehicle section in CPACS is divided into different subsections such as airplane, rotor-craft, engine etc. However, since the purpose of the project is to implement only the outer geometry data of an airplane in CPACS XML, only the highlighted sections in Figure 2 are used. In this case, every other section, except the header and the vehicle sections are excluded. In addition to the aircraft, the profiles sections are used after the expansion of the vehicle's path as shown in Figure 3.

The shape profiles of the cross-section of the fuselage and the airfoils of the wing, horizontal and vertical stabilizer respectively are implemented into the profile section of the vehicle property in CPACS. Vectors in x, y, and z-axis are translated into points to complete the different shape profiles.

The basic model of the aircraft in CPACS can be found in the aircraft section of the XML. Every part is designed separately. The parts used for the completion of the aircraft are the fuselage, wing, horizontal and vertical stabilizer and a canard, Figure 3 shows a more detailed sections structure in CPACS.

3.1.1 Wing Design in CPACS

To create a part in CPACS XML, the position of the part must be defined first. The position can be defined in the transformation section of the part as shown in the highlighted area in Figure 3. The wing, in this case, can be positioned by changing the x, y, and z-axis in the translation section. The part can be scaled or rotated by using the scale and rotate option respectively.

Different sections and segments are implemented for the creation and completion of each part. For the creation of the wing, there are five-sections and four-segments. The dimensions are set in the section part and when two-sections are connected to each other, they create a segment according to the given dimensions from the section. All the coordinates of the airfoil are given in the profile section. Figure 4 shows the overview of how sections and segments are structured in CPACS and the wing profiles [8],

The wing is divided into four-segments, just like in BeX. The first three-segments are trapezoids. The height of each segment is calculated as in Figure 5. The sweep angle, root and tip chord are known. The height of the segment is resulted by using the trigonometric function of the tangent at the right triangle highlighted in Figure 5.

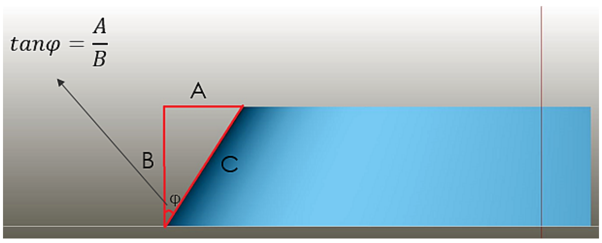


Fig. 5 : Wing segment showed in TIGL viewer [9].

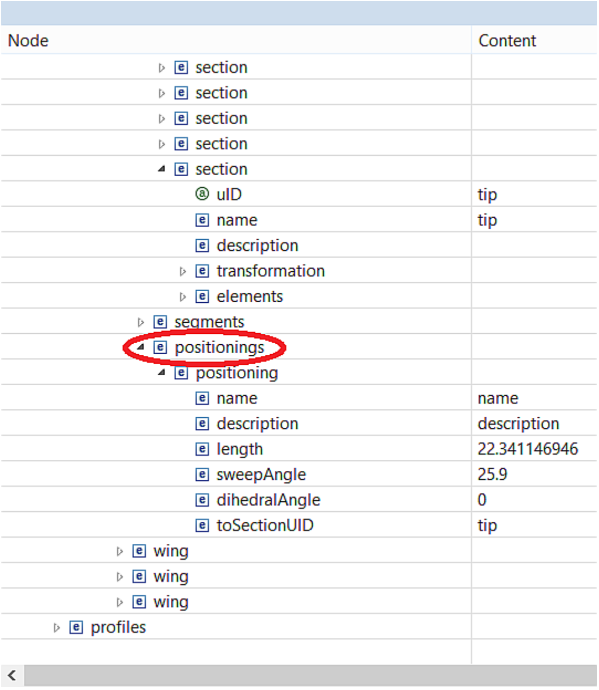


Fig. 6 : Positioning partition in CPACS [1].

The last segment in CPACS is created by the positioning option as shown in Figure 6. The overall length of the wing and the sweep angle are implemented to create the last segment in positioning. The airfoil used for the wing is the NACA 2412 [10] [11], Figure 7 shows the complete set of wings in TiGL viewer in the x-y plane.

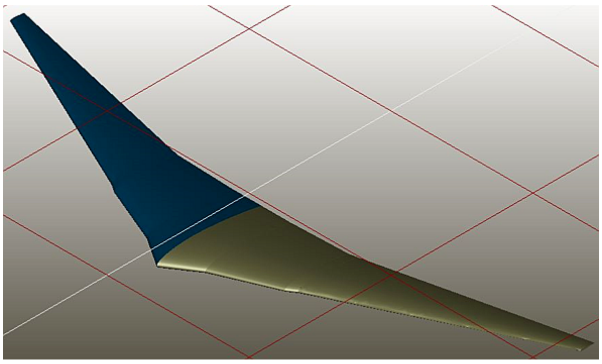


Fig. 7 : Complete wing showed in TIGL viewer [9].

3.1.2 Canard, Horizontal and Vertical Stabilizer Design in CPACS

The creation of canard, horizontal and vertical stabilizer in CPACS follows the same procedure as the wing. The translation option determines the position of each part in x, y, and z-axis. Two-sections and one-segment is created, one-section each for the root and tip chords. Finally, by using the position option, and implementing the sweep angle and the overall length of each part, the canard of horizontal/vertical stabilizer are created. The airfoil used to implement the profile of the canard, the horizontal and vertical stabilizers is NACA 0012, refer to [10] [12] for more information. Figure 8 shows the complete geometry canard, horizontal and vertical stabilizer in x-y plane with their symmetry in gold.

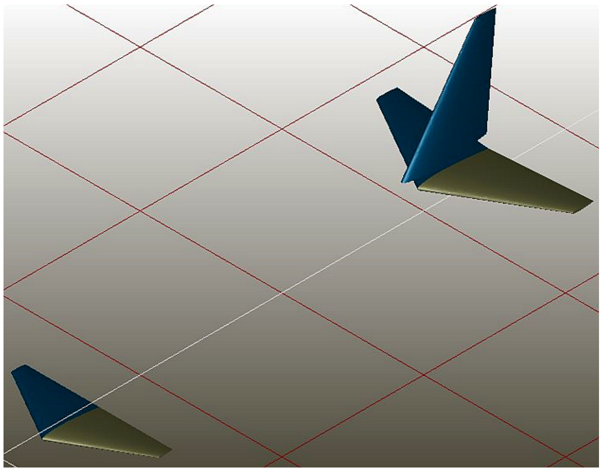


Fig. 8 : Complete canard, vertical and horizontal stabilizers showed in TIGL viewer [9].

3.1.3 Fuselage Design in CPACS

The same principle applied to the wing design in CPACS is used for the design of the fuselage. The position of the fuselage is determined using the translation option. The dimensions and the cross-section profiles of each fuselage segment are defined in the section option.

The fuselage cross-section profiles, along with the wing airfoils, are defined in the profile part of the CPCAS XML file and they are vectors in y and z-axis. For the fuselage profiles, the x-axis is always equal to zero because of the length of the segment is defined by the translation option. The data for these profiles and the dimensions for the creation of the fuselage segments are taken from an Aircraft conceptual design tool (BeX in this project). According to BeX, fourteen-profiles have been implemented to CPACS. Those profiles are defined by different points on the upper, bottom and side curve of the aircraft in BeX. The size of the profiles is defined by vectors created according to the coordinates of of these points in y and z-axis. The distance between these profiles, which is also the length of each segment, can be defined in the "section" part of the fuselage. Figure 9 shows the overall geometry of the aircraft in CPACS, illustrated in the TiGL viewer.

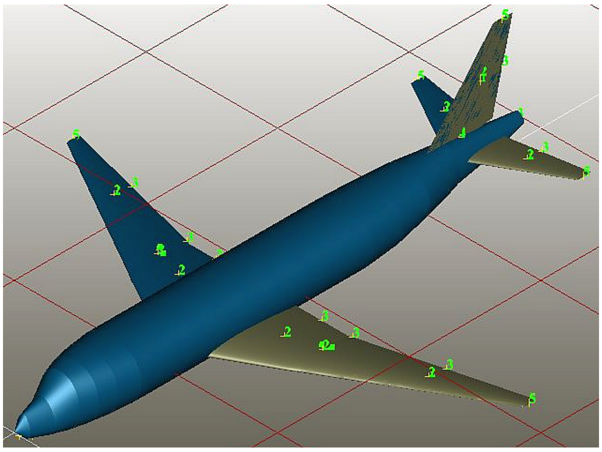


Fig. 9 : Complete aircraft showed in TIGL viewer [9]

3.2 Exchange data with BeX

The data of the external geometry of the aircraft is taken from BeX. One macro to import and one macro to export the data is created in DxI (for more information on macros reference [13]). The data exchanged are the geometrical features of the aircraft, such as the wing, the fuselage and the horizontal and vertical stabilizers.

3.2.1 Fuselage data exchange

Three parts are created for the creation of the fuselage in BeX, the front, middle and rear part. Three curves define each part, the upper, the lower and the side curve. Figure 10 shows the position of the fuselage curves.

Different control points define each curve and each points coordination for the upper, lower and

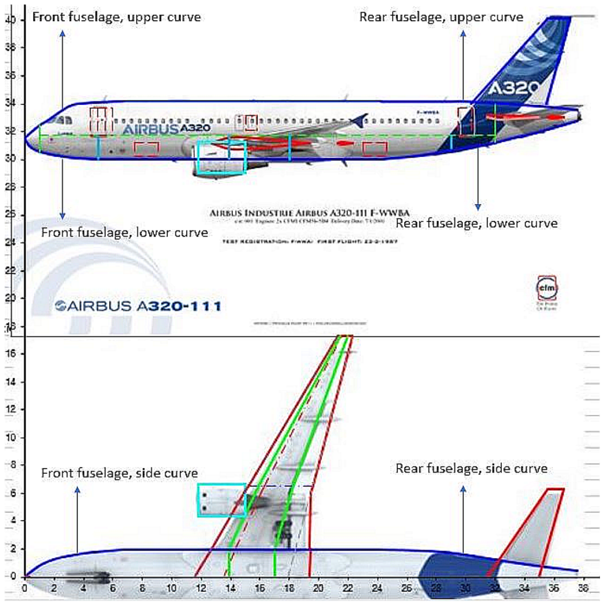


Fig. 10 : Fuselage guide curves in BeX [2].

side curve is available in CPACS XML file. The highlighted yellow cells in Figure 11 defines the position of the points on the front fuselage.

The creation of the fuselage points in CPACS XML file is important when the data is transferred to BeX through the DxI. The number of profiles in CPACS XML file is fourteen and they are in a form of a vector. The coordinates of each point on every fuselage curve in BeX is the range of the profile vector. Different cross-sections are created in different parts of the length of the fuselage. Via a macro created in DxI, all profile vec-

x-pos	z-pos (side view)	
0	31.5	front fuselage (lower lobe)
0.5	30.8	shoulder point
1.5	30.4	shoulder point
3.2	30.1	shoulder point
4	30.05	shoulder point
4.8	30	shoulder point
6.6625	30	
0	31.5	front fuselage (top lobe)
1	32.4	shoulder point
1.62	32.8	shoulder point
3.06	33.8	shoulder point
4	34	shoulder point
5.75	34.1	shoulder point
6.6625	34.14	

Fig. 11 : Forward fuselage point input in BeX [2].

tors can be separated and can be exported to BeX as coordinates to the initial points of the fuselage curves.

3.2.2 Wing, Horizontal and Vertical stabilizer data exchange

The wing is divided into four-segments and five-sections and the horizontal and vertical stabilizers are made of one-segment and two-sections in BeX and this data is exchanged using DxI. The position of the wing and the horizontal and vertical stabilizer in x and z-axis, the root and tip chords of each segment are exported from BeX through DxI and to CPACS XML file. The span and the sweep of each partition of the wing or the horizontal and vertical stabilizer in BeX represent the height and the angle of the leading edge of the segment respectively. All the imported values from BeX can be exported back via the DxI.

3.3 Data exchange with PreSTo

The interior configuration of the aircraft is designed in PreSTo. The fuselage dimensions from BeX can be implemented in PreSTo via the DxI. The fuselage dimensions exported from BeX to PreSTo are the width, overall length and height and the front and rear lengths of the fuselage. In PreSTo, the overall cabin length is defined by the number of passengers.

3.3.1 Interior data exchange

The interior configuration in PreSTo can be modified by changing the settings: seat configuration which defines the number of classes (first, business, economy class), number of aisles (one, two aisles), position and dimensions of seats, cockpit configuration, lavatories, galleys and exit doors configuration. Figure 12 shows the interior configuration of a conventional aircraft. The interior configuration from PreSTo is exported to RAPID via the DxI and a 3D models of the cabin configuration is obtained.

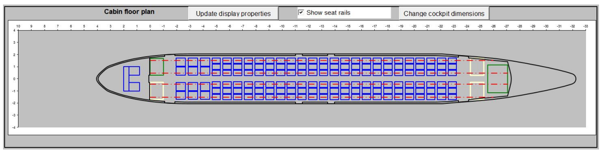


Fig. 12 : Interior configuration in PreSTo [3].

3.4 Interior configuration in RAPID

The outer geometry of the aircraft is obtained from BeX and the interior configuration from PreSTo, via DxI, is exported to RAPID. A 3D model of the aircraft along with the cabin is created in RAPID. It is to note that in this work the existing interior geometry of RAPID is coupled with PreSTo, for more information on RAPID refer [5, 6].

The dimensions and the positioning of the passenger, cargo doors and bulkheads are implemented in RAPID, from BeX. The following are the most important interior items taken from PreSTo:

- Number of classes
- Number of aisles
- Number of seats First class, Business class, Economy class
- Seat Positioning
- Seat dimension
- Number of seats in a row
- Number of Lavatories
- Lavatory Positioning
- Number of Galleys
- Galley Positioning

Instances of exit doors, windows and seats are created in RAPID using catalogues in Knowledge Pattern in CATIA V5®. A macro in DxI is created for defining the positions in X and Y axis and dimensions of all instances. Similarly, the position and the activity of lavatories and galleys along the cabin's length according to the cabin configuration in PreSTo are created in DxI. The seat configuration depends on the number and position of the lavatories and galleys. The lavatories or galleys are usually located either in the front, back or the middle part of the cabin such that the seats must not interfere. For this reason, wherever there is a lavatory or a galley in the cabin, a new instance of seats is created after the lavatory/galley in RAPID.

3.4.1 Lavatories and galleys configuration

The available data regarding the galleys and lavatories from PreSTo is implemented to DxI with the same pattern. The nose offset, which is the cockpit wall, defines the position of the first lavatory or galley in RAPID. Figure 13 shows the nose offset distance on the front fuselage which is the starting point in PreSTo and RAPID.

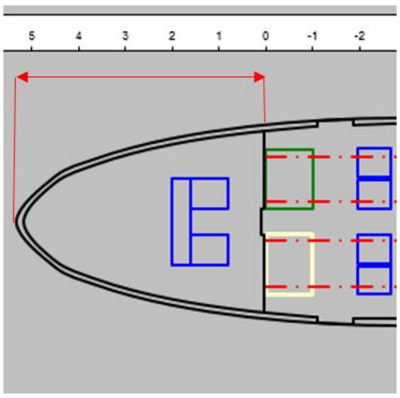


Fig. 13 : Nose offset distance in PreSTo [3].

The number of seats, lavatories and galleys defines the cabin length, according to their position and the width of the lavatories/galleys defines the position behind the first lavatory/galley both in PreSTo and RAPID. A dedicated macro in VBA for the lavatory and galley configuration is created to determine their position in the cabin according to the data taken from PreSTo.

3.4.2 Seats configuration

The number of classes (first, business and economy class) and the number of aisles (if it is single or double aisle) define the seat number, position and row number in PreSTo. All seat data from PreSTo is implemented in DxI. The nose offset, which is the cockpit wall, defines the position of the first seat row in RAPID along with the aisle number which defines how many aisles are in-between the seat, the number of classes, numbers of rows and how many seats are in every row for each different class.

Several instances of seats are created in RAPID according to the data exported from PreSTo. A macro in DxI is created for the management of the seats. If a lavatory or a galley is located in between the rows of seats, then automatically a new instance of seats is created behind the lavatory or galley.

3.4.3 Doors configuration

Table 1: Doors dimension definition in DxI, the data of the door type is taken from PreSTo

Type of exit in PreSTo	PAX allowed	Size (b*h)
Type A (Floor-level exit)	110	1,07m*1,83m
Type B (Floor-level exit)	75	0,81m*1,83m
Type C (Floor-level exit)	55	0,76m*1,22m
Type I (Floor-level exit)	45	0,61m*1,22m
Type II (Floor-level or over-wing exit)	40	0,51m*1,12m
Type III (Rectangular opening)	35	0,51m*0,91m
Type IV (Located over the wing)	9	0,48m*0,66m

Doors related data, such as doors types, general dimensions and positioning, is exported to DxI from PreSTo. The position of the doors is defined, as the lavatories and galleys, by the nose offset. The same table that controls the positioning of the lavatories and galleys is used for the doors in PreSTo. A similar table is created in DxI to receive the data from PreSTo and then to export the data to RAPID. Furthermore, a table is created in DxI to implement the type and the dimensions of each door taken from PreSTo. The door dimensions taken from PreSTo are shown in Table 1.

3.4.4 Containers

The dimensions of the cargo containers are defined in PreSTo and exported to DxI. However, only the type and the dimensions of the containers can be defined in PreSTo, hence the position in X-axis of the containers must set manually in RAPID.

3.5 Exchange data with OpenVSP

The outer geometry of the aircraft data taken from BeX through CPACS is transferred to OpenVSP via DxI. The file exported from OpenVSP can be converted into an XML file, this file is implemented in DxI. A macro is created to import and export data from BeX via DxI to the OpenVSP converted to XML file. The updated XML file will be converted into a VSP3 file, which is the type of file used by OpenVSP, and the aircraft 3D model is created automatically into OpenVSP.

3.6 Data Exchange Interface (DxI)

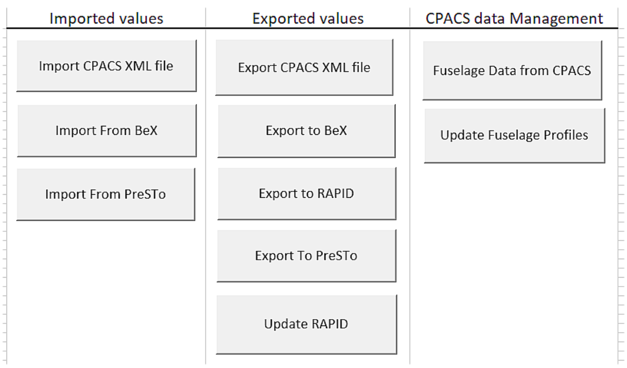


Fig. 14 : Control Buttons of Data Exchange Interface in Excel®

A spreadsheet in Excel ® is created for the implementation of data from CPACS to BeX, PreSTo, OpenVSP, RAPID and vice versa. The created Excel spreadsheet is called DxI. Several macros are created for the management of data between the available applications. The data stored in DxI can be exported and saved to an XML file. The exported XML file can be imported again to DxI in case of loss of data. Certain cells in the spreadsheet are modified according to the CPACS structure. This way it is easier for the user to trace eventual mistakes. The CPACS XML file is implemented in DxI and macros are created for the classification of data. Figure 14 shows the buttons created for the control of various applications in DxI.

4 Results

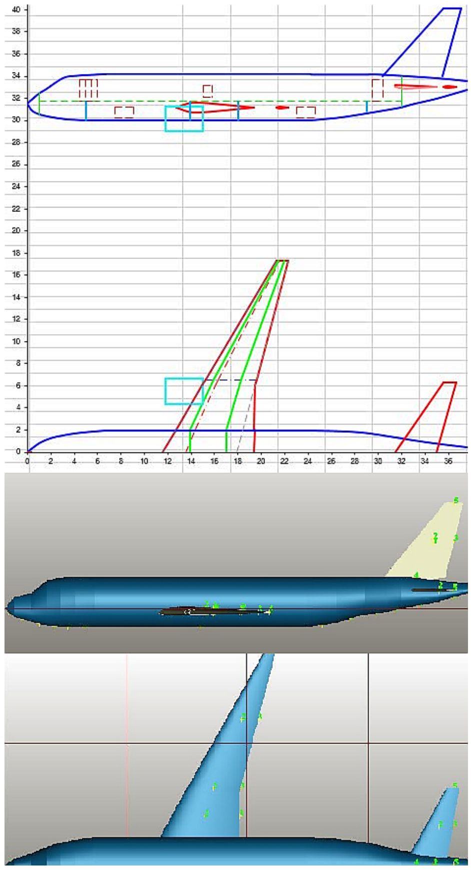
4.1 Aircraft complete geometry from BeX implemented in DxI

The most representative data of the aircraft geometry is transferred from BeX to DxI. TiGL viewer is a software which illustrates a 3D model of an aircraft by reading the CPACS XML file. This model can be exported as other CAD formats such as IGES and STP. TiGL viewer can be used for virtual comparison of different kind of aircraft. Figures 15 (a) and 16 (a) show the geometry in BeX and TiGL viewer for a passenger aircraft and a business jet. It is observed that the geometries in both cases are similar in both BeX and TiGL viewer.

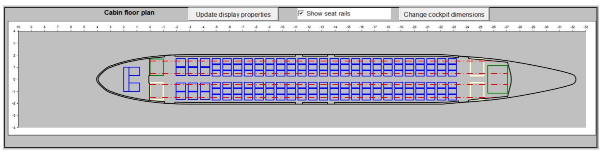
4.2 Interior configuration from PreSTo-cabin implemented in RAPID via DxI application

The cabin design is created in PreSTo. The values from PreSTo are exported to DxI and then to RAPID, an integrated 3D geometry of the the aircraft created in RAPID built CATIAV5® using knowledge-based engineering principles. Figure 15 (c) shows the cabin layout of passenger aircraft in top and side-view. The configuration is two classes, single aisle-layout.

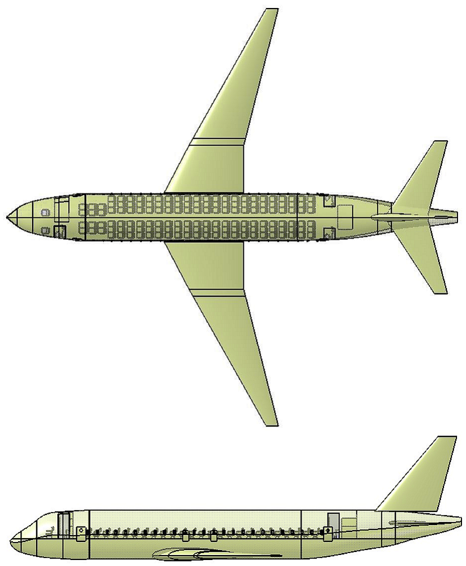
Figure 16 (b) shows the cabin layout in PreSTo of another example, a business jet. Figure 16 (c) shows another example of aircraft in RAPID, the cabin layout of a business jet in top and view. The configuration is a one class-single aisle layout.



(a) Aircraft geometry of a passenger aircraft in BeX (Top) and CPACS illustrated in TiGL viewer(Bottom).

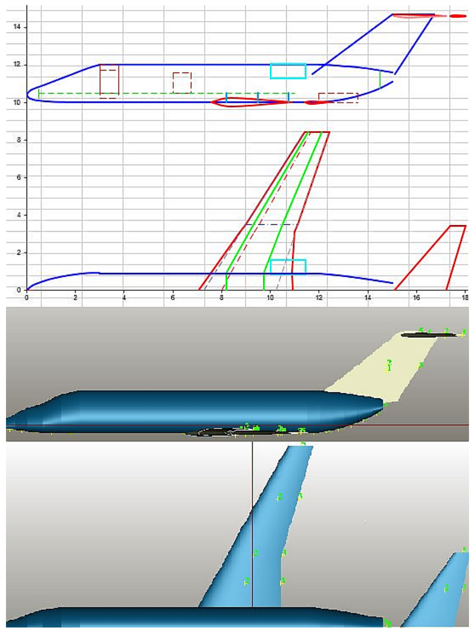


(b) Cabin layout of a business jet in PreSTo, single aisle

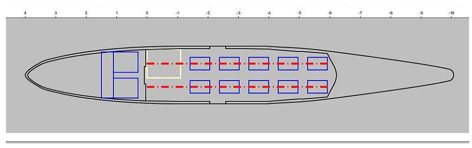


(c) Cabin Layout in RAPID, single aisle side and top-view

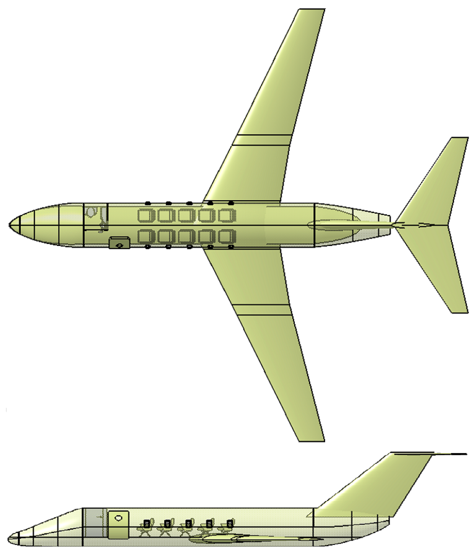
Fig. 15 : All the results of a passenger aircraft geometry in all the applications.



(a) Aircraft geometry of a business jet in BeX (Top) and CPACS illustrated in TiGL viewer(Bottom).

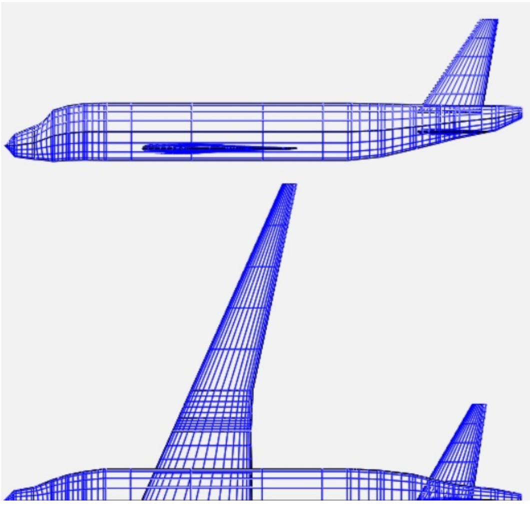


(b) Cabin layout of a business jet in PreSTo, single aisle

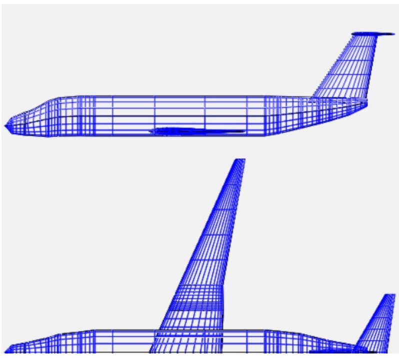


(c) Cabin Layout in RAPID, single aisle side and top-view

Fig. 16 : All the results of a business jet geometry in all the applications.



(a) Aircraft geometry of a passenger aircraft in OpenVSP.



(b) Aircraft geometry of a business jet in OpenVSP.

Fig. 17 : All the results of a passenger aircraft and a business jet geometry in OpenVSP.

4.3 Aircraft complete geometry from BeX implemented in OpenVSP

The macro created in DxI transfers aircraft outer geometry data from BeX to OpenVSP. Figure 17(a) shows the outer geometry of a passenger aircraft implemented in OpenVSP in top and side view. Figure 17(b) shows the outer geometry of a business jet implemented in OpenVSP in top and side view. Many similarities are observed in the outer geometry between the aircraft models implemented in TiGL viewer (Figure 15 (a) and Figure 16 (a)) and in OpenVSP (Figure 17(a) and Figure 17(b)).

5 Conclusion

This paper presents an improved and user-friendly way for the exchange of data between aircraft conceptual design applications. With the assistance of the Microsoft Excel® and its features, such as compatibility with XML scripts and VBA programming language helps the exchange of data between the applications easier and more effective. This research can inspire aeronautical engineers to use similar techniques to exchange data between their tools for more effective sharing. Valuable time can be saved for calculations since the geometry of the aircraft is updated automatically in every application with precision.

Although this research concerns only the external geometry of the aircraft and interior configuration, more attributes can be added according to the structure of the original CPACS schema, such as the fuselage and wing structures, landing gears, engines and various types of analyses. The work presented is performed as a Master's thesis at the Division of Fluid and Mechatronic Systems, Linköping University, Linköping, Sweden.

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