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Study of the Boeing C17 Globemaster III structure and reproduction of a 1:50 scale model

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Final Degree Project

Grau en Enginyeria de Vehicles Aerospacials

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1 Abstract

The present project consists on the structural study of the Boeing C-17 Globemaster III in order to create a 1:50 scale model. The main research that is developed will define the most important features that assemble the structural design of the mentioned aircraft. All these information will be focused on a CAD model that will both represent the structural techniques of Boeing's design and it will parallely be designed in order to create a wooden scale model.

The main objective of this project is to be able to compile the enough information to end up with a deep study. This will describe functionality of the structural design so that logical reasoning can then be made to understand why this aircraft needs the issues investigated.

A CAD representation will then be developed. It will be constructed in the 3D software SolidWorks with UPC's student license. The main parts of the aircraft will be drawn with the objetive and necessary techniques to export it and create a 1:50 scale model, which represents the main structural features of the aircraft.

The CAD will then be exported. The necessary draws will be developed to then be transformed into pieces of wood. This draws will have the peculiarity that they don't need dimensions or indications, but only the outline so that the automatic laser cut machine reads it without any problem.

Once the pieces are ready, they will be put together to construct a 1:50 scale model using glue for wooden models and basic tools. To do that, the pieces will be placed together carefully adding the necessary components to reinforce whatever piece that doesn't have the eough strength to support itself or other pieces.

Finally, a set of conclusions will be developed to understand how this project affects the student's knowledge and how it can be improved, apart from other aspects.

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2 Aim of the project

The aim of this final degree project is to study the main structural elements of the Boeing C-17 Globemaster III. Once having compiled all the necessary information, a CAD model will be developed bearing in mind that it will be the tool to represent a 1:50 scale model of the aircraft, so it will not represent the real structural elements of the Boeing, but a simplified example of the most important techniques used.

3 Scope of the project

The scope of the project, presented next, will define in detail the different tasks to enable the project:

3.1 Research of the structural design of the aircraft

First of all, a deep research has to be done to have a clear knowledge of the structural elements that form the C-17. As Boeing do not publish their engineering projects, most of the information saved will come from photographs or sketches provided from other sources. Bearing in mind that not all the aircraft's structure will be found, some elements will have to be deduced with the knowledge collected during the degree. All features have functions that are always based on the main use of the aircraft, so a brief history research of the C-17 Globemaster III project is going to be described.

3.2 3D CAD representation

After having collected all the profitable information, a 3D CAD design will be assembled focused on the next step: the reproduction of a scale model. In the software SolidWorks, an assembly will be design to export the necessary draws in order to create the model, so that the construction of it will be easier.

It is important as well to decide how to construct the model. This will immediately affect the way of designing the CAD design, for example, if the model will be constructed with a 3D printer, some pieces such as spars or ribs can be printed together. However, if the model is constructed with wood plates, an H-section shaped spar will be made in three parts and joined together with appropriate glue.

Some structural elements have also mechanical functions such as flaps, stabilisation elements or landing gear.

3.3 General research of the materials and processes that will be used to construct the model

The first and probably the final material decision that will be taken will regard wood plates cut with laser. This is a cheap and quick solution easy to represent with a CAD model and easy to export so that the machines read it without problems. This means that vector representation will have to be created throughout the CAD model.

Another solution is to print the pieces. However, this technique requires a lot of time and a more expensive material. All the pieces though that may present a shape that with simple tools cannot be manufactured can be 3D printed and assembled to the rest of the pieces.

To choose the technique and company that will manage the transformation of the final pieces; the draws will be sent to several contacts asking for price and service. The chosen one will be the one that offers the best service at the lower price.

3.4 Exportation of the draws and provider

Once the structure is defined throughout the CAD model, all the pieces that have to be manufactured by a provider will be exported into draws. The format of these draws will depend on how the provider works, so a deep and clear contact with them is very important to achieve the pieces as it is needed to construct the model.

As the most probable technique of manufacturing the pieces will be laser-cut in wood plates, the CAD model will be developed bearing in mind this technique. In order to do that, most pieces will have a shape that will be then transformed in a perpendicular extrusion.

3.5 Construction of the scale model

The material ordered will be assembled to create the scale model. The necessary techniques to assemble will depend on the material ordered and the tools available to develop it. It is really important to follow the measures indicated in the CAD representation, as all pieces will depend on each other.

The objective of the scale model is to represent the study of the aircraft's structural design in a visual way. This method helps to comprehend the function of each detail without numerical calculation, only a general site of how the aircraft sustains itself on the ground and flying.

3.6 Economical analysis

After the construction of the scale model, an analysis of economical and time invested to realise the project will be describe to have a general conclusion of the cost of it. This will be use for further projects or design of prototypes that require a scale and physical model to describe it. It is a very important aspect when designing new machines, air crafts or whatever engineering projects which can be much more attractive for investors or clients if they are represented as described above.

3.7 Conclusions

To end up the study of the C-17 Globemaster III structure, some conclusions will be shared to have a reasonable opinion of how can this affect the student's learning, future engineering projects and analysis of studies based in research and personal knowledge.

4 Research of the aircraft

4.1 The chosen aircraft

The first step to develop this final degree project is to choose the aircraft that is going to be analysed. The first general idea was to choose an interesting aircraft that allowed a deep structural study throughout research and general aeronautical knowledge. The objective is to find the reason or function of the most common structural techniques used in the aeronautical sector, so the aeroplane that was going to be chosen would present common-used aeronautical features.

Finally, after considering several options, a high-wing, four-engine, T-tailed military transport aircraft [4] was chosen: the Boeing C-17 Globemaster III, used to transport supplies and troops directly to small airfields in harsh terrain anywhere in the world.

4.2 The Boeing C-17 Globemaster III

The Boeing C-17 Globemaster III is a large military transport aircraft. Designed for the first time in the United States Air Force (USAF) in the 1980 up to the early 90's, its creator, McDonnel Douglas, came up with the design by merging two previous piston-engined military cargo aircraft; Douglas C-74 Globemaster and Douglas C-124 Globemaster II. By that time, McDonnel was a major aerospace manufacturing corporation and defense contractor, so the objectives and goals set by this corporation were fulfilled when the idea of the Boeing C-17 Globemaster III came to fruition (first operational appearance on 17th January 1995).

At first, it was developed by Charleston Air Force Base, South Carolina, to replace the already existing shuttle aircraft Lockheed C-5 Galaxy. Currently, within the latest designs and improvements of a high-wing, four-engine, T-tailed military transport, it is able to carry large equipment, supplies and troops directly to small airfields in harsh terrain anywhere in the world. The massive, sturdy, long-haul aircraft tackles distance, destination and heavy, oversized payloads in unpredictable conditions. An important fact which the corporation willingly shares is that, ever since the 1990s, the aircraft has delivered cargo in every worldwide operation fruitfully.

4.3 Background and design phase

In the later 1970's, the original design team was dealing with budget and funding issues, which caused a take off delay of 4 years. Eventually, this was not seen as a big problem since that time was used as a phase for rethinking and evaluating the project. Errors were found, and so, able to rectify.

However, even with the thorough and meticulous examination, the first prototype of aircraft did not succeed at passing the rigorous tactical and statistic tests by a 128% over a 150% required. The main issue was the wing failing. All of the wings buckled rear to the front and provoked failure to the stringers, spars and ribs. Being a military designed transport with high payloads, this error had to be corrected. Over a 100$ million were spent to redesign the project and improve it. [5]

It was only in 1993, after naming it the Boeing C-17 Globemaster III, that it was fully developed and, although still being over budget and having problems with weight, fuel burn, payload and range, augmented its demand (from the 32 first forecasted up to 120 at least). The characteristics of the first design had been improved and ameliorated and so, in that time, it finally was able to nail the tests and allowed to perform (several years after). Augmenting the maximum payload up to 77.500kg, establishing the maximum altitude to 8.500m, settling for an unrefueled range of about 2400 nautical miles on the first 71 aircrafts, then up to 2800 on the extended-range models. These are only some of the several changes that were done to the project.

4.4 Technical specifications

As indicated in [4], the C-17 presents the following specifications:

External dimensions	
Wingspan to Winglet Tip	51,74m
Length	53,04m
Height at Tail	16,79m
Fuselage diameter	6,86m
Engines	
Four Pratt and Whitney PW2040	
Seating	
Sidewall	54 (27 each side, 18 inches wide, 24 inch spacing center to center)
Centerline	48 (in sets of six back-to-back, 8 sets)
Palletized	80 on 8 pallets, plus 54 passengers on sidewall seats
Cockpit	
Flightcrew	2 pilots
Observer positions	2
Instrument displays	2 fulltime all-function head-up displays (HUD), 4 multi-function active matrix liquid crystal displays
Navigation system	Digital electronics
Communication	Integrated radio management system with communications system open architecture (COSA)
Flight controls system	Quadruple-redundant electronic flight control with mechanical backup system
Wing	
Area	3800 sq. ft. (353 sq. m.)
Aspect ratio	7,165
Sweep angle	25 degrees
Airfoil type	Supercritical
Flaps	Fixed-vane, double-slotted, simple-hinged
Horizontal tail	
Area	78,50 sq. m.
Span	19,81 m
Aspect ratio	5,0
Sweep	27 degrees

Table 1: C-17 Globemaster III Technical Specifications [4]

Basically, the aircraft that is going to be studied has conventional specifications. However, its scale is one of the biggest in the world. Both the wingspan and the length are around 50 meters. Meanwhile, its height is around the 16 meters. This design makes it viable to transport heavy cargo around the world, as well as troupes near battle areas. For cargo operations the C-17 requires a crew of three: pilot, copilot, and loadmaster. The cargo compartment is 88 feet (27 m) long by 18 feet (5.5 m) wide by 12 feet 4 inches (3.76 m) high. The cargo floor has rollers for palletized cargo but it can be flipped to provide a flat floor suitable for vehicles and other rolling stock. Figure 1 indicates the cargo dimensions of the Globemaster III:

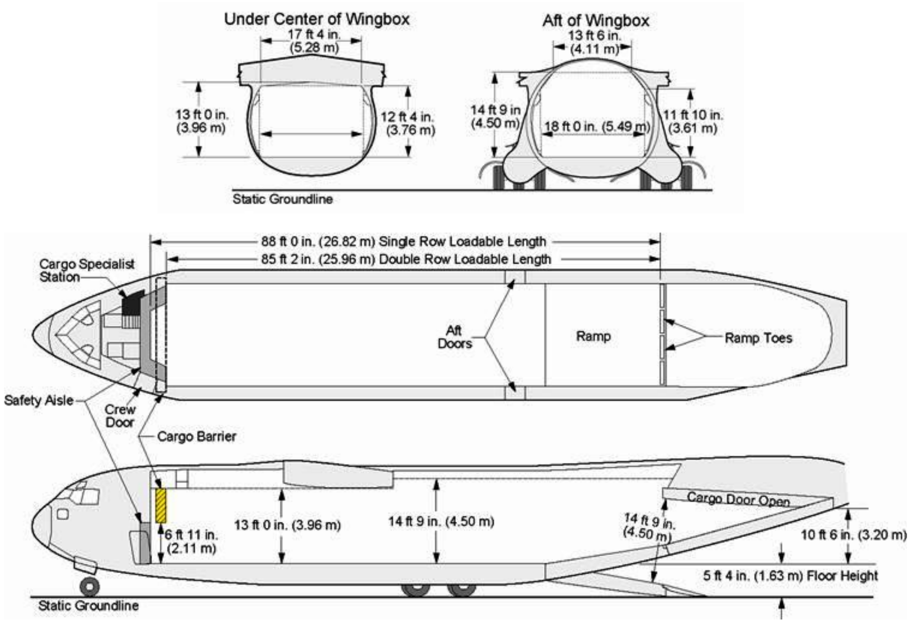

Figure 1: Boeing C-17 Globemaster III's cargo dimensions [1]

Figure 2: The United States Air Force's C-17 Globemaster III

As said in [2], the C-17 is powered by four Pratt Whitney F117-PW-100 turbofan engines, which are based on the commercial Pratt and Whitney

PW2040 used on the Boeing 757, each of them rated at 180kN of thrust. So these specification should satisfy the following performances that the Boeing Company [4] affirms:

- Take off from a 2359 meter airfield
- Carry a payload of up to 74797 kg
- Fly 6230 nautical miles with no payload
- Refuel while in flight in 914 meters or less on a small unpaved or paved airfield in day or night.
- Carry a cargo of wheeled U.S Army vehicles in two side-by-side rows, including the U.S Army's main battle tank, the M-1
- Drop a single 27216 kg payload, with sequential load drops of 49895 kg
- back up a 254 on the sidewall and 48 in the centerline

4.5 Actually operating C-17 Globemaster III

Currently, 274 C-17s operate around the world. The aircraft's largest customer is the United States Air Force, with 223 in 12 bases. Outside of that country, the United Kingdom, Australia, Canada, Kuwait, Qatar, the United Arab Emirates, India and the 12-nation Strategic Airlift Capability all operate the C-17 Globemaster III.

Figure 3: Qatar's C-17 Globemaster III

4.6 Structural research

Boeing has decided not to publish much information about the structural design of the C-17 Globemaster III. However, other sources of information can lead the study to an approximate design of the aircraft's "skeleton".

4.6.1 The fuselage's structure

The Globemaster III presents a semi-monocoque fuselage which allows a maximum profit of space to carry big elements such as tanks or trucks. Its structure is composed by approximately 74 formers which gives the final shape to the aircraft's skin. They are mounted parallel to each other and connected by longerons throughout the perimeter of the surface. There are also a few bulkheads which separates the different compartments of the aircraft and semi-bulkheads which support hydraulic systems, such as the pistons that open and close the back doors. In the following image, it can be observed how the formers are placed, the approximate distance between them and the incomplete formers that support the back door:

Figure 4: Image of the C-17's formers [2]

At the background of figure 4, it can be observed the bulkhead that separates the cargo compartment of the pilot's cockpit. From this element to the nose of the aircraft, the formers continue giving shape to the aircraft, however, they are considerably smaller and there is less space between them. This is because of the sudden change of diameter in the fuselage, so it is necessary to define the skins surface with more references. Also, the front part of the aircraft is separated in two floors, the lower one has the pilot's entrance and the second one contains the cockpit, as well as many electrical instruments and other devices or the landing gear's front wheel.

The fuselage's tail is assembled by smaller formers, longerons and stringers that diminish in diameter. The separation and the thickness of these formers is the same as the rest of the fuselage (despite the cockpit). As the formers are smaller but its thickness is constant, they are more rigid so that there are no structural problems to support both the horizontal and vertical stabilisers.

4.6.2 Wing's structure

The wing's structure is a complex issue to solve for the designers of the C-17 Globemaster III, as its super critical airfoil to minimize the aircraft's drag is directly affected to its structural design. To solve it, commonly used techniques have been applied: two I-shaped spars are constructed from the root to the wing's tip. Between them, approximately 30 ribs are separated in 3 sections: the leading edge, which is formed by the first quarter of the wing's ribs, and present mobile devices to move the front flaps. The second section, between both spars, is the thickest part of the ribs, and it is reinforced by stringers along the wing. Finally, the third section presents both mobile and static parts, depending on the point observed; if it is part of the rear flaps, there will not be any ribs giving shape to it, but a few structural elements are enough to support the impact of the air, however, the rest of static points follow the wings airfoil, which is detailed next:

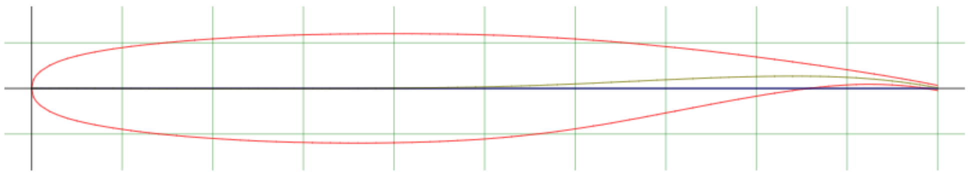

Figure 5: The C-17 wing's approximate airfoil: NASA SC(2)-0412 AIRFOIL [3]

The airfoil shown above is constant along the wing, with practically no torsion applied. Its c_l is 0,4, its c_{lmax} is around 1,5 and the wing's area is approximatly 353 m^2. The wing's root are placed at approximately 1/4 of the total length of the Globemaster. They are hold by uncompleted formers which have a small surfaces where the whole wing's structure relaxes.

Though its not an structural element, but aerodynamical feature to consider, the aircraft has winglets at the tip of the wings. Also, the wings' ribs have wholes in their section for different reasons such as: lighten up weight or communication between devices that work along the wings. Finally, the Boeing C17 is very characteristic because of its corpulent aspect at the wings' root, which reinforces characteristically the structure in that area of the aeroplane, which is probably the most delicate.

Apart from supporting the weight of the wings, the engines' weight has to be considered also. Their assembly to the the wings is very similar to the vertical stabiliser: ribs that cross between them to create the surface needed.

The 4 Pratt Whitney engines are held the same way, and the ribs are directly affected because an extra rib is placed on top of each engine to reinforce the structure.

Finally, at the trailing edge of the wings we can find flap hinge fairings to increase the streamlining in order to have a better performance while flying.

4.6.3 Stabilizer's structure

The T-tail structure presents a multi-spar and rib fin structure which gives shape to the vertical stabiliser. They cross themselves to result in a rigid structure that is then given aeronautical features by semicircular ribs placed on the vertical leading edge. This structure commented is separated in two parts: the fixed vertical stabiliser and the rudder, which its height follows the proportion of the tail and leads itself to the trailing edge.

Regarding the horizontal stabiliser, its structure design is very similar to the wing's design. Two H-shaped spares separate in three sections the approximately 19 ribs per side: the leading edge, the middle section where the airfoil thickness is higher, and the trailing edge, which is made by a third spar which allows its movement so that the aircraft has an elevator.

4.6.4 The C-17 Globemaster III cutaway

The information given in sections 4.6.1, 4.6.2 and 4.6.3 have been deduced from the cutaway sketch in [6] which is shown next and presents in detail the C-17 Globemaster III structure:

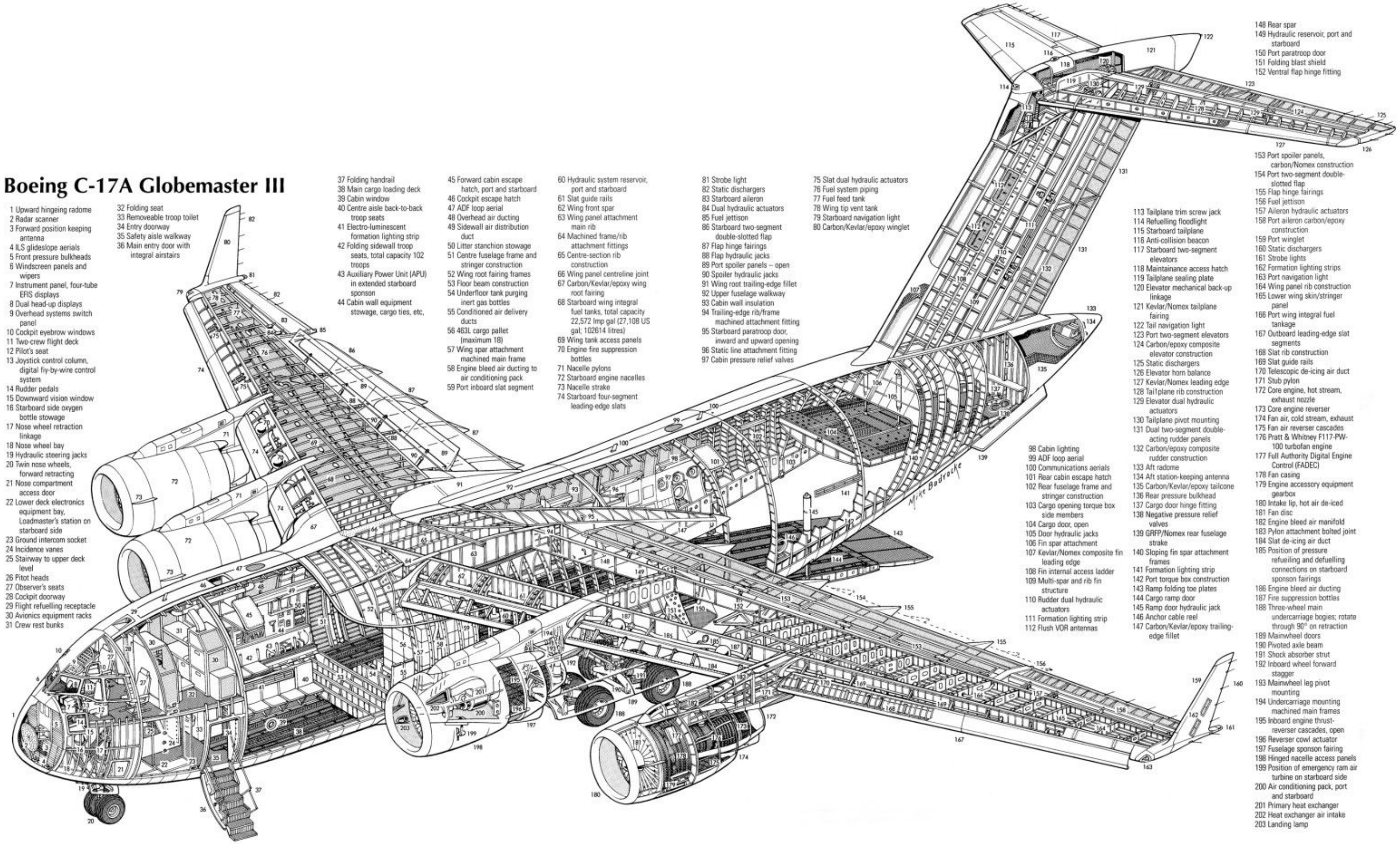

Figure 6: Boeing C-17 Globemaster III cutaway

5 CAD representation

This section will explain how the CAD representation has been developed and designed to later represent a 1:50 scale model of the aircraft. The creation of the 3D virtual model has been separated in four parts: fuselage, wings, vertical and horizontal stabiliser.

5.1 General dimensions

In order to start with the CAD representation, a template is needed to follow some of the key points of the aircraft. A research was done, and 3 very useful DXF files were found. They correspond to the three main views of the aircraft: top view, side view and front view. They were inserted in the SolidWorks assembly and they all shared the origin, which it was placed on the nose and represented the first point, starting from the front, of the Boeing. The following images represent the DXF imported:

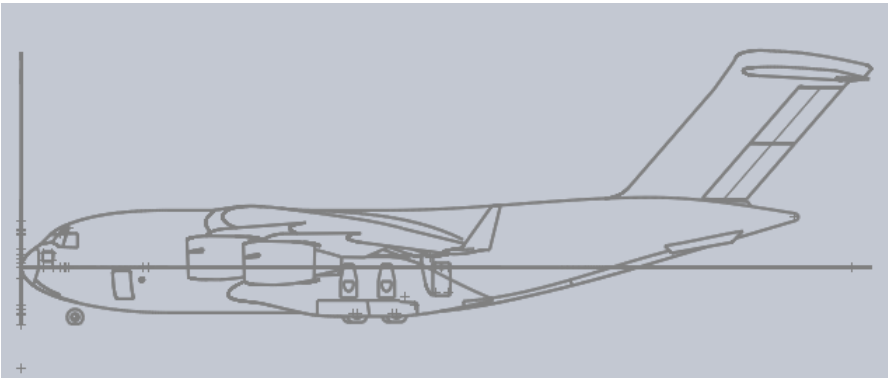

Figure 7: Imported DXF of the C-17's side-view

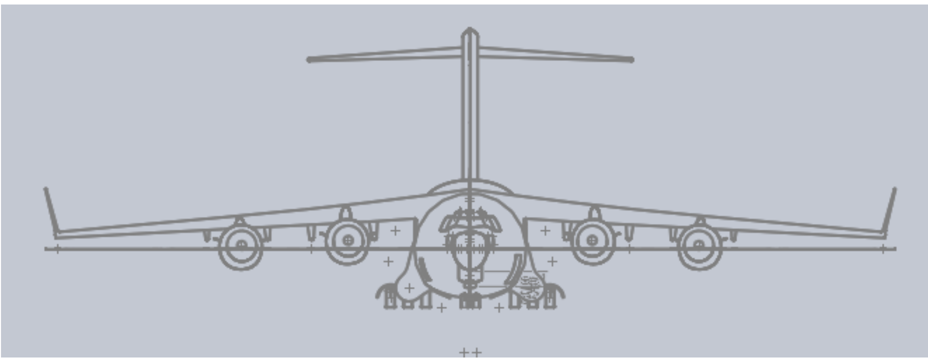

Figure 8: Imported DXF of the C-17's front-view

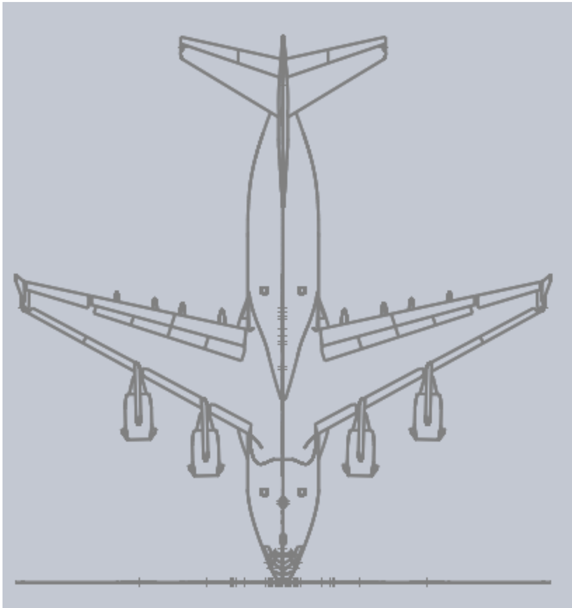

Figure 9: Imported DXF of the C-17's top-view

Images 7, 8 and 9 will be very helpful when positioning crucial points needed to represent the aircraft's structure in SolidWorks. After fixing this and having checked that the dimensions match with the ones detailed in 4, the CAD construction will be now developed in diferent parts: the horizontal stabiliser, the vertical stabiliser, the fuselage and the wings, so the breakdown will be resulting as follows:

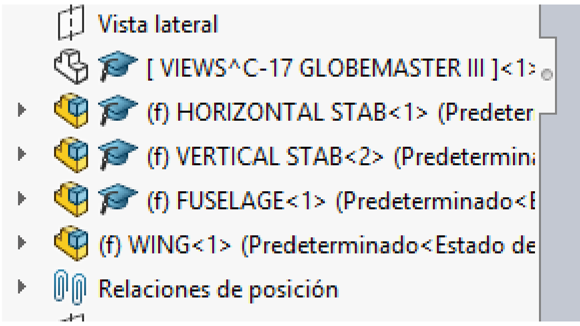

Figure 10: The CAD's model breakdown

Inside each assembly, the breakdown is separated in spars, ribs or other features represented in the model. These will be detailed in the following sections.

5.2 Representation of the horizontal stabiliser

The horizontal stabiliser presents two h-section beams with ribs in between, which gives the airfoil shape presented in the aircraft. To do that, the surface of the whole horizontal stabiliser was defined to have a template to work on. The surface was defined by both the tip's airfoil and the root airfoil, imported from [3]. Then, a covering was executed as follows:

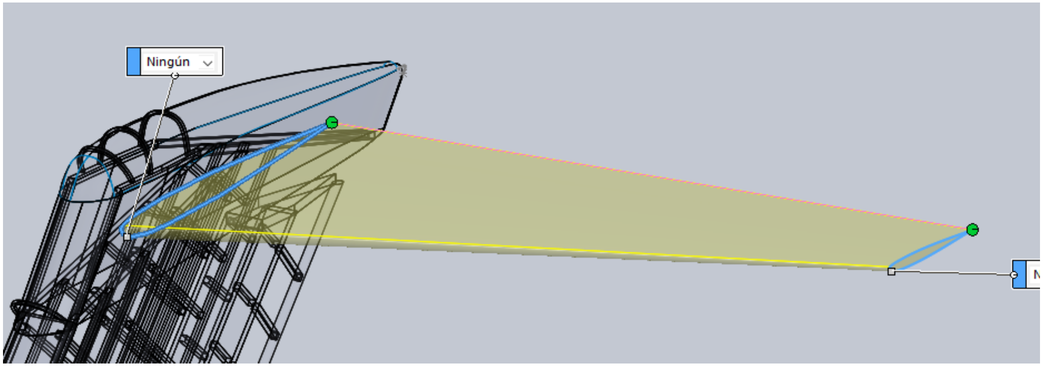

Figure 11: Construction of horizontal stabiliser's surface

Once the surface was defined, the H-shaped spars were defined. Bearing in mind that the model will be constructed from wooden plates, the H-shape will be assembled in 3 parts. It has been constructed as shown in

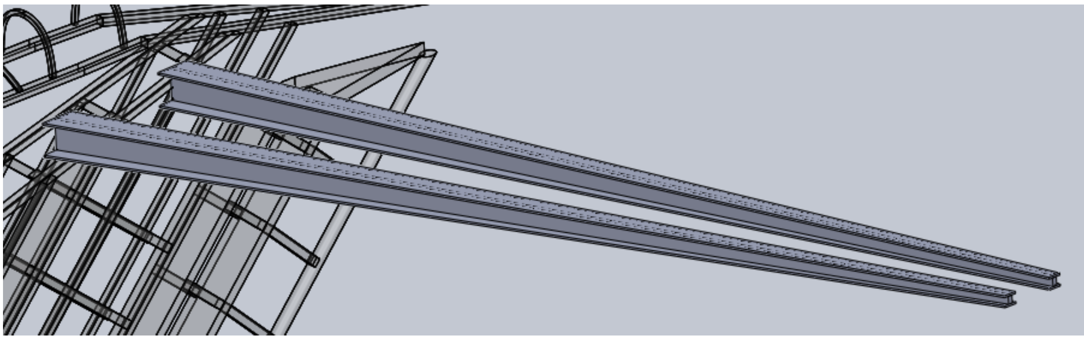

Figure 12: CAD construction of the horizontal stabiliser's spars

Once the spars are defined, the ribs were assembled one by one using as a template the stabiliser's surface. Finally, a third and fourth I-shaped spars have been designed to represent the elevator, also following the surface defined in 11. The result is shown next:

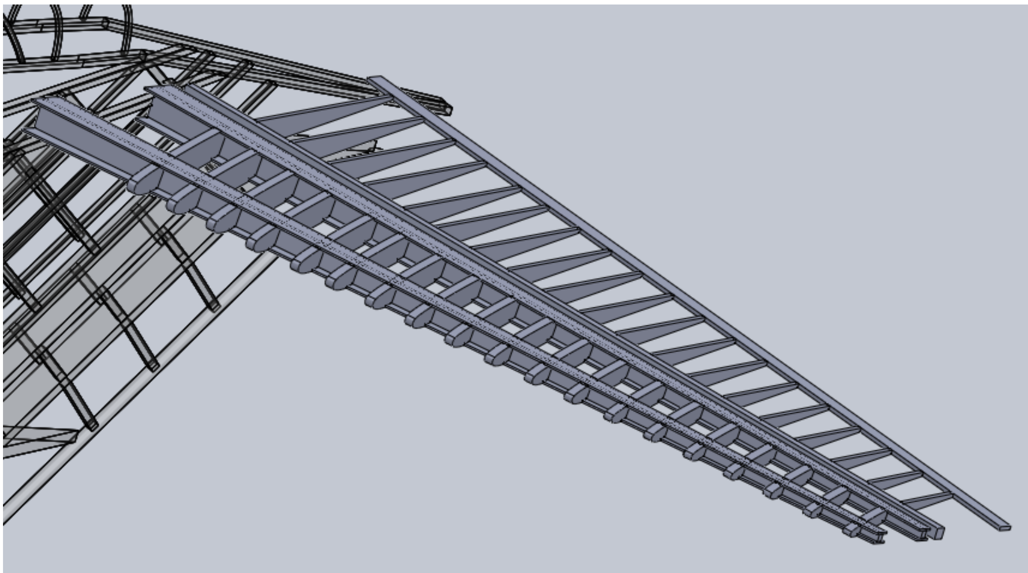

Figure 13: Completed horizontal stabiliser CAD model

The next step is the representation of the vertical stabiliser.

5.3 Representation of the vertical stabiliser

The steps to represent the vertical stabiliser are similar to the horizontal: a surface will be defined to be used as a template to construct the internal structure. Again, the DXF imported from [7] has been used to define the position of it:

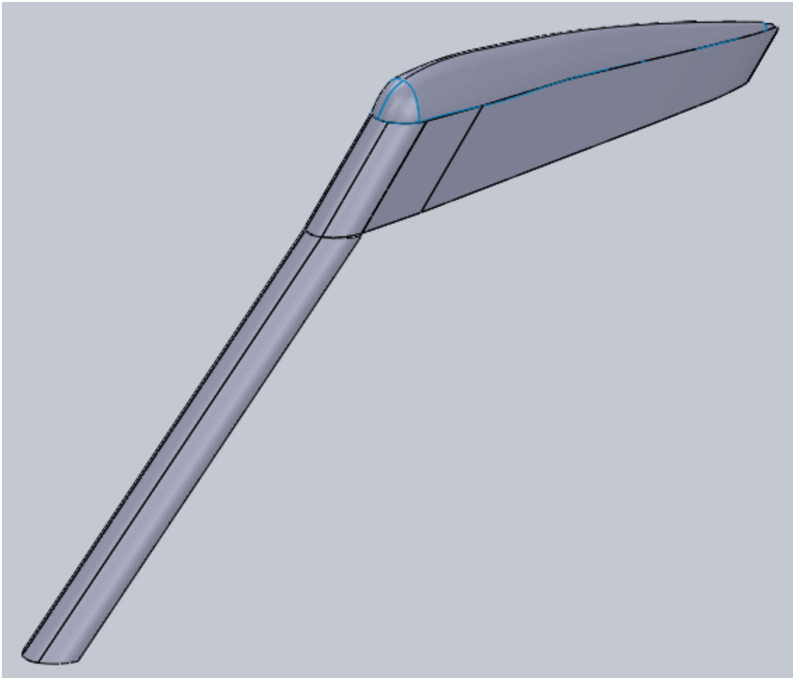

Figure 14: Vertical stabiliser's surface

Once again, the surface will help to define the structural features that assemble the vertical stabiliser. Again, the rudder will be fixed by a hinge in the scale model. The following result has been achieved:

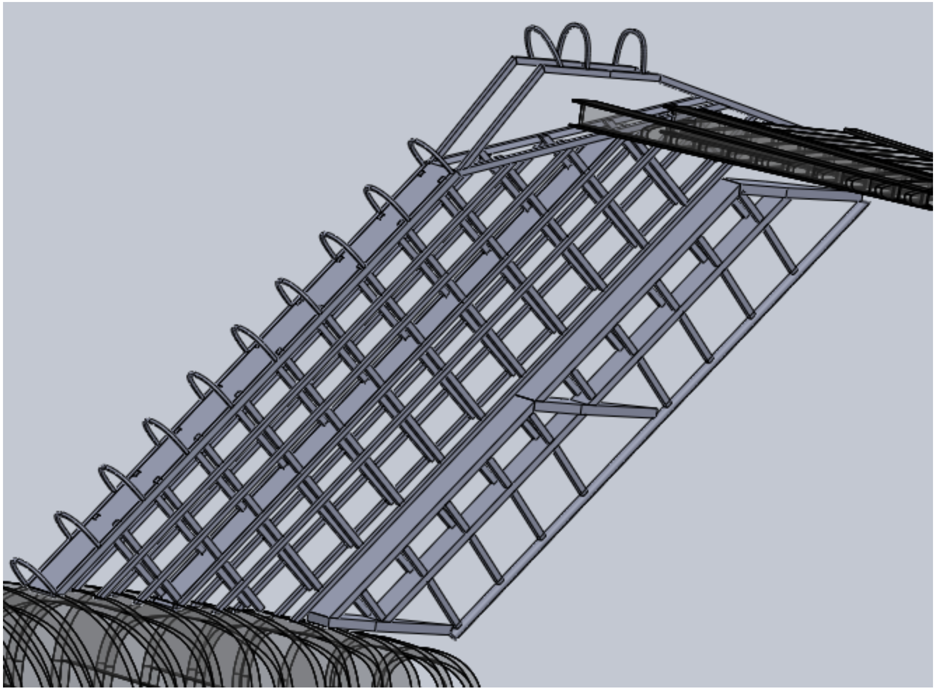

Figure 15: Result of the vertical stabiliser CAD

As it is shown in 15, the vertical stabiliser is formed by two inclined walls connected by crossed stringers along the surface defined in 14. To complete the circular features of it, semicircular ribs have been assembled throughout the front wall. The superior part of the vertical stabiliser follows the shape of the surface, which presents a convergence at the trailing edge. As it can be observed, the fixed part of the vertical stabiliser is sustained on top of the rear formers of the C-17.

5.4 Representation of the wings

The wings were represented following the same steps than 5.2 and 5.3: a surface was defined importing the wing's airfoil from [7] and defining the spars and ribs that form it. However, the root of it had to be adjusted to the affected formers of the fuselage, which will be detailed in 5.5.

In this case, the flaps and slats that form the wing of the C-17 don't present ribs, as the skin defines its shape. The following figure shows the result of the wing's CAD representation:

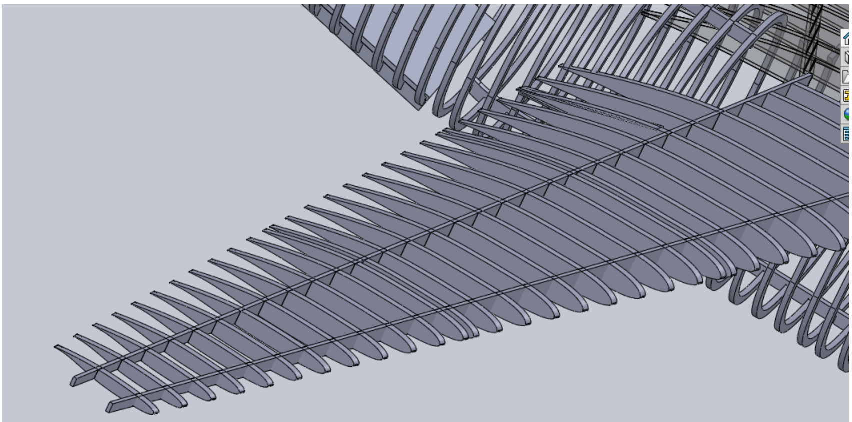

Figure 16: Result of the wing's CAD

Figure 16 shows that the ribs have been divided in 3 solids separated by the two I-shaped spars. It can also been observed two double spars that present structural strength to support the motor's weight. In the boarding edge of the wing, most part of it is formed by the flaps and the slats, so this section will not present ribs, it will be formed by a few bars which define its shape.

5.5 Representation of the fuselage

Finaly, the fuselage will assemble the rest of the C-17 Globemaster III. Its CAD representation has been the most laborious, as it has to follow the limits defined by the DXF imported from [7] and has to adjust to the rest of elements constructed before.

The nose of the aircraft has been designed leaving a space that represents the cockpit's front window, as well as a side space to represent the entrance door. Following this, the formers that suppost the wings don't present the top part of it, though they have a base for the wings to lay on. The rear formers will adapt the cargo entrance doors, which have an opposite direction movement to use the maximum space possible. To do this, the formers will not complete the circle at the lower space. The following figures show in detail:

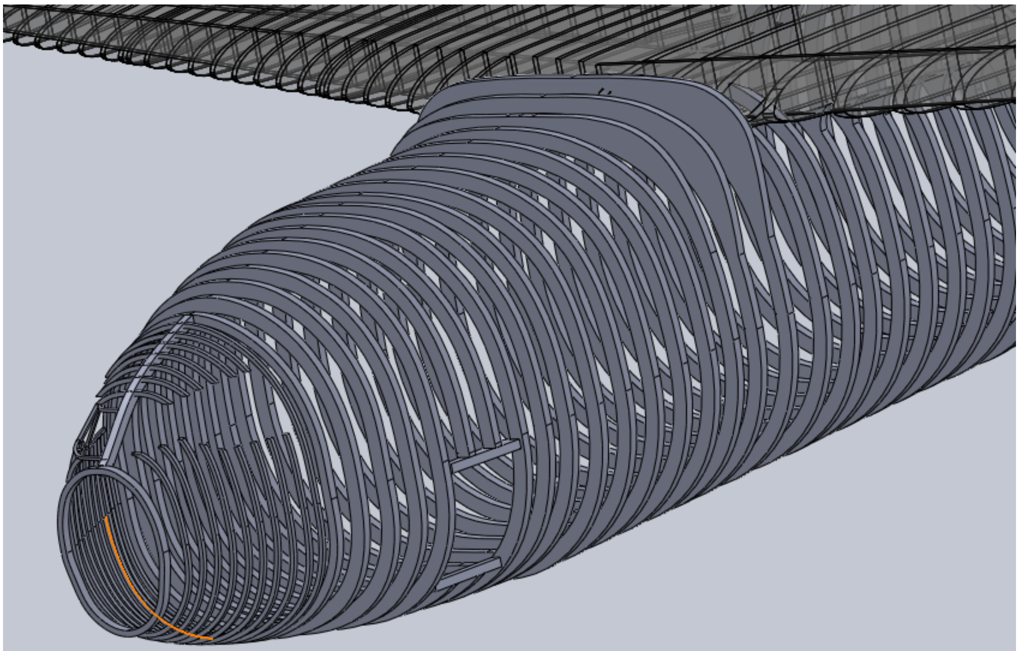

Figure 17: CAD representation of the fuselage (1)

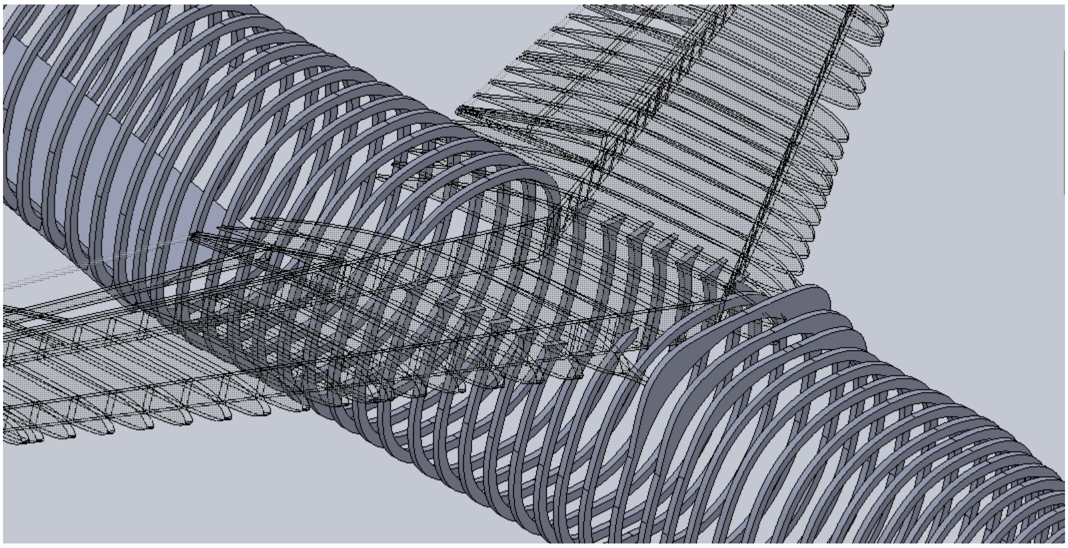

Figure 18: CAD representation of the fuselage (2)

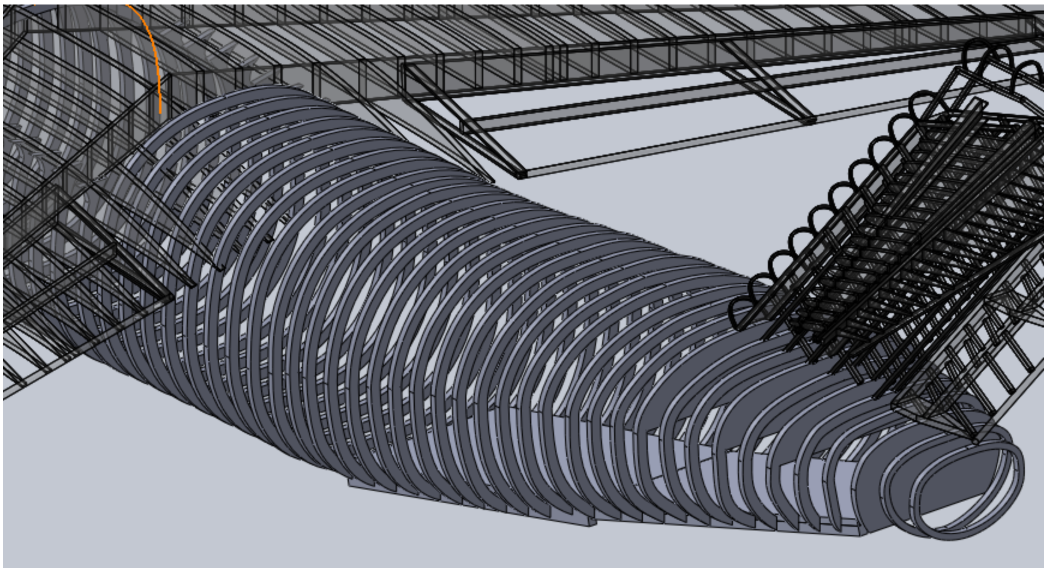

Figure 19: CAD representation of the fuselage (3)

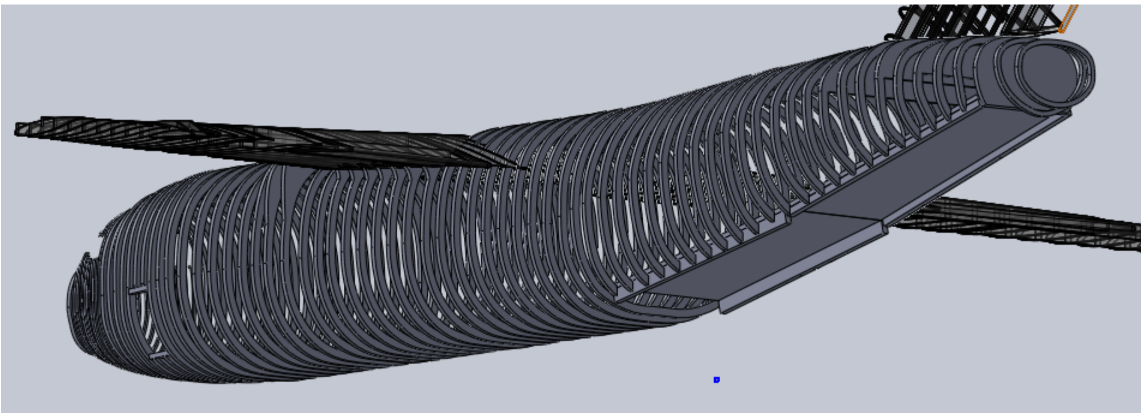

Figure 20: CAD representation of the fuselage (4)

As it can be observed, once the formers reach the wings, their shape changes. This is because the wing's front spar is placed higher than the formers, so the fuselage has to adapt its shape so that the current is not suddenly disturbed. Once the wings are over, the formers that go behind follow a matrix (they are all the same repetitive piece) until the back doors appear. From here to the back of the fuselage, the diameter of the former diminish to converge to the tail, once completed the approximately 50 meters.

The fuselage was the most laborious part to assemble. The different reference points regarding the formers were taken from the DXF imported from [7]. However, if there was a small mistake that moved all the other formers, many errors appeared and they had to be corrected one by one, so it took a lot of time.

6 Exportation of the draws and provider

After the first contact with the project's director, a very attractive way of constructing the 1:50 scale model was throughout wooden laser cut pieces. Its precision will help to develop the model in an easier way, as many pieces can fit in together without problem, as well as its resistance to possible deformations. To do that, it is necessary to export each piece into draws at the appropriate scale.

Parallel to this, a research of possible providers has to be made and it will directly affect the way of exporting each piece into its draw. Whats more, each laser-cutting company has its material or specific machine with limitations that also will affect the final model.

6.1 Exportation of the pieces

Firstly, to represent each piece into its draw, it has be reduced 50 times in order to accomplish the mentioned scale. To do that, all pieces have been named and reduced individually to $\frac{1}{5} = 0,02$ times smaller. This requires a new configuration for each piece in SolidWorks, which will be the one represented in the draws exported after.

Secondly, an appropriate view of the piece is performed so that it is then represented parallel to its extrusion direction, as the laser cut will incise perpendicularly to the wooden plane.

6.2 Provider research

The general research of the provider has been done throughout the Internet. The first filter applied was its location: to speed up the process and save time invested in transport, the provider had to be in the city of Barcelona. A total of 4 providers will be compared in quality service and price to choose the most attractive one.

Table 6.2 shows a comparison of the contacted companies in the city of Barcelona:

Company name	Location	Material available (thickness)	Price
BUIT TALLER (LASER/CNC) [8]	C/Llibertat, Barcelona	Many types of wood (1 - 3 mm)	35€/h
WE CAN CUT [9]	C/Pallars, Barcelona	Wooden plates (1 - 5 mm)	25€/h
VERDIAL [10]	Les Corts , Barcelona	Wooden plates (not specified)	25€/h
LASER PROJECT [11]	C/Camino de la Riereta 33	Wooden plates (not specified)	30€/h

Table 2: Comparison of wooden laser cut providers

6.3 Provider's requirements

As commented in 6.2, *We Can Cut* [9] is the provider that will deliver the pieces needed. In this section, it will be detailed step by step how the material was achieved.

First of all, the DWG template that *We Can Cut* is posted in their web page was downloaded to fulfil it with the draws. This template defines the wooden plate dimensions, different pages for each thickness and the following layers:

- no impression
- commentaries
- exterior cut
- strong engraving
- weak engraving
- engraving
- interior cut

Figure 21: SolidWorks' list of layers imported form *We Can Cut*'s template

However, the ones used were interior and exterior cut. The dimensions fixed by the provider, for both 2 and 3 mm thick, which were the final thicknesses used, were 970x620 mm, which corresponds to the dimensions of the laser cut machine.

Once the pieces were placed in the templates, it was realised that the formers could be filled with smaller pieces to save up materials, such as the wing or horizontal stabiliser's ribs. In addition, the formers that support the wings are opened at the top can be placed alternatively to save material, as it is shown in 22.

Once the draws are ready, they are sent via e-mail in *DWG* format so that they can manage it without problems when importing it to the laser cut machine's software. Once sent, they indicated that in one day time the material would be ready, so the service was much better than expected. However, once the material was ready, they indicated that the 2mm plate was, because of an error, made with a 2,5mm plate instead. This would directly affect those pieces which were small and required a lot of precision, such as the horizontal stabiliser.

6.4 Final draws

In this section, the process followed to realise the final draws before sending it to the provider, as detailed in 6.3, will be described.

All pieces developed in the CAD representation of the C-17 Globemaster III were scaled as indicated in 6.1 and placed in the templates. The most important and delicate step was to choose the appropriate position for the cutting of the pieces, as the view had to be the absolute figure, so that there are no proportional errors because of a wrong perspective.

As a result, three 970x620x3 mm and one 970x620x2 mm wooden plates were needed to have all the pieces detailed. An example of a 3 mm thickness plate is shown next:

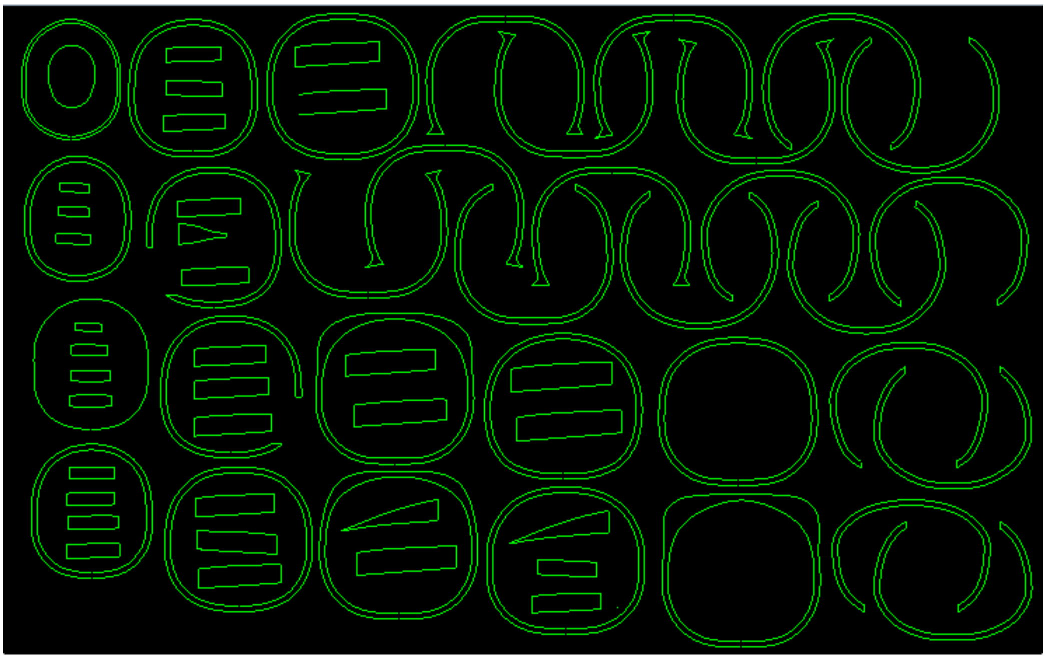

Figure 22: Exported DWG for the provider's operation

22 is an example of one of the 3mm wooden plates sent to *We Can Cut* to realise the pieces. In this case, they will cut some of the formers and the middle wing ribs. On the other hand, the 2mm plate presented an error: the provider accidentally delivered a 2.5mm thickness plate. The difference is not that big, but some pieces have been modified "in situ" in order to fit with the rest.

7 Construction of the scale model

Once the material was received, the model could be constructed. To do it, different materials were needed in order to construct the model:

- Glue for wood models
- Different thickness files
- Scissors
- Cutter
- Masking tape
- Diary paper
- Cello tape

Once everything was prepared, all the pieces received from *We Can Cut* were identify for two reasons: to check that the provider has cut every piece ordered and to make it easier to find them when assembling.

In the following sections, the different parts of the Boeing will be described regarding the model, supporting its explanation by images.

7.1 Horizontal stabiliser scale model

The horizontal stabiliser is a really delicate part to assembly because of its dimensions. First of all, the spars were marked with a pencil to indicate the position of each rib. They fixed in the work place respecting the angle between them and their relative position so that all the ribs could then be stick. The third spar was then assembled with the third section of the ribs (the trailing edge).

Finally, the H-shape of the spars were assembled after filing the horizontal spars so that the stabilisers' airfoil surface had a smooth result with no alterations in its shape. The following image shows the final horizontal stabiliser:

Figure 23: The model's horizontal stabiliser

As it can be observed, the elevator has been assembled with three small pieces of elastic rubber to create a dynamisation of its movement. Although the rubber does not follow the airfoil's surface, it creates a very interesting aspect in the model, which allows the people who looks at it observe the movement of such an important aeronautical element. It can also be observed the different thicknesses of the vertical part and the horizontal part of the H-section beam. This is because of an error of the provider that will be explained in the conclusions of this final degree project.

7.2 Vertical stabiliser scale model

The vertical stabiliser had two key pieces that facilitated its construction: the two solid ladders, as described in [6], that had small wholes to place the different ribs. That helped to maintain them in the final position while the glue dries itself. The rest of the ribs were placed as shown in figure 15. Some problems appeared when assembling the top part of the vertical stabiliser, which was made of three sticks on each side without any crossing element that could reinforced it, so constantly their position had to be corrected.

Finally, once the ribs were placed, the semicircular sections of the leading edge were stuck, so a clear idea of the final surface is easy to acquire. Some corrections had to be made so that the lower part of the ribs ended up at the correct point so that there would be no problems of unsymmetrical result.

Until now, the fixed part of the vertical stabiliser is completed. However, the same method as the elevator will be used for the rudder: again elastic rubber will assemble the rudder so that a small characterisation of its movement can be observed. The rudder is made by a solid rib at the front with small wholes that allow the other ribs to follow the desired direction, and two more solid ribs at the middle of the rudder, separated by horizontal ribs that reinforce the aeronautical shape needed. The following image shows the complete vertical stabiliser while the glue in the rubbers was drying:

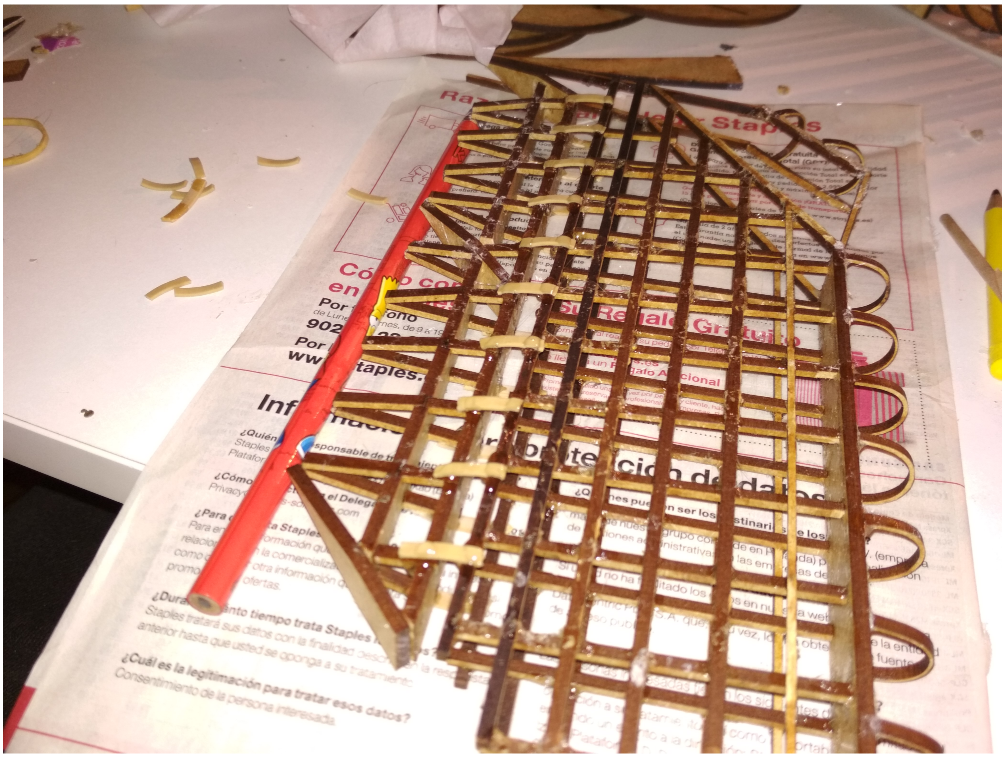

Figure 24: The model's vertical stabiliser

Although the CAD representation gives a very precise measure of each piece, when sticking them together, there can be some imprecise results. That's why some pieces have been adjusted depending on the assembly with the files. As a result, the adjusted pieces have chamfers such as the following image:

Figure 25: Realization of a chamfer to adjust the vertical stabiliser

Other examples of pieces that have been adjusted are the one shown in 25 so that the ribs entered the teeth in it, the small pieces that represent the border of the cockpit's window or the half-formers that held the wings' root.

7.3 The wing's scale model

The wing follows the same method as the horizontal stabiliser in section 7.1 despite the fact that the wing has I-shaped spars. The structure that holds the motors will not be included to simplify the model.

The difficult aspect when constructing the wings was to keep the ribs parallel between them because of the imprecise tools used. However, both ribs were marked in pencil to know exactly where the ribs are positioned. Also, the sweep angle was measured to maintain the relations indicated in the CAD model. The following image represents the 1:50 scale model of the wings.

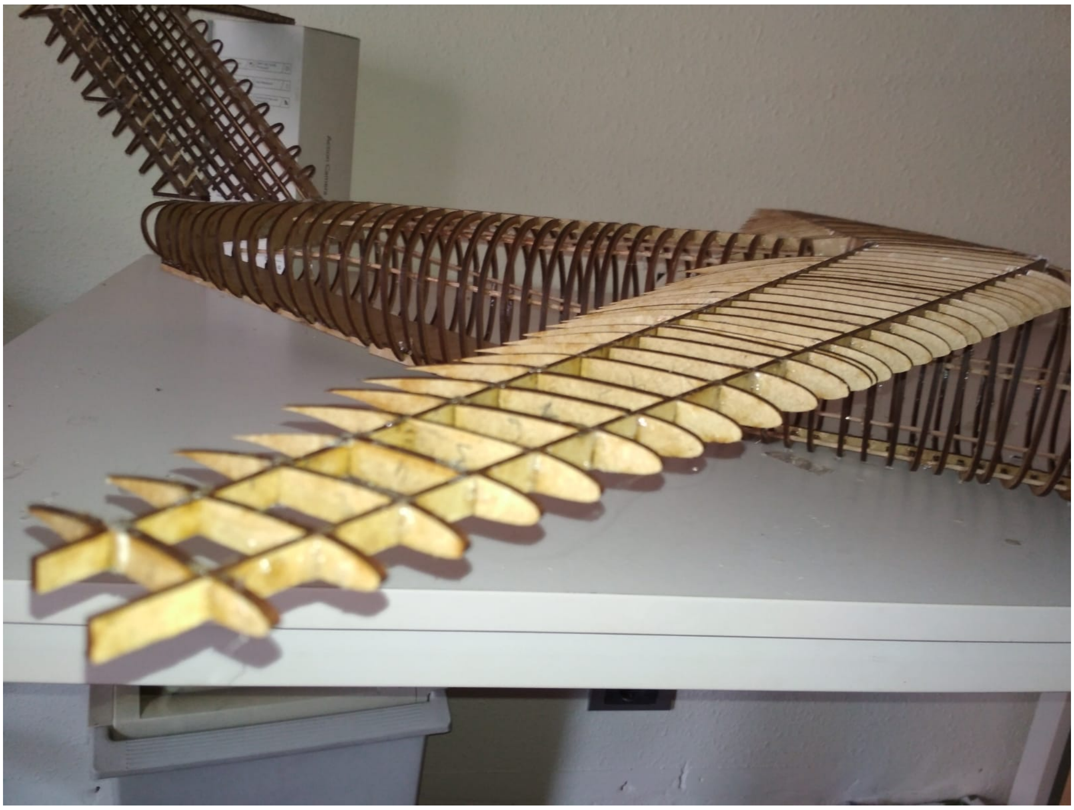

Figure 26: Photograph of the model's wings

When assembling the trailing edge parts of the wings, it was very important to maintain directions of all the ribs as it is described in the cutaway. In this case, the whole wing will be represented static in order to have a smooth surface line to follow. However, this is a problem because the flap's structure is much lighter than all the trailing edge ribs that are going to be placed. This should be something to improve.

When assembling the wings to the fuselage, it will be difficult to maintain them in position because of their high weight and the low resistance of the glue used. However, once they are placed, they will follow the CAD representation described in section 5 except for one thing: a wooden plate placed in the root. This will be detailed in 7.5.

7.4 The fuselage's scale model

The fuselage scale model was a difficult part to assembly. The first idea was to put together all the formers with wooden sticks that had a diameter of 3mm each. Some tests were made before assembling the final pieces with spare parts that were also ordered to *We Can Cut*. The idea was to use as the longerons these circular sticks, but it was very difficult to maintain the desired shape while the glue got dry.

So a solution had to be developed. As mentioned in section 7.2, the small wholes cut in the "ladders" helped to position each rib in the correct place, so the solution was found. To maintain in a fixed position the formers of the fuselage, structural "tooth-shaped" longerons were used to position each former in its place. Once this was done, the success of the idea should have been applied to other features of the model such as the horizontal stabiliser or the wings, in order to have a perfect parallelism between the ribs and the same distance between them. For future projects, it should be something to consider.

First of all, the cockpit was assembled. To do that, the solid former that ends up the cockpit was placed horizontally in the work space. Then, the cockpit's floor was stuck to it, having before taken the necessary measures to have it in the correct position. After that, both the top and bottom "toothed" longerons were placed, so that the formers placed next could rest in the correct position while the glue dries itself.

After having placed the formers, the pieces that give shape to the cockpits ceiling were placed carefully to avoid damaging the model. The following image represents the constructed part of the fuselage until this moment:

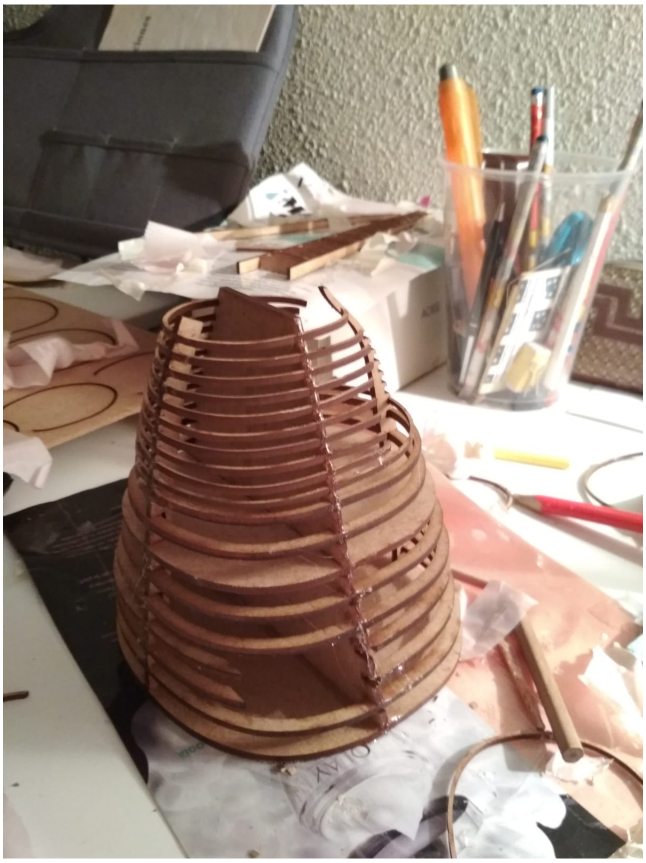

Figure 27: The cockpit's model

Once the front part of the aircraft was completed, the fuselage assembly was continued in the same way, despite the fact that it had to be assembled with the formers in the final position because their weight didn't permit to rest while the glue was drying. However, the teeth in the top and bottom longerons helped the model to maintain itself. The important fact here was to place each piece in the correct position so that there is a clear visualisation of the Globemaster's surface.

The fuselage was constructed depending on the longeroons with "teeth". These end up when a solid former comes up, as it would be difficult to represent it with a non stoppable longeron. So the rest of the fuselage was assembled one part behind the other, as shown in the next images:

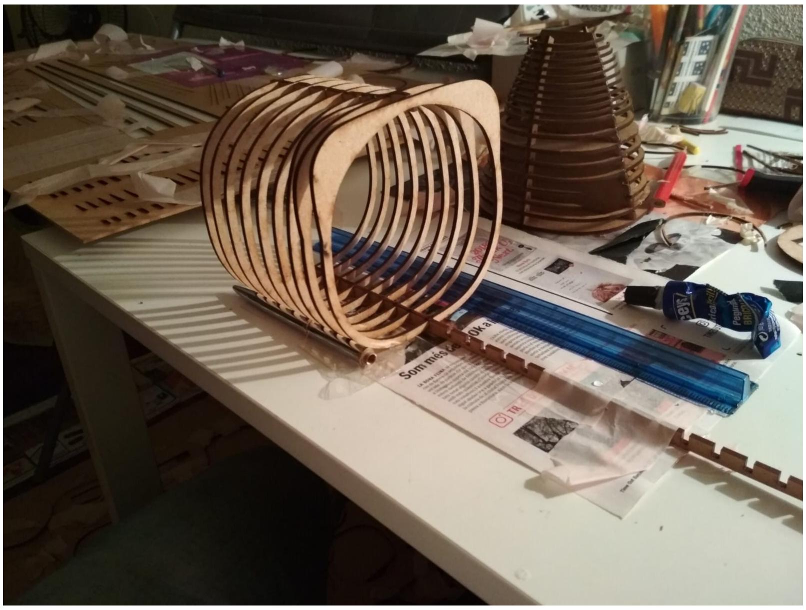

Figure 28: The fuselage's model (1)

Figure 29: The fuselage's model (2)

Figure 30: The fuselage's model (3)

As mentioned in 4, the fuselage is shaped by longerons that cross the entire body of the Globemaster. To represent that, a total of 6 longerons throughout the fuselage were placed. These were not cut at *We Can Cut*, but 200 3mm diameter wooden sticks were bought from *Amazon* [12]. They were also helpful when small pieces had to be stuck together, as human fingers can sometimes have difficulties with such pieces.

The cockpit's front window had to be made as well, as detailed in the CAD model. To do that, small rectangular pieces were cut and placed together to define the border of the window. This is shown in the next image:

Figure 31: The cockpit's window

Finally, the back door was also ordered to the provider for cutting. It consists on two rectangular plates with two sticks on each side from front to back. They are then placed in the last formers which have the bottom part opened and measured so that the door does not have any problem to fit in. In terms of the model, it gives a structural strength to move up the rear part of the fusealge which, as the DXF imported from [7] indicate.

Figure 32: The back door from the inside

7.5 The aircraft's complete assembly

The parts mentioned above are all the necessary components to construct the final model. To do that, many daily objects have been used to support the pieces while the glue got dried.

Regarding the vertical stabiliser, its weight was enough light to be supported by the rear part of the fuselage and its displaced gravity of center was not affected by the strength of the glue. However, the horizontal stabiliser could not be supported by the glue, so a rectangular piece of wood was placed in between both parts so that it could be maintained. As mentioned before, a very effective way of solving this could have been with teeth were the different pieces could be inserted and presenting a structural strength by means of the glue and the pressure between the pieces.

A similar situation was presented when assembling the wings. The half-formers below them could not support the weight of the wings, so a wooden plate was placed below to give some support to it. This means adding some weight to the model, but structurally speaking, everything was under control.

Finally, the model is completed. The photographs presented next represents the whole assembly, which is the result of the research made regarding the C-17 Globemaster III, a CAD representation with an exportation of the piece's draws and finally, the construction of the CAD model:

Figure 33: The complete scale model of the C-17 Globemaster III

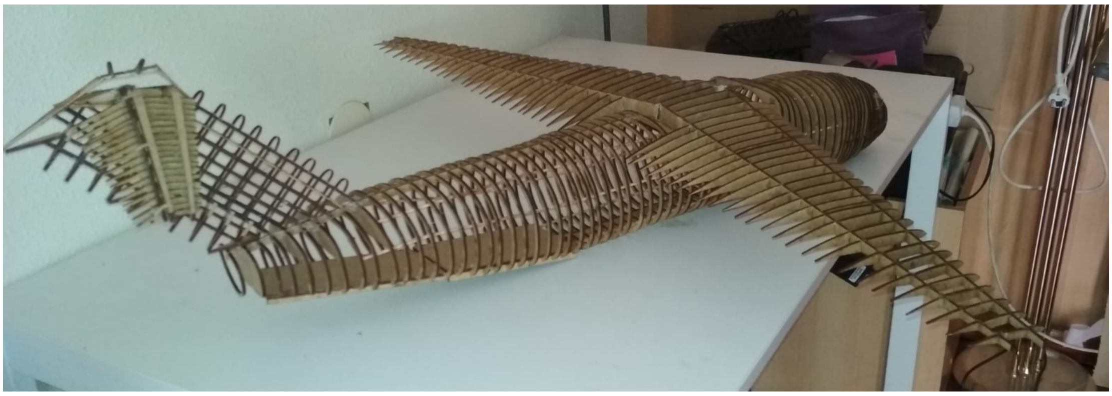

Figure 34: The complete scale model from behind

The following images represent the final dimensions of the scale model. As specified in section 8.2, the total length is 53m and the wingspan 51.77m, so in the scale model it will be 1.06m of length and 1.035m of wingspan.

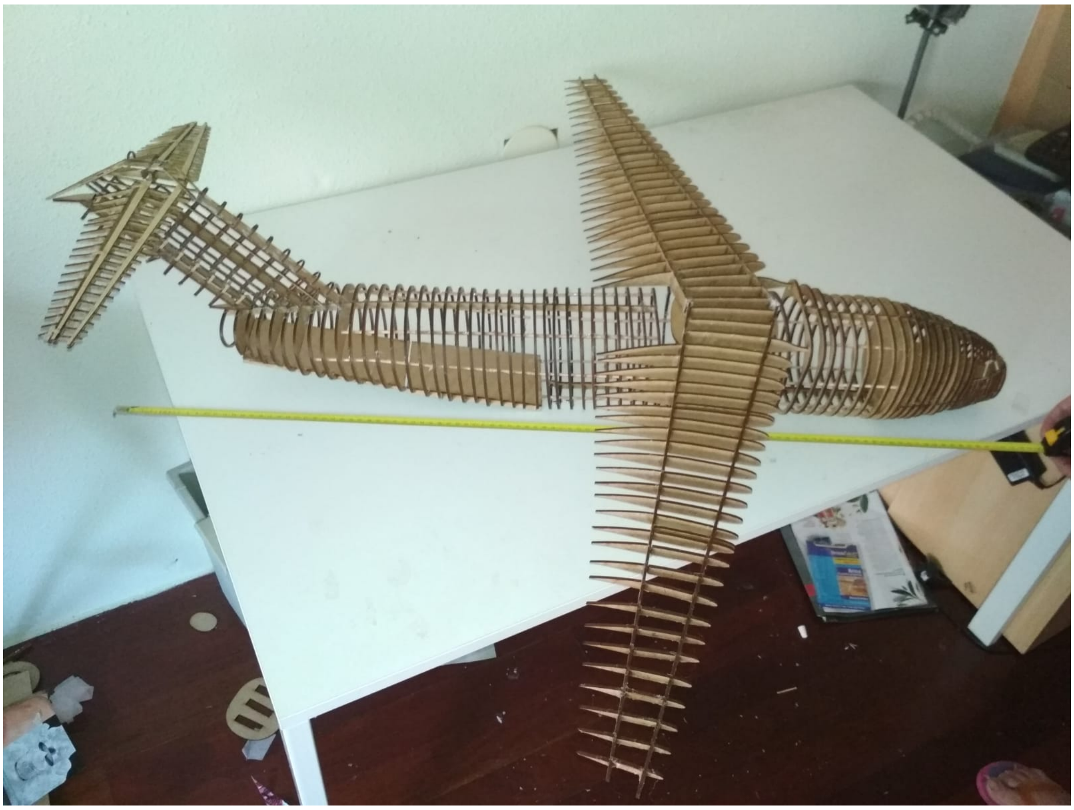

Figure 35: The scale model next to the measuring tape

Figure 36: The scale model's total length

Figure 37: The scale model's wingspan nest to the measuring tape

Figure 38: The scale model wingspan length

As a result, the scale model has the features that have been described and the dimensions that should satisfy, so the reproduction can be considered successful.

8 Economical analysis

This 3th section will describe the economical aspects of the design and construction of the Boeign C-17 Globemaster III 1:50 scale model.

The economical aspects will not only include the price of the materials and tools used, but also the hours dedicated to construct the model, as well as an approximate estimation of the hours dedicated to the CAD representation, so if anytime it is necessary to realise a similar project, there will be an economical guide to develop it.

8.1 Material list, price and time

In this subsection, an economical summary of the materials will be presented. The next table indicates the price of each element used:

Element	Price
Software: SolidWorks	UPC's student license
Wooden pieces	140 €
Glue	6 x 2,35 = 14,1 €
3mm diameter sticks	2 x 8 = 16 €
Transport	10 €
Total price	180,10 €

Table 3: Boeing C-17 Globemaster III model's economical analysis

Table 3 indicates that the software used was proportioned by the university ESEIAAT in order to develop the CAD representation and the exportation of the pieces to the draws. On the other hand, the material ordered and the tools had to be payed as it is shown next.

As it can be observed, the wooden pieces are not that cheap. However, the final price is also affected by the time spent to create the model, as detailed next.

8.2 Time dedicated

In this section, the hours invested to create the CAD model and the scale model are shown in the next table:

Task	Hours
CAD representation	80 hours
Scale model	65 hours
Total	145 hours

Table 4: Boeing C-17 Globemaster III model's economical analysis (2)

In 4, a total of 145 hours have been dedicated to the construction of the CAD representation and the scale model. These numbers are the ones which, in case of selling the scale model, they delimit a price depending on the €/hour indicated. The rest of the hours that are not specified, correspond to the research of information about the C-17 Globemaster III and the written down report.

9 Environmental impact analysis

This final degree project has had an environmental impact since it was started. However, there was also a practical construction that also has to be analysed to know its impact to the environment.

As commented in section 3, there has been a total amount of 80 hours of development of the CAD representation. This means that during 80 hours, there has been an approximate consumption of 220W, so this means that there has been a total intake of energy of 17.6kWh (without including the light used at that moment).

Regarding the spare material, there has been a total amount of 4kg. However, this is an organic material that doesn't have an important impact on the environment. However, the glue used yes it does, so this affects negatively. A total amount of 6 pots of glue have been used, this means that there has been an impact.

Adding to this, it is also important the environmental impact of the laser machine. A laser cut machine used for cutting wood uses around 1500W at maximum power. As the price of the wooden pieces has been 140 and the price is 25€/h, so the machine has been working a total amount of 5,6 hours. So 1500 x 5,6 = 8.4kWh have been consumed. If we sum this to the power consumed using the computer, a total amount of 26kWh have been consumed.

However, this amount of power used will not increase anymore. It has to be bared in mind that it is the first time that a model like this is done, so from now on, the amount of energy or chemical elements that have an environmental impact will diminish.

The idea for a future project is to construct a model that has the minimum amount of glue, so that will be an argument to qualify the project as sustainable project.

10 Comparison with the project charter

The project charter delivered at the beginning of this semester has been compared to what have happened. In this section, a comparison between the Gantt diagram and the points detailed in the project charter will be compared to the final process followed throughout the project.

The following image represents the Gantt diagram detailed in the project charter:

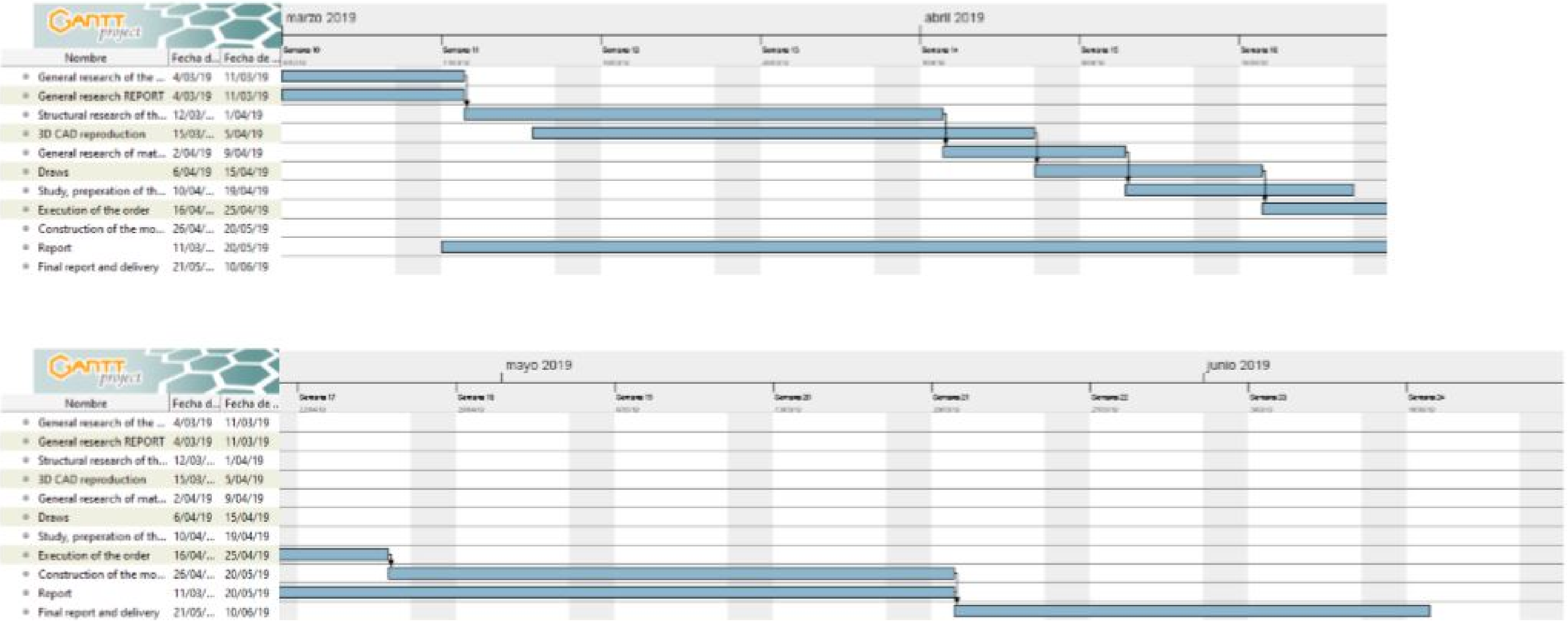

Figure 39: The Gantt diagram detailed in the project charter

The first tasks detailed in the Gantt diagram have followed the timeline. As the diagram indicates, around the second or third week of April, the CAD representation was completed and the draws were exported. A few days later, the material was ordered to *We Can Cut* and the problems started coming up. Theoretically, the next step was to construct the model, and it went like this, until it was realised that it was impossible to construct the fuselage only with rounded sticks. Any former that was stuck wasn't parallel to the one it had next because of imprecise tools to work with. So the Gantt project couldn't be followed as planned. Again, the tasks returned to SolidWorks and longerons with teeth which couple with the formers were asked to *We Can Cut* to be cut.

The provider had the material ready in a few hours, so that helped not to delay much the planning done. However, the 2,5mm thickness mistake also affected the construction of the model. Some pieces had to be filed and adjusted to the whole assembly. So the scale model was finished around the 30^{th} of May.

Regarding the construction of the report, it has been done along the semester parallel to the research, CAD representation or the construction of the model. The report was finished on the 8^{th} of June, and some corrections were made during the two days after.

11 Conclusions

To conclude this final degree project, it is necessary to say that having experience on modelling could have made it much easier to develop, as well as taking advantage of the time limitations. However, personally speaking, the result is what it was expected, despite of some facts that will be commented next.

Regarding the research of the aircraft, it is a pity that there is not much information about the techniques used in the C-17 Globemaster III and that the main source of information has come out from Mike Badrocke's book [6]. But the information has to be developed, so starting from this cutaway and adding aeronautical and structural knowledge, a final design could be made. An important fact to be considered was to simplify the information compiled, however, it will be really interesting to take profit from it and continue adding features and details to the model. All projects can be continued, and this is the case.

Regarding the CAD representation, it has been a head ake to create the assembly, also, because of lack of experience. The simplest operations in SolidWorks were no problem, but designing a model from 3 views and relationships between all pieces have result in many conflict problems. They finally were solved. It would also have been very interesting to create interior pieces with much more detail, but time had its limits and it could not be possible.

After the CAD model, another head ake appeared: exporting the pieces. A total of approximately 500 pieces have been represented in a draw so that it could be cut. A lot of revision was required to avoid forgetting any piece, as it was an easy mistake to realise. This task was really repetitive: scaling all pieces, importing them to the draw, hide all the not necessary lines and place the pieces to profit the maximum material possible. This task was difficult because of its repeatability. I am sure that there is a way in SolidWorks to do it automatically throughout some type of "macro". But the complexity of some of the pieces and the way of choosing the correct point of view is not that easy for the computer to do it by itself, so a big programming should have been done and it could be a solution in case that this projects wants to be continued.

We Can Cut has been a very serious and responsible provider which hasn't presented any problem despite of one: they cut at 2.5mm by error, when

I needed 2mm thick. This supposed many changes of pieces that did not couple correctly to the others. Most of them were solved, though. But this has affected on weight in some delicate points. There were two important facts with the provider that should be bared in mind for future orders and deliveries:

- First of all, the little amount of time needed for them to deliver my order
- Secondly, the proximity, as it was in the city of Barcelona

These are very important factors to consider in the case something has to be manufactured and some pieces are delivered by an outsourced company.

Regarding the model, many problems have appeared when assembling the different pieces. This is not favourable because of the time invested on solving them. However, they are necessary to have them in mind for future projects. Also, as commented before, it is really useful and helpful to couple pieces with each other instead of sticking them. It ensures that the pieces are placed correctly without taking any measures. What's more, it also gives structural strength to the aircraft, as wood will always have a better structural performance than any type of glue.

It is really interesting the importance of having the maximum information in the CAD representation before constructing the CAD model. This is really helpful, and in my case it hasn't been completely like this, that all the pieces are exactly where they have to be, without impossible figures or placements that in real life are impossible to achieve. This is a very important point to care about in every engineering project that is developed, because the better you design with different type of software, the easier is then to bring it to life or make it work correctly.

Finally, a few comments about the economical aspects. Before starting the project, a meeting with the directon took place. In that meeting, he estimated that the cost of the model would be around the 200 €. He nearly guessed the price of my model, which has reached 180,10 €. This is a reasonable price bearing in mind that is the first model done. However, for a further analysis, it could be interesting to try to minimise the laser cutting time to achieve the cheapest model possible. In the case that this model had to be sold in great quantities, it would be a good idea to develop.

So, generally speaking, this project has given me the opportunity to learn about something I am really interested with: the structural methods used in the aeronautical sector. In addition, the construction of the model has taught me to care about CAD representations before ordering any material, and to be sure of what is going on in each feature of the design. However, I am satisfied of having achieved a final result which is a scale model of the biggest aircrafts in the world in the time given, as this 4 months have been really difficult for me because of sentimental problems. This project will not end up here, further investigation will be made.

12 Gratitudes

I would like to acknowledge the following people:

- To my familiy for the enormous support throught the project and the entire degree
- To my collegues Alvaro, Arnau, Marti, Sergio and Jordi ho have given me very useful advice for the project
- To Sara for supporting me throughout the semester

Thank you to all of you!

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A ANNEX I – PORTADA DELS DOCUMENTS DE TFG / TFM

Titulació:
Grau en Enginyeria de Vehicles Aeroespacials

Alumne (nom i cognoms):
Daniel Longarón Yanes

Enunciat TFG / TFM:
Study of the Boeing C17 Globemaster III structure and reproduction of a 1:50 scale model

Director/a del TFG / TFM:
Oriol Lordan Gonzalez

Convocatòria de lliurament del TFG / TFM:
10 de juny de 2019

B ANNEX II – ACORD DE CONFIDENCIALITAT DE TFG / TFM

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C ANNEX III – INFORME DEL DIRECTOR DE TFM

INFORME DEL DIRECTOR DEL TFM
(imprescindible per poder presentar el Treball realitzat)

El Director: Sr/a ....

es responsabilitza del present informe i en conseqüència autoritza a l'estudiant/a: Sr/a ....

a lliurar el Treball per a la seva defensa i qualificació.

Àrea temàtica del TFM: (indiqueu l'àrea temàtica o la titulació corresponent)

Valoració:

Originalitat del treball	o Molt alta	o Alta	o Mitjana	o Baixa
Dificultat del treball	o Molt alta	o Alta	o Mitjana	o Baixa
Iniciativa de l'estudiant	o Molt alta	o Alta	o Mitjana	o Baixa
Aspectes innovadors	o Molt alts	o Alts	o Mitjans	o Baixos
Contingut pràctic	o Molt alt	o Alt	o Mig	o Baix
Acompliment dels objectius	o Total	o Elevat	o Parcial	

Altres consideracions:
....
(signatura del Director del TFM)

Data:

D ANNEX IV – AUTOINFORME DE QUALITAT (TFG / TFM)

NOM DE L'ESTUDIANT :	DATA :
TITULACIÓ :	CONVOCATÒRIA :

PARÀMETRE A VERIFICAR: ASPECTES FORMALS – CONTINENT	RESULTAT			
	1	2	3	COMENTARIS
A1 - Formats portades				
A2 - Sumari de continguts				
A3 - Sumari de taules i figures				
A4 – Ortografia / Unitats				
A5 – Taules / Gràfics				
A6 – Formats dels documents				
A7 – Extensió de la memòria				
A8 - Bibliografia				
A9 - Relació de documents				
PARÀMETRE A VERIFICAR: ASPECTES FORMALS - CONTINGUT	**RESULTAT**			
	1	**2**	**3**	**COMENTARIS**
B1 – Plantejament problema				
B2 – Antecedents i estat de l'art				
B3 – Plantejament i justificació solucions				
B4 – Acompliment abast i especificacions				
B5 – Aspectes econòmics, ambientals i seguretat				
B6 – Aspectes temporals				
B7 – Conclusions i recomanacions				

1.- DEFICIÈNCIES GREUS / 2.-DEFICIÈNCIES MENORS / 3.- NO S'HAN IDENTIFICAT DEFICIÈNCIES

Aspectes formals - Continent
- A1. Formats adequats de les portades dels documents (han d'incloure la data/convocatòria, el logo i el nom de l'Escola, el títol del treball, el nom dels estudis, el nom de l'estudiant/a i el nom del director/a del treball).
- A2. Sumari de continguts correctament desenvolupat:

INTRODUCCIÓ

- Objecte del TFG / TFM.
- Abast del TFG 7 TFM.
- Requeriments del TFG / TFM (especificacions bàsiques).
- Justificació de utilitat / necessitat / oportunitat del TFG / TFM.

DESENVOLUPAMENT

- Antecedents, revisió de l'estat de l'art, si s'escau.
- Plantejament i decisió sobre les possibles solucions.
- Desenvolupament de la o les solucions escollides.

RESUM DE RESULTATS

- Resum de pressupost o estudi de viabilitat econòmica.
- Anàlisi i valoració de les implicacions ambientals.
- Planificació i programació de la fase següent.
- Conclusions i recomanacions de continuïtat.
- Bibliografia i normativa considerada.

- A3. Existència de sumari de taules i figures del treball.
- A4. Absència de faltes d'ortografia al document i ús adequat de les unitats del Sistema Internacional.
- A5. Taules amb un nombre de decimals significatiu i gràfics ben identificats i amb eixos clarament definits.
- A6. Formats de títols, text, justificacions i interlineats coherents al llarg dels documents.
- A7. Extensió de la memòria adequada (70 pàgines approx).
- A8. Bibliografia i referències ben documentades, i citades totes correctament en el treball.
- A9. Relació de documents del treball adequats segons la tipologia de projecte o estudi:
- Memòria i Annexes (sempre).
- Pressupost (sempre).

• Plànols (a projecte; a estudi si s'escau).
• Plec de condicions (a projecte).

Aspectes formals – Contingut

- B1. Adequat plantejament del problema (a l'objecte i la justificació) i adequat plantejament de la seva solució (a l'abast i les especificacions):
• Objecte : Resultat final que es vol aconseguir.
• Justificació de la necessitat / Justificació de la utilitat: Plantejament del problema des d'una visió global i aproximant-lo a una visió específica.
• Abast: Desenvolupament de les activitats per arribar a la solució.
• Especificacions bàsiques o requeriments bàsics: Restriccions sobre la solució proposada.

- B2. Desenvolupament dels antecedents i de l'estat de l'art.
- B3. Plantejament de les solucions possibles i alternatives, i justificació de la solució proposada.
- B4. Desenvolupament de la solució proposada fins el nivell de profunditat marcat a l'abast i justificació de l'acompliment de les especificacions o requeriments definits a l'inici.
- B5. Desenvolupament dels aspectes econòmics, ambientals i de seguretat del treball (si s'escau).
- B6. Desenvolupament dels aspectes temporals del projecte (planificació de tasques i programació temporal del desenvolupament futur del treball).
- B7. Desenvolupament de les conclusions (en coherència amb l'objecte i l'abast inicials) i recomanacions del treball (en referència a futures activitats relacionades).

Aquest autoinforme no té com a objectiu la avaluació específica dels continguts dels documents de TFG / TFM doncs aquesta avaluació la durà a terme el tribunal que es designi per a aquesta tasca. Per tant, les indicacions que aquí es donen només fan referència a la millora dels aspectes formals dels documents que seran avaluats, a la coherència existent entre el que es descriu que es farà al plantejament del TFG / TFM i el que s'explica en el desenvolupament del TFG / TFM, així com a la presència dels capítols referents a l'anàlisi de les implicacions econòmiques, ambientals, temporals i de seguretat del treball desenvolupat.

NOTA MOLT IMPORTANT:

AQUEST AUTO-INFORME SERÀ CONSIDERAT COM **FAVORABLE** SI NO S'INDIQUEN DEFICIÈNCIES GREUS A CAP DELS ASPECTES DE CONTINGUT I EL NOMBRE DE DEFICIÈNCIES GREUS ALS ASPECTES DE CONTINENT ÉS INFERIOR O IGUAL A TRES.

E ANNEX V – QUALITY SELF-ASSESSMENT (TFM)

STUDENT's NAME :	DATE :
DEGREE :	CALL : SPRING / FALL YEAR 20__

PARAMETER TO VERIFY: FORMAL ASPECTS – CONTINENT	RESULT			
	1	2	3	REMARKS
A1 – Cover formats				
A2 – Summary of contents				
A3 - Summary of tables, figures				
A4 – Spelling/Units				
A5 – Tables/Figures				
A6 – Format of documents				
A7 – Length of the report				
A8 – Bibliography				
A9 – List of documents				
PARAMETER TO VERIFY: FORMAL ASPECTS - CONTENTS	**RESULT**			
	1	**2**	**3**	**REMARKS**
B1 – Approach to the problem				
B2 – Background and state of the art				
B3 – Approach and justification of the proposed solutions				
B4 – Fulfilment of scope and requirements				
B5 – Economic, environmental and safety aspects				
B6 – Time-related aspects				
B7 – Conclusions and recommendations				

1.- SERIOUS FAILURES / 2.-MINOR FAILURES / 3.- FAILURES NOT DETECTED

Formal aspects - Continent

- A1. Appropriate formats of the covers of documents (they must include date and call, logo and name of the school, title of the TFM, name of the master degree, student's name and the name of your TFM director).
- A2. Properly developed summary of contents:

INTRODUCTION

- Aim of the THESIS.
- Scope of the MASTER'S THESIS.
- Requirements of the MASTER'S THESIS (basic specs).
- Justification of the usefulness/need/opportunity of the MASTER'S THESIS.

DEVELOPMENT

- Background and review of the state of the art, if necessary.
- Approach and decision on possible solutions.
- Development of the chosen solutions.

SUMMARY OF RESULTS

- Budget summary or economic feasibility study.
- Analysis and assessment of the environmental implications.
- Planning and programming of the next stage.
- Conclusions and recommendations of continuity.
- Considered bibliography and legislation.

- A3. Presence of the tables and figures index.
- A4. Absence of spelling mistakes in your document and appropriate use of the International System units.
- A5. Tables with a significant number of decimals and well identified graphics with clearly defined headings or footprints.
- A6. Consistent formats of titles, text, justifications and interlining throughout the documents.
- A7. Extension of the report (70 pages, approx).
- A8. Well identified and quoted bibliography and references. - A9. Presence

of the compulsory project documents depending on the type of MASTER'S THESIS, project or study:

- Report plus report attachments (always).
- Budget (always).
- Drawings (always in projects and in studies just if appropriate).
- Technical sheets or Terms Of Reference (just in projects).

Formal aspects – Contents

- B1. Clear approach to the problem (inside the aim and justification) and appropriate approach to its solution (inside the scope and requirements):

- Aim: Final goal you want to achieve.
- Justification of the need/justification of the usefulness: approaching the problem starting from a global view and zoom in to a specific vision.
- Scope: development of activities to reach the solution.
- Basic specifications or requirements: restriction over the proposed solutions.

- B2. Development of the background and the State of the Art.
- B3. Approach to the possible solutions and alternatives, and justification of the proposed solution.
- B4. Development of the solution to a level of detail matching with the scope and requirements.
- B5. Development of the economic, environmental and safety aspects of the project (if applicable).
- B6. Development of the temporal aspects of the project (task Planning and Scheduling of the future development of the project).
- B7. Development of the conclusions (in coherence with the previously defined aim and scope) and recommendations about the future work.

The aim of this self-assessment is not the assessment of the specific objectives of your MASTER'S THESIS, as far as the evaluation of them will be done by the designed reviewing panel. Therefore, the instructions that are given here only refer to the improvement of the formal aspects of the documents that will be evaluated, to the coherence between what is described in the approach and what's explained in the MASTER'S THESIS, as well as the presence of the chapters related with the analysis of the economic, temporal, environmental and safety implications of the work.

VERY IMPORTANT NOTE:

THIS SELF-ASSESSMENT WILL BE CONSIDERED AS **FAVOURABLE** IF THERE ARE NO SERIOUS FAILURES IN CONTENT, AND IF THE NUMBER OF SERIOUS FAILURES IN THE CONTINENT ASPECTS ARE LESS THAN OR EQUAL TO THREE.

F ANNEX VI – DECLARACIÓ D'HONOR