AirCargoChallenge 2022

Technical Report

Team 24

Locreum Project

LOCREUM PROJECT

Contents

1 Introduction

Locreum project (LCP) is a project founded by a small group of aerospace engineering students from the University of Cádiz, located in south Spain, concretely in a small town called Puerto Real. LCP is a subdivision of the spanish association called LEEM, whose objective is to participate in all ACC contests as possible.

In this document you will find all the process of predesign, design and optimization of our aircraft taking into account all the different fields: aerodynamics, structural and thrust studies.

In our second edition participating in this challenging contest, we tried to do our best and make this project possible. Our team is formed by a few first or second year engineering students and some of the ones who participated in the last contest. Even though we had all these complications, we have achieved our goal: to make **ÑANDÚ** fly in a safe way and reach the sky without any complications.

Thus, our aircraft is mainly made of balsa wood and some aeronautical materials like aluminum. However, we have taken the risk of trying to do our winglets in composites. This is with no doubts one of the most difficult parts of our project, since for the majority of the group, it is the first time working with composites. A separate chapter is dedicated to talk about manufacturing solutions where we will get into detail about the creation of the winglets.

1.1 Some previous stadistics

The first thing we did before doing the predesign was analysing some interesting data about previous ACC editions and other UAV models, to see the relationship between the wingspan/length and the weight to learn for our project. It can seem pretty obvious but for us it was one of the most important things to do. The recollected data is shown in the Table 1.1.

Name of the aircraft	Wingspan	Weight	Length
Raven RQ-11B	1,4	2,05	0,9
Desert Hawk III	1,2	3,2	0,95
ETM Aladin	1,5	3,2	1,53
Elbit Skylark I	3	7,5	1,8
EADS Tracker	3,6	8	1,5
SkyRanger	1,2	3,3	0,7
LM450 UAS	1	1,25	0,65
Akamodell (Winer ACC)	3,9	10,2	1,7
Icarus Polito (ACC)	3,5	8,25	-
MA Vinci SIRIUS UAS	1,6	2,8	1
Valcam Project (ACC)	2,5	6,8	1,9

Table 1: Table 1.1

Among the aircraft of the 2019 edition, those that ended up in top rankings, including the AkaModell München team (hosts of the next edition in 2022) winner of the last edition thanks to the design that was shown in figure 1. In it you can see that he made use of a straight wing and slender with a small arrow on the tips, V-shaped tail, fuselage shaped small diameter cylinder and cargo hold under the main wing. As it is mentioned in reference [1] with this configuration they were able to lift a mass 9.8kg.

Figure 1: Design by the AkaModell München team.

The AERO UBI team came in fifth position with the UAV design shown in figure 2, which again has a straight and slender wing but in this case with a Winglet and no arrow at the tips, an inverted T-shaped tail with stabiliser vertical stabiliser (VTP) much larger than horizontal stabiliser (HTP), fuselage shaped of variable diameter cylinder, fuselated cargo hold under the main wing and landing gear landing under said hold.

Figure 2: AERO UBI team design.

Another starting reference can be the aircraft designed by the ICARUS team POLITO, which, as can be seen in figure 3, presents how in both previous models a straight wing with the difference that this one has winglets considerably higher than the previous model and flaps in the inner area of the same.The tail is arranged in a V shape, the fuselage incorporates a wider section possibly carrying payload and trailing-tail type landing gear.

Figure 3: ICARUS POLITO team design.

Finally, the design of the aircraft of the LEEM CÁDIZ team will be analyzed since it is the team for which this project is being carried out. The aircraft that participated in 2019 (see figure 4) consists of a straight and slender wing characteristic of the gliders, an inverted T-shaped tail composed of flat plates, fuselage of Aluminum hollow rectangular section, underwing cargo bay and landing gear of the type of dragged tail with wheels manufactured by 3D printing. Being very similar projects, this document has been one of the main references for the development of this project.

To start the iterative method, the program must have access to a initial geometry to start from. This initial sketch has been designed following a conventional process for educational purposes by a class work team of which the author was a part, during its design the regulations of the contest, so that the result is a starting point quite close to the optimum. mo, thus lightening the computation process for the required optimisation.

As shown in figure 3.5, it is a UAV with a straight wing, tail in the shape of a Inverted T whose vertical stabiliser has a certain angle of arrow, fuselage cylindrical, cargo bay positioned as close to the centre of gravity as possible to avoid modifications in it by varying the load and landing gear of the type of dragged tail.

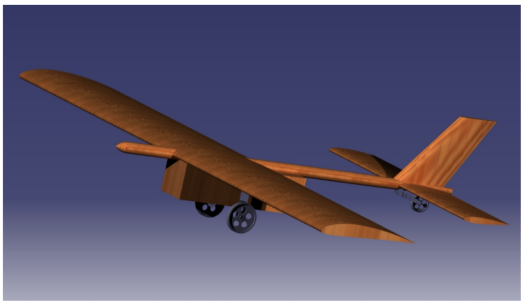

Figure 4: Initial sketch design. Image rendered with CATIA.

2 Project management

At the start of this project we encountered a major issue: we did not have the economical resources needed to accomplish the creation and flight of our designed aircraft proposal for the Air-Cargo Challenge. Therefore, we started to contact and ask industries of the area to sponsor us. Currently, we can divide our sponsors in three different categories:

- Sponsors that help us with money.
- Sponsors that help us with machines and workspace.

In this chapter we will explain how the project was planned in different ways.

2.1 Financial Management

The financial management is focused on raising the needed money to cover all costs. Within this main aim, there is distinction between raising all the money to pay the inscriptions and the purchase of all the materials required. All these expenses were assumed by our sponsors: Drones UCA, University of Cádiz and 'La Gaviota' Flying Club. It is important to note, that on the first day it was assumed that the transport expenses and pocket money would be paid by each team member.

2.1.1 Getting the money for the inscriptions

The first important quantity of money we had to pay were the inscriptions. LCP is formed by eleven team members, so we had to make the inscription as: seven team members. This means that the total balance we needed to pay was 1750.00 €.

2.1.2 Budget of the materials

Two periods can be distinguished in the budget of materials: the pre-design and the construction of the aircraft.

Pre-design:

The first budget was proposed after the pre-design of the aircraft was finished. Although most of the measures were not contemplated, the preliminary design provided some guidance on these quantities. Therefore, this budget considers some tools and main materials, where some of them were exposed in the regulations of ACC Munich 2022.

Material Description	Quantity	Total Cost
Motor: AXI Gold 2826/10 GOLD LINE V2	1	92,60 €
Batteries LiPo	5	169,95 €
ESC	1	32,58 €
Receptor	1	14,99 €
EH and XH Connector	15	30,00 €
XT60/XT90 Plugs	4	9,99 €
Radio Control	1	15,00 €
Servos	4	58,84 €
Balsa wood (3.0x100x1000)	1	11,89 €
Corchopan	6	12,00 €
Handles	2	11,98 €
Rod	1	20,00 €
Epoxy	6	49,50 €
Carbon rod	8	45,04 €
Toolbox	1	69,95 €
Other(screws, hinges, clamps, wire, ...)	-	73,59 €
	Total	**835,90 €**

Table 2: Breakdown of Budget 1

Construction:

This budget was developed during the construction of the aircraft. Thus, all the characterisation of the wing design, landing gear and cargo bay was done; and some forecasted materials (i.e. fuselage) were considered. Consequently, some materials that were not included in the first budget are shown in the one below.

For the construction we will divide into three groups and each group will be in charge of a specific task. Each subgroup must always collect their daily work in the construction diary so that the other colleagues know how to continue in their hour of work. The three subgroups will be internal structure of the aircraft, external structure of the aircraft and radio control.

The main material that will make up the plane will be balsa wood for the fuselage and model windframe paneling for the wings. We have distributed ourselves to dedicate five hours a week per person to the construction and working extra hours in case there are possible errors in the design.

Material Description	Quantity	Total Cost
Propeller	1	3,45 €
Y Connectors	1	2,00 €
Heat-Shrinkable plastic	2	20,00 €
Wheels	3	7,35 €
Front rod	1	8,00 €
Wooden box transport	2	400,00 €
Wood for the box	6	30,00 €
Ribbons	1	14,88 €
Padlock	2	10,00 €
University sticker	2	10,00 €
Team Sticker	2	10,00 €
Team T-shirt	11	132,00 €
Fiberglass cloth	1,27	6,35 €
Rear landding gear	1	4,35 €
Rear wheel	1	3,00 €
Landing gear	1	16,90 €
Cork	6	23,40 €
	Total	**701,68 €**

Table 3: Breakdown of Budget 2

On the whole, adding both budgets and the money for the inscriptions we would have **4.287,58€** as expenses

2.2 Planning management

Besides money, some deadlines needed to be set from the beginning. The following figure consists of a planification of the project where the start and end dates of several events are shown with different colors. These events are explained right afterwards.

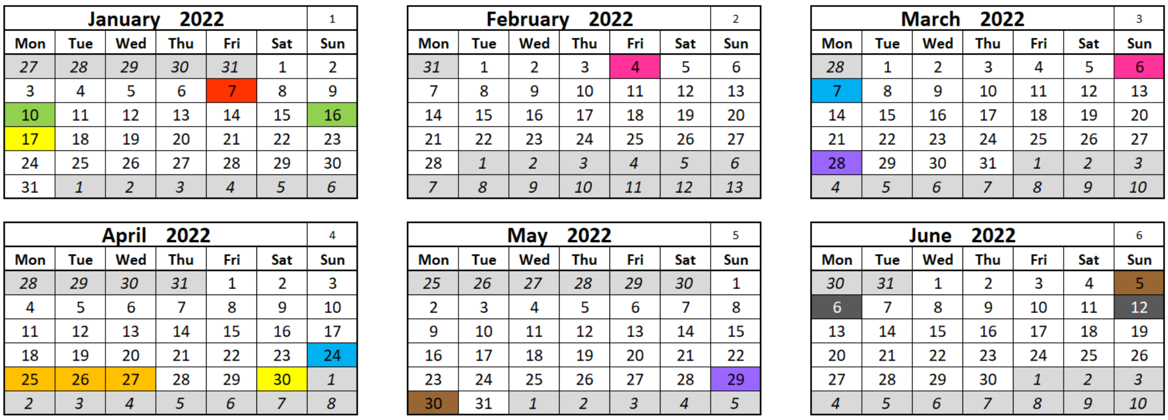

Figure 5: Planification of Locreum Project

- **LCP Team Creation** [**Red**:] After a selection procedure, the LCP team was selected to participate in the ACC Munich 2022 competition and its project/investigation that goes with it.
- **Start of Social Networks** [**Green**]**:** The corporate image of LPC was created by letting people know what our project was about and its implications.
- **Getting sponsors** [Yellow]**:** This event may be the longest since it considers the first round of sponsors search. where we will test our aircraft.

- **Predesign [Pink]:** The general characterization of our aircraft was developed, where some major decisions were taken. For instance, we agreed to have a simple tail configuration, and we would not include flaps on our design.
- **Design [Blue]:** The team was divided into three coordinated subteams: wing, cargo bay and tail. During this period, a stability study for the tail as well as several structural analyses were performed to check whether some materials would withstand the stress.
- **Manufacturing and assembly [Purple]:** The wing building was the start point of the manufacturing and assembly phase, followed by the cargo bay and winglets. The latter took the longest time - finishing at the same time as the tail - since it is a very complex process. Lastly, the fuselage and final assembly were executed.
- **Final 'Technical Report and Drawings' Draft [Orange]:** A three days intensive meeting with the aim of finishing the Technical Report and Drawings before the 1st May 2022 deadline.
- **Tests flights [Brown]:** Flight tests will be carried out in order to check the behavior of the aircraft in case any modifications are needed
- **Aircraft modifications [Black]:** Currently, there is no knowledge on whether any modifications will be needed, however, we want to foresee a gap where we could solve any outcoming issues.

3 Software

For the design of the aircraft we have based ourselves on the code developed by Antonio Chamorro Ortiz, an old member of the team. The main function of this code is to optimise by iterations an initial design created by Open VSP. This initial design will be modified with each iteration until reaching an optimal final design according to the criteria of the code. The code also use the stability equations to make stable the plane, improve the aerodynamics and be able to lift 1kg of payload.

Used software:

3.1 OpenVSP

OpenVSP is a parametric geometry tool with especial application on aircraft design that allows the designer to create 3D models for a later processing in engineering analysis. One of its main features is its capability to automatise processes by script insertion in a command window.

This tool has been used for this project to visualise the aircraft's geometry in any moment and for the obtaining of aerodynamic and geometric date.

The implication of this software has not made any impact on the cost of the project for being free-licensed.

3.2 Matlab

Matlab is a tool for programming and calculating used for develop algorithms. In addition, it uses a matrixes and arrays directly, that do this programme perfect for the project.

We have use the student version provided for university of Cadiz.

3.3 XFOIL

XFOIL is a programme of parametric design and profile analysis. Thanks to the software's ability to be easily operated via the command line, it is used in the project for the analysis of different profiles in different regimes and configurations.

Since it is free software, the full version of the programme has been used at no extra cost to the project.

3.4 CATIA

For more precise design of some plane's components, CATIA has been used, being capable of creating complex geometries with no difficulty, it has been specially useful for mass calculations. Student's version has been used, provided by the University Of Cádiz.

4 Design requirements

This section will present the requirements for the design of the aircraft for the ACC 2022 contest.

4.1 Flight objectives

In the 2022 edition, the theme of the contest is about quickly suppling medical supplies and trying not to harm the environment. The objective of this flight is to transport emergency medical goods from one point to another, more specifically blood bags. This will be the payload of the aircraft.

4.2 Plane's requirements

The challenge of the competition consists in designing an aircraft propelled by an electric motor and a propeller assembly, which generates lift with the forces that act on the remaining fixed surfaces, except for the control surfaces. Such aircraft must be controlled by remote control by a pilot on the ground.

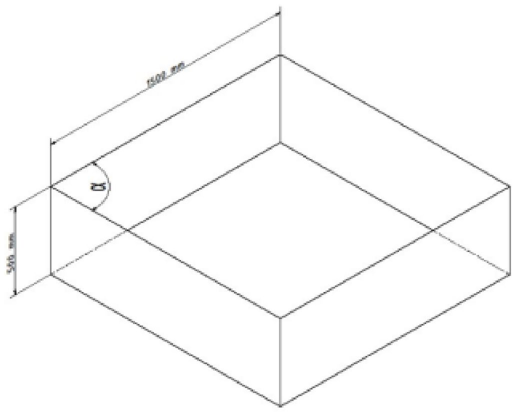

Figure 6: Diamond box

4.3 Dimensional restrictions

The size of the assembled "flight ready" aircraft must fit into a rhombus-shaped box with an edge length of 1.5m each. The angle between the edges is NOT fixed! You may variate them as you want.

The maximum height is 0.5m. (Standing on the floor by itself in take-off configuration, no additional support)

4.4 Propulsion

Propulsion set has to be according to the contest's requirements, being so:

- **Prop:** Only one prop is permitted on the air plane and has to be one of this concrete models: APC-E 10×6E y Aeronaut CAMcarbon Light 10"×6".

- **Engine:** The engine is a component that must be common to all participants, it is the AXI 2826/10 GOLD LINE V2 model, unique and unmodifiable. In the following table 7 you can see its features.

Nro de celdas	3 - 5 Li-Poly
RPM/V	920 RPM/V
Máx. eficiencia	86 %
Máx. eficiencia de corriente	20 - 30 A (>78 %)
Intensidad	1,7 A
Capacidad de corriente	43 A/ 60 s
Resistencia interna	20 mΩ
Dimensiones ($\phi \times$ L)	35$\times$52 mm
Diámetro eje	5 mm
Peso	177 g
Máx. potencia	740 W

Figure 7: Characteristics of the AXI 2826/10 GOLD LINE V2 motor

- **speed variator (ESC):** It is allowed to choose any variable speed drive that has a minimum constant current of 30 A as long as it does not increase the battery voltage.
- **Battery:** The three battery types allowed by the regulations are LiPo, Lilo and LiFePo having 3 cells in series, with a maximum voltage of 12.6 V and a maximum discharge rate of at least 30 A.

5 Aerodynamic Design

The aerodynamic design of the aircraft has been developed using an iterative method which provides a stable geometry from a random initial geometry. For this first geometry, however, we began from a design that follows the regulations set by the ACC 2022 Munich, aiming to speed up the computing process for the required optimisation.

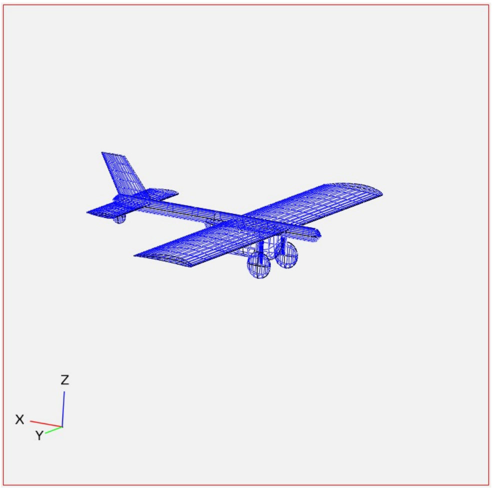

Figure 8: Initial design.

As shown in the figure, 9, the aircraft is, in fact, a straight-wing-UAV, with an inverted T-shape for the tail, whose vertical stabiliser presents a light V-shape. In the main body; the aircraft is assembled in a cylindrical shaped fuselage with a cargo bay centred with the centre of gravity to avoid modifying it once the payload gets introduced. Finally, we opted for a dragged tail shape for the landing gear.

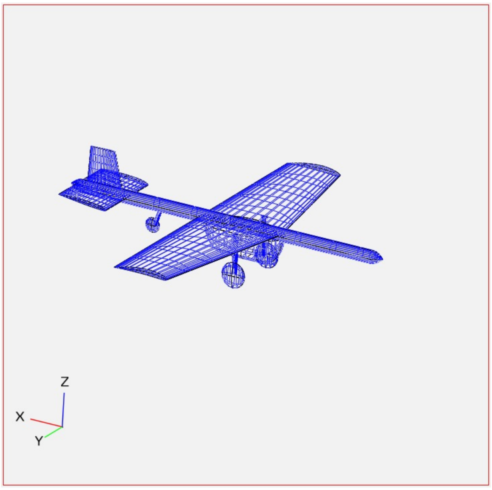

Figure 9: Final design.

Note: the ideal would have been to create a design based on historical data of commercial aircraft - whose data can be accessed. However, the aircraft that we will be designing is unconventional due to its reduced size and the use of basic materials and manufacturing methods. Although any reference documentation on historical data of commercial and military aircraft is not valid. Therefore, due to the nature of the project, we will take the aircraft that have competed in previous editions of the ACC as reference.

6 Cargo Bay design

The Cargo Bay is the structure that will house the payload that the aircraft will carry throughout its flight mission. It should be recalled that the entire design of the aircraft involved in this project is subject to the ACC 2022 regulations, which also define the type of cargo that the aircraft must carry.

If the competition rules are analysed, in this edition of the competition the contestant aircrafts must carry blood bags like the one shown in the figure below. There are three different sizes according to their mass, of 100, 200, and 300 g. The approximate dimensions of each bag size can be approximated from the images provided by the competition in the absence of the height of the 100 g bag. Since the length and width of the bag remain constant for the three bag sizes, an average density value of the liquid contained in the bags is determined to establish a general rule and to know the height of the three bags. The approximate height of the 200 and 300 g bags is 2 and 3.5 cm respectively. Knowing the mass and volume we can determine the density of the liquid they contain, obtaining densities of 356.58 and 305.64 kg/m3 respectively. The average density (331.11 kg/m3) will be used to approximate the measurements of all the bags following a common standard for the three cases, the dimensions obtained can be seen in the table below.

The objective is to transport as much payload mass as possible, so the design of the cargo nacelle will be done in such a way that the load capacity is large initially, if after finishing the optimisation process it turns out that the maximum load admitted by the cargo bay is much larger than the load supported by the aircraft, it is advisable to reduce its size in order to reduce the total weight of the aircraft as well as the aerodynamic drag during flight.

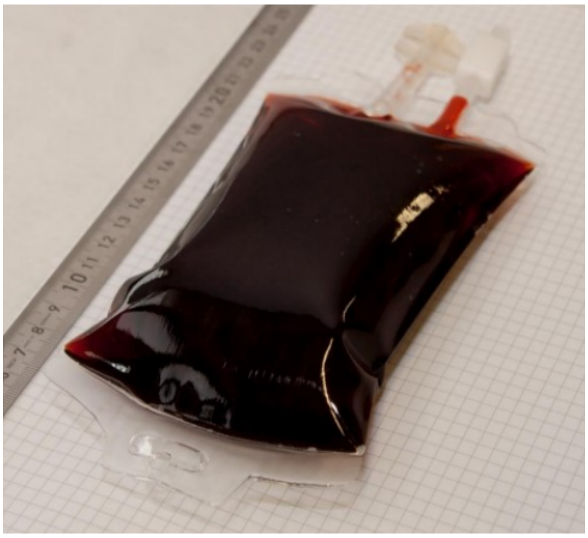

Figure 10: Blood bags as payload

Masa (g)	Largo (cm)	Ancho (cm)	Alto (cm)
100	24,6	11,4	1,07
200	24,6	11,4	2,15
300	24,6	11,4	3,23

Figure 11: Blood bag dimensions

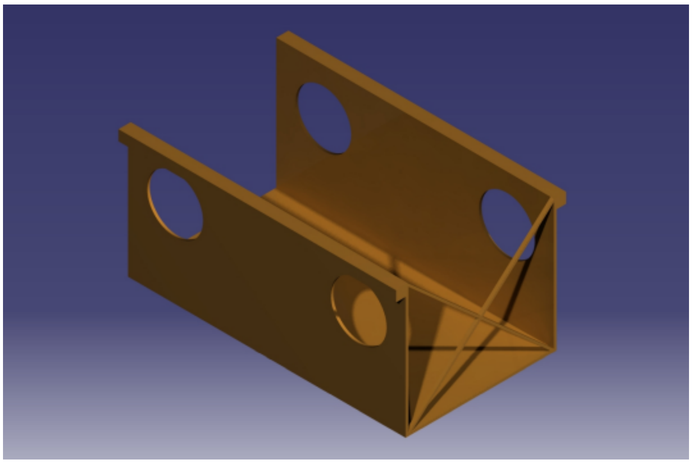

Figure 12: Payload Storage Box

The cargo bay, due to its complex geometry, has been designed with the CATIA software tool to later incorporate its approximate dimensions to a simpler geometry in OpenVSP to be analyzed with the rest of the aircraft components.

The starting point was the design of the cargo nacelle of the aircraft designed by the LEEM team in the last edition of the LEEM team in the last edition of the contest. It turned out to be a quite efficient design and the author of this project has decided to recycle it. In order to use it in this edition, the interior cargo bay had to be resized so that the blood bags fit perfectly inside it.

Knowing the dimensions of the blood bags 10 the interior space of the box has been given dimensions of 13×11.57×24.5 cm. This box, as can be seen in the figure, consists of a rectangular base, two side walls with cavities to reduce the total weight of the loading bay and two bars of the box. of the loading bay and two bars arranged crosswise at one end to avoid losing the load. As can be seen, it is a simple design that seeks to have a lightweight structure in which to store cargo during flight.

The next component to be designed is the external casing of the bay, which is intended to provide the the bay is intended to give it a slightly more aerodynamic shape in order to reduce aerodynamic drag.
the aerodynamic drag that this component will produce when the aircraft is in flight. the aircraft in flight. This aerodynamic geometry was devised by the LEEM team for last year's edition.

LEEM team for last year's edition, for this edition only the dimensions have been adapted the dimensions of the box so that it can fit inside it. The bay has a hollow inside, which can be seen in the figure 13, in which will be placed the box that has been previously seen, in the upper part of the hollow can be seen some rails by which the box will slide to be placed and adjusted inside. In order to reduce the cost of its production, the cost of materials and the total weight of the loading bay, this component turns out to be hollow inside as can be seen in the figure 14.

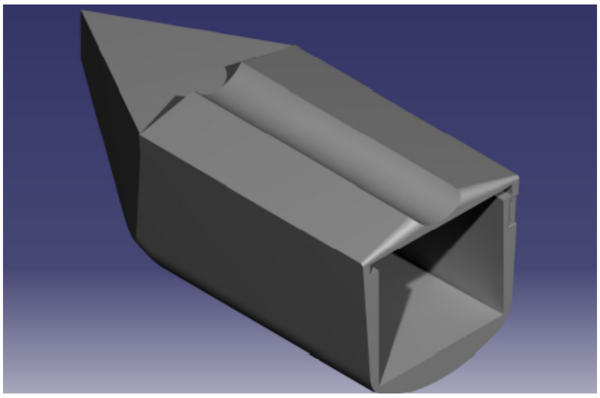

Figure 13: Cargo bay

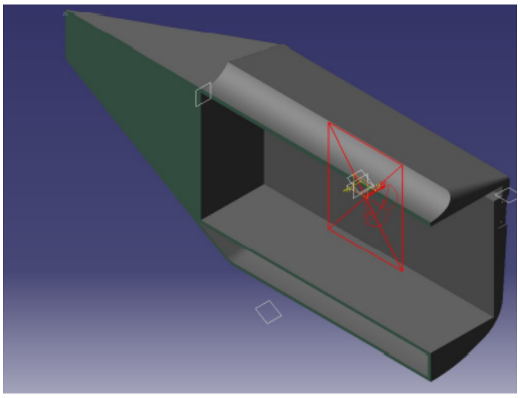

Figure 14: Sección del elemento

Finally, the head of this component is designed, through which the load will be incorporated. Once it is mounted on the plane.

This element has a dual purpose, the first of which is to be able to enclose the cargo box within the cargo bay itself, avoiding the possibility of losing part of the payload during the flight. Another reason why this element is incorporated is to provide the front area of the bay with a more fuselage shape. Lastly, given that this component is going to be able to open, it will allow the load to be changed without the need to disassemble the entire nacelle, it will be attached to the casing by means of a hinge system, providing it with the ideal movement of the loading of the plane.

The head of the cargo bay has been given a rounded shape in order to to improve aerodynamics with a flat area in the upper part to facilitate coupling with the plane, a hole has been made in its interior with the shape of the cargo box section so that it adapts correctly once the bay is closed. As with the outer casing, this component is hollow inside to reduce costs and weight, as can be seen in the figure. 15.

The hinge system that has been previously mentioned must be installed in one of the sides so that in this way the opening of the head of the bay does not present any problem when it is mounted on the plane.

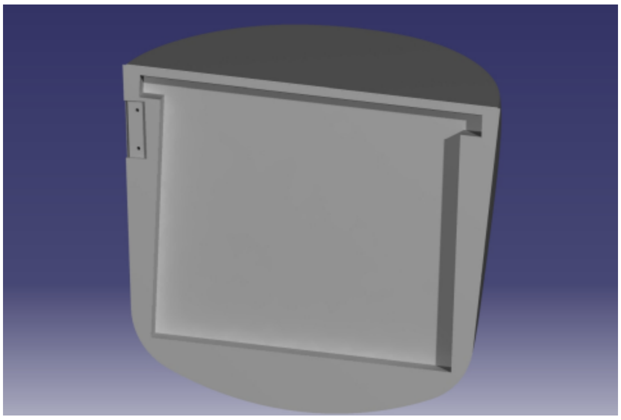

Figure 15: General view

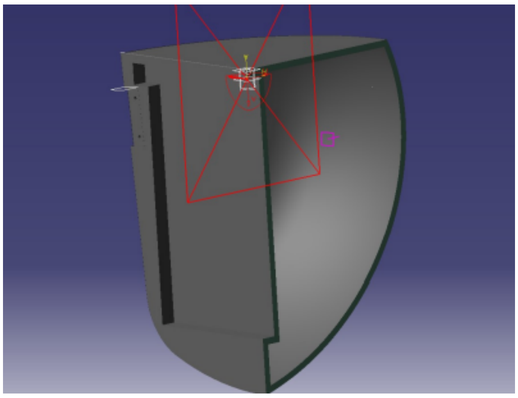

Figure 16: Section of the element

7 Cargo Bay Structural Analysis

In this chapter we are going to simulate the most critical parts of our aircraft in order to see how it behaves regarding the aerodynamic loads.

The Cargo Bay has been done using 3D manufacturing techniques, in PLA. We wanted to ensure that it does not break during the flight so then a structural simulation was rather than a need an obligation. To do that we used the software Patran/Nastran. From the design the very first step was selecting the anchor points, which in fact were our screws. Then we introduce the loads in the bottom part of the cargo bay and an inertial moment. Then we introduce the loads in the bottom part of the cargo bay and an inertial moment.

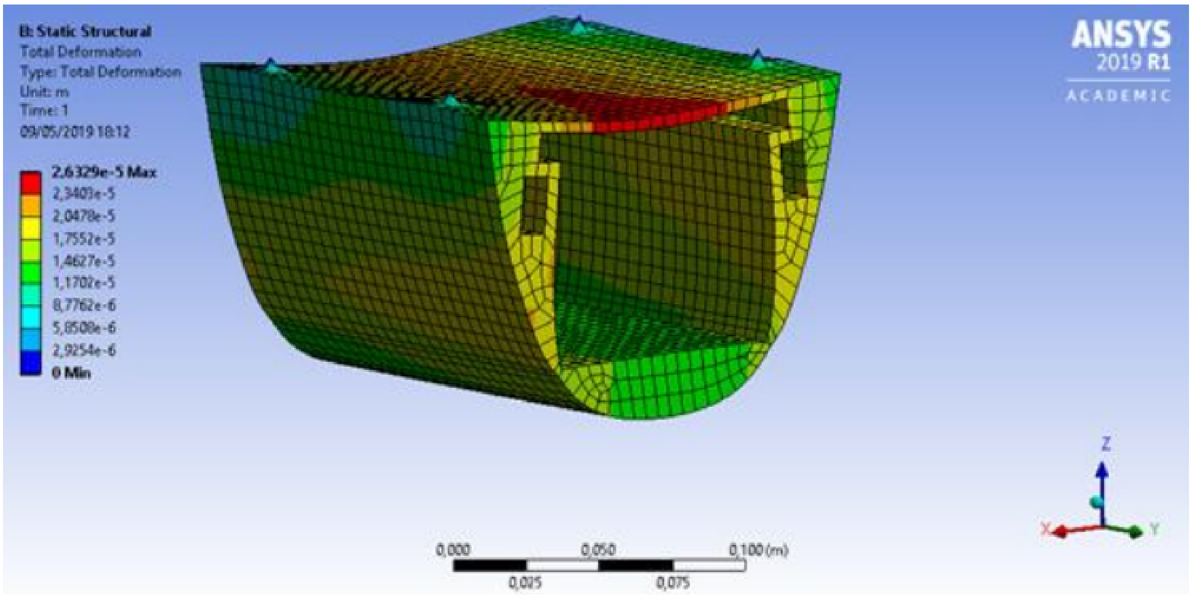

Figure 17: Final design of the cargo bay

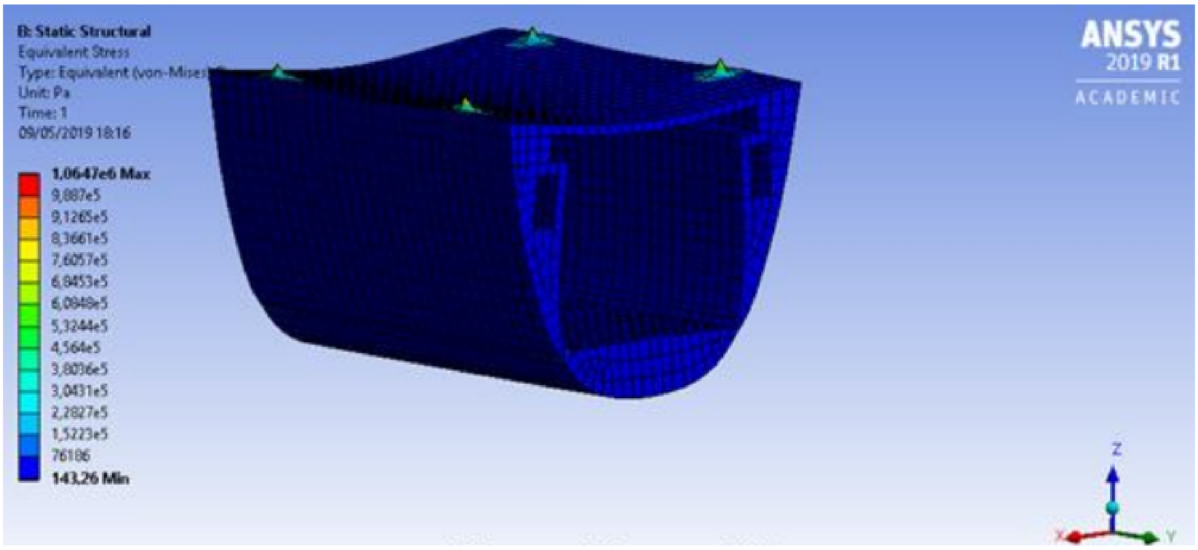

Figure 18: Final design of the cargo bay

Moreover, we modelled the percentage, used to fill the structure, to scale the properties of the PLA. For instance, if the tensile strength is 66 MPa using 100% of fill, we considered that using a 10% was being modified to 0.1·60 MPa. Of course, this is an approximation we established and has some error but in overall gives us really interesting and reliables results.

Thanks to the simulation we could notice that in fact our design was not optimized. The results clarified us that the design could be optimised in terms of having less weight and thus lightening weight, being able to lift even more payload.

8 Payload Prediction

The first component of the cargo bay to be designed based on the previous model was the inner box, as it had to be was the inner box, since the dimensions of this box determine the dimensions of the rest of the components that make up the bay.

Its dimensions were adapted to accommodate up to a maximum of 1 kg of cargo. As mentioned above, this sizing is done by estimating the maximum mass of cargo that the aircraft will be able to carry, if this differs greatly from 1 kg it is convenient to resize the cargo bay to further adjust the weight of the aircraft.

9 Drawings

Once terminated the optimisation; the blueprints were exported to AutoCad to have access to the final measurements and make sure it fits inside the size restrictions:

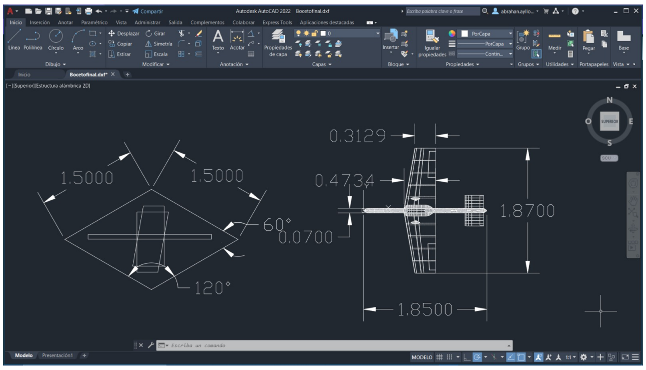

Figure 19: Software generated optimisation of the model

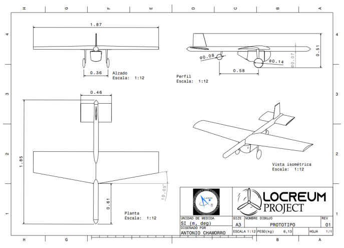

Figure 20: Drawings of the optimised model pre-deescalation

As shown, on the capture, final measurements get over the requirements, so an deescalation was applied, due to the fact that, keeping the same geometry, does not revert in any major inconvenience.

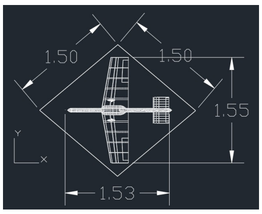

Figure 21: Final shape after applying the deescalation

10 Outlook

In short, our aircraft, "ÑANDU" has been designed using the most advances tools of engineering; lots of CFD, stability simulations, propulsion test and others. Also, we wanted to manufacture some parts using balsa wood. We studied the propulsion using OpenVSP and Matlab, Patran/Nastran.

Due to difficulties with the different programmes used and lack of organisation, we considered adjourning the project one year, but we decided to focus on it and spend lots of our free time to make this project a reality.

Another thing we have to mention is that this group is replacing the one from 2019, because they graduated and they could no longer continue with the project.

In overall this has been an incredible experience, in which we have learned a lot about aircraft design, and we are really excited to take part in this and exhibit the project to which we have dedicated so much enthusiasm and work.