Integrated Design Project Group 21. "The Horus"

The Horus will revolutionize modern day commuting. It will be the first hydrogen powered flying car that is capable of Vertical-Take-Off and Landing (VTOL). Using a pre-loaded flight system, it is capable of autonomous flight to ensure that there are no collisions in the air with other aircrafts and commuters. Using hydrogen fuel cells to power the Horus will make it one of the cleanest vehicles in terms of emissions and also one of the most technologically advanced aircrafts. The Horus is designed to be user friendly to allow it to be used for everyday commuting in order to optimise its potential to preserve and protect the environment. The Horus harnesses the best parts of normal Internal Combustion Engine vehicles and Electric powered vehicles without any of the drawbacks as there is negligible emissions and no extortionate recharging/refuelling times.

Team Members

Ellis Roderick
MEng Mechanical Engineering with a year in industry
Question 2: How can it be improved?
Our design can only fit a maximum of 2 people inside. An improvement can be to increase the size to allow 4 or 5 people to fit inside. This will increase our market as families will purchase the vehicle to replace their large cars which will further reduce emissions.

Adam Piggott
MEng Mechanical Engineering with a year in industry
Question 4: What will the impact of this design on the wider world?
This design uses emission free hydrogen fuel cells in its design to power the engine helping to inhibit global climate change. As a product that will potentially revolutionise daily travel, it will also cause other companies to compete with its design, leading to greater research into sustainable energy solutions and such competition breeding greater technological advancements.

Rhys Coldrick
MEng Mechanical Engineering with a year in industry
Question 1: Why is this a good solution and design?
The solution of a flying car and our design meets the goals of the SDG that we are looking at by reducing the road traffic while at the same time not reducing the capability of the vehicle to drive on the road as expected from a car so therefore not limiting the owner to only flying.

Yolan Chung
BEng Electrical Engineering
Question 4: What will be its impact on the wider world?
As the vehicle becomes more popular owners can choose between driving it as a car and using it as an aircraft. If the owner wishes to travel long distance then the aircraft mode is more beneficial however it can be used as a road vehicle for short distance journeys. Therefore there would be less congestion on main highways. Additionally, as the vehicle travels faster in flight mode the owner could travel to their desired location in a faster and more convenient manner.

Jingyi Chu
BEng Electrical Engineering
Question 4: What will be its impact on the wider world?
Firstly our design concept is above the typical model of a driving car, it provides a new commuting way between flying and driving and makes life easier. Hydrogen fuel cells are the main energy source in our design, using these for larger transportation services can lead to investment and further research into renewable and sustainable energy sources. Thus, reducing the emphasis and use of fossil fuels for transportation and commuting.

Aidan Smith
BEng Mechanical Engineering
Question 3: What is the true cost of this solution? Who will pay? Who will profit?
The true cost to this project will be significant, the technology used, whilst very prominent in research, will still be in its infancy in terms of manufacturability and thus great costs for the infrastructure will be required to start production. It is likely that alongside any funds from sales, significant financial investors both private and public will be required to allow for the subsidization of the of the startup costs. Financially, it will be the private investment that profit the largest however, it is likely that countries would also indirectly profit as wellness would improve from reduced toxic emissions. By funding a project which directly tackles a main SDG, it would profit a country significantly in achieving what was laid out in the UN Assembly by the agreed year, 2030.

Claire Berry
MEng Civil Engineering
Question 5: What risks does the project carry and what are we doing to address them?
The biggest risk to our plane is a power shut down mid-flight due to drained fuel cells. We've addressed this problem by including a backup fuel cell which immediately activates an automated emergency landing at the closest safe location.

Concept Designs

Concept 1 (figure 1)

The benefits of this design include the location of the wings and propellers as they provide a useful and realistic way of taking off. The limitations include the mass and the overall poor aerodynamic design of the aircraft as both of these limitations will mean the propeller motors will require more power due to resistive forces. Additionally, the wings on this aircraft are fixed which makes it difficult to use and store this vehicle due to the width.

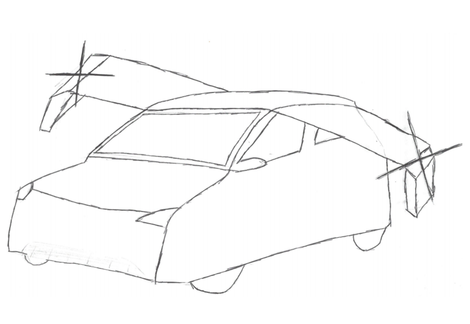


Figure 1.

Concept 2 (figure 2)

This design is a continuation of the first concept such that it is based on a normal car however it includes a method of reducing the wingspan for storage or for when the vehicle is being used on the road. The advantages of this design are the ability to reduce the wingspan of the vehicle and a more aerodynamic design than concept 1 which creates a more efficient aircraft which requires less power. However, limitations include a potentially poor landing method as it lands like a conventional aircraft and does not contain any extension for its landing gear thus meaning any landing could potentially damage the undercarriage of the aircraft i.e. it lacks Vertical Take Off and Landing capabilities (VTOL).

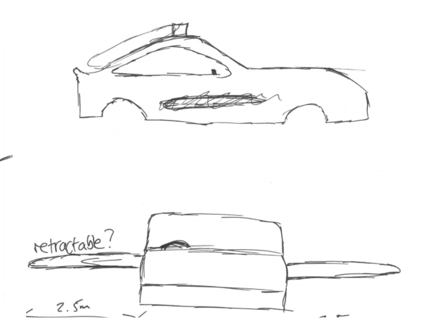


Figure 2.

Concept 3 (figure 3)

Concept 3 includes a more realistic solution to reduce the wingspan using a rotational device placed on top of the vehicle that is able to control the location of the wings so they can retract for when the vehicle needs to be stored or used on the road. Additionally, the aircraft also features VTOL as the propellers can change their angle of attack to allow VTOL and then horizontal flight. This creates more a viable selling point as the aircraft can take off anywhere rather than only taking off on straight roads or runways. However, limitations to this design include a poor aerodynamic design and the lack of inclusion of landing gear in case the aircraft cannot land using VTOL.

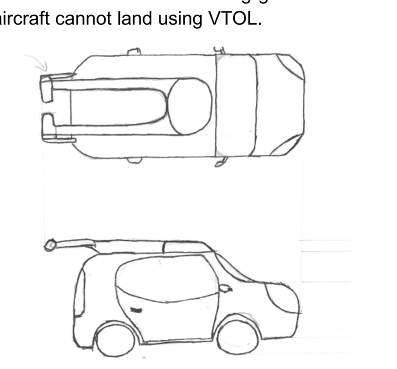


Figure 3.

Final Concept (figure 4)

The final concept is a combination of the VTOL capabilities of concept 3 and an improvement of the aerodynamics of concept 2. In addition to this merge there is also the inclusion of aircraft landing gear in case of a forced emergency landing. The advantages of this final design include VTOL capabilities, an aerodynamic design and correct landing gear. One limitation for this design is the use of 3 wheels which might provide instability on the road.

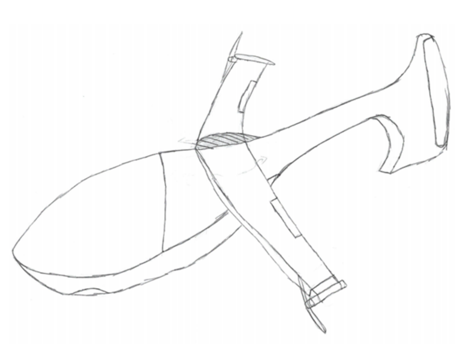


Figure 4 displays the final concept design.

Design Specification Horus (table 1)

Parameter	Value
Take-off method	Vertical Take-Off and Landing (VTOL)
Length	5 m
Height	1.74 m
Width of car	2 m
Wingspan of plane	4.19 m
Weight	1132 kg
Product service life	8 years
Product shelf life	10 years
Main power source	Hydrogen fuel cells
Body material	Carbon fibre
Landing gear retraction time	20-25 s
Ground speed	80 mph
Air speed	100 mph
Ascent Time	4 minutes
Average vertical ascent speed	2.083 m/s
Passengers	2
Wheelbase	1.84 m
Track	1.03 m
Operating temperature	-30C to 60C
Flying altitude	500 m above ground level
Wheel motor power	3x 13 kW
Propeller motor power	2x 22kW

Table 1 contains the design specification for The Horus.

Chassis
The chassis (figure 12) is made up of various I-beams and C-sections. It includes the mounting points for the suspension and wheel system as well as the body. It has been designed to withstand the exerted shock forces from the wheel on landing.

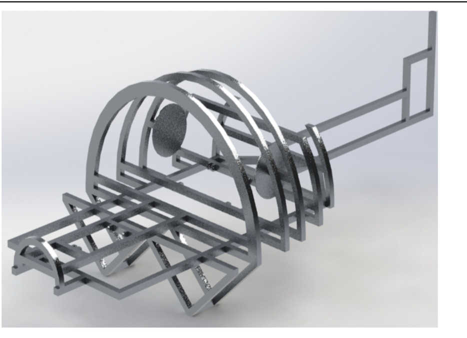
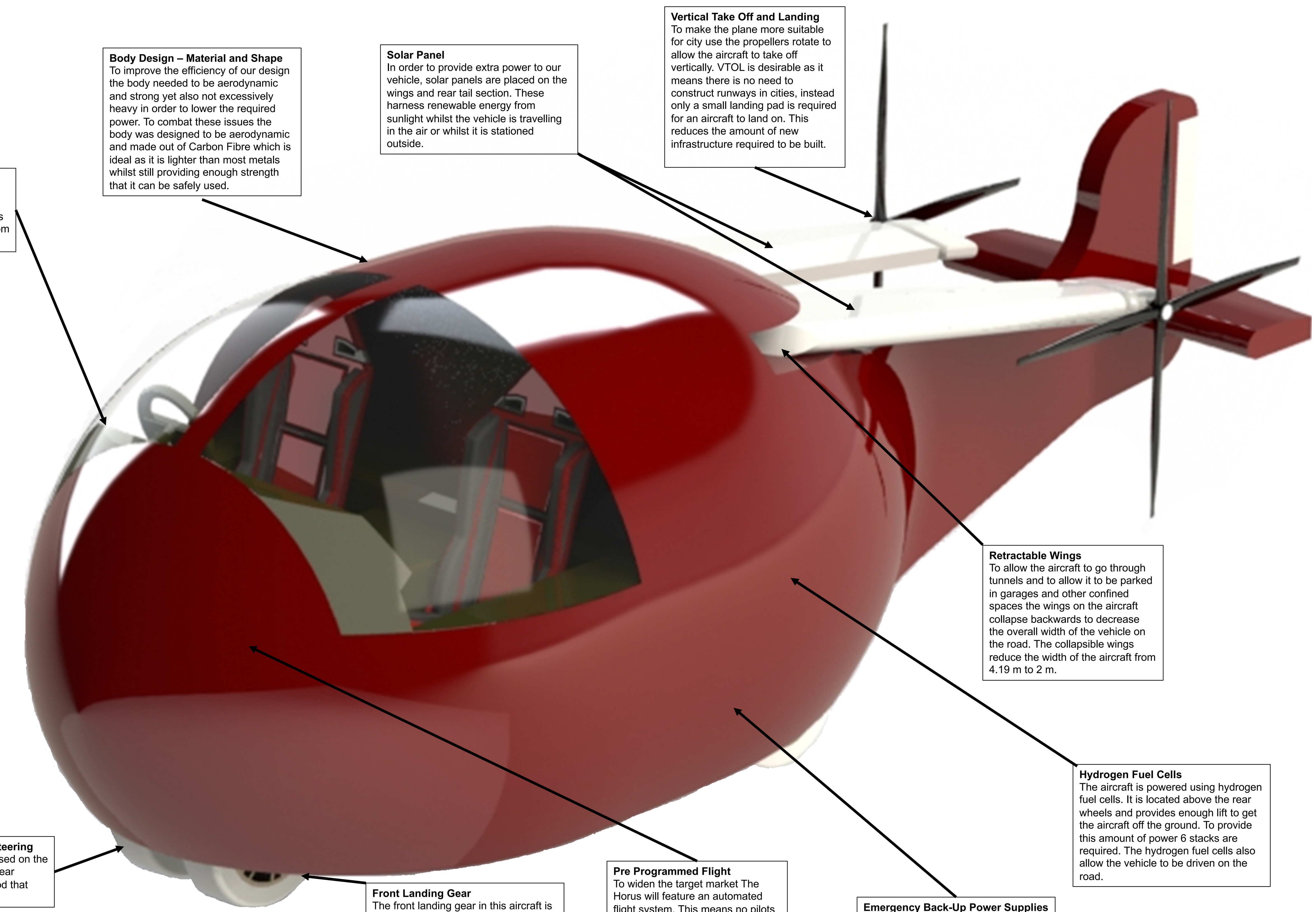


Figure 12 – Isometric view of chassis

Body Design – Material and Shape
To improve the efficiency of our design the body needed to be aerodynamic and strong yet also not excessively heavy in order to lower the required power. To combat these issues the body was designed to be aerodynamic and made out of Carbon Fibre which is ideal as it is lighter than most metals whilst still providing enough strength that it can be safely used.

Solar Panel
In order to provide extra power to our vehicle, solar panels are placed on the wings and rear tail section. These harness renewable energy from sunlight whilst the vehicle is travelling in the air or whilst it is stationed outside.

Vertical Take Off and Landing
To make the plane more suitable for city use the propellers rotate to allow the aircraft to take off vertically. VTOL is desirable as it means there is no need to construct runways in cities, instead only a small landing pad is required for an aircraft to land on. This reduces the amount of new infrastructure required to be built.



Retractable Wings
To allow the aircraft to go through tunnels and to allow it to be parked in garages and other confined spaces the wings on the aircraft collapse backwards to decrease the overall width of the vehicle on the road. The collapsible wings reduce the width of the aircraft from 4.19 m to 2 m.

Hydrogen Fuel Cells
The aircraft is powered using hydrogen fuel cells. It is located above the rear wheels and provides enough lift to get the aircraft off the ground. To provide this amount of power 6 stacks are required. The hydrogen fuel cells also allow the vehicle to be driven on the road.

Front Landing Gear – Steering
The Horus is able to be used on the road as its front landing gear contains a steering method that uses motors.

Front Landing Gear
The front landing gear in this aircraft is able to retract through the use of an actuator. The landing gear is connected to the main chassis of the aircraft via 4 pins as seen in figure 5

Figure 5 displays the landing gear connecting to the chassis.

Pre Programmed Flight
To widen the target market The Horus will feature an automated flight system. This means no pilots license is required to pilot The Horus. The automated system also prevents any sort of air collision as there are no human errors. Additionally, in emergency situations the system is able to locate the safest place to land and ensures the aircraft proceeds there

Emergency Back-Up Power Supplies
To ensure there is minimal risks to the health and safety of the users of The Horus, safety measures have been taken to ensure maximum safety and comfort for the commuters. This includes the use of emergency back up batteries that are capable of powering The Horus until it can land safely. These will be used if there is a fault with the hydrogen fuel cells.

Enterprise

Our company will be a design company operating as a partnership. The company will aim to be environmentally friendly in the production of our planes as well as producing profit to reinvest into the company. The company will also focus on the health and wellbeing of its staff and owners. The company will have staff, monetary assets, intellectual property rights and VR software in order to aid the design process.
The main marketing point of our design is the use of a cleaner fuel in the form of hydrogen fuel cells to power the majority of our electrical systems. Currently hydrogen fuel cells are classed as zero emission systems allowing us to use them and still fit in with our aim of being an environmentally friendly company. We will also market the plane on the use of the VTOL system to allow take-off and landing at any suitable location. Another main feature of our aircraft is the retractable wings allowing the vehicle to be driven on roads and also used as a light aircraft. This allows some journeys to be completed by driving and those which are going to be more affected by traffic can be completed by flying. Our automated flight route system and auto pilot system allow flight to be autonomous from the point of take-off to the point of landing at the destination. This automated system also means that there is less risk of air accidents occurring and no need for owners to have a pilot's license. Our aircraft's individual subsections are broken down in an organisation structure (figure 9) showing the main components that are included in each sub section. Additionally a complete PEST analysis was also completed (table 2).

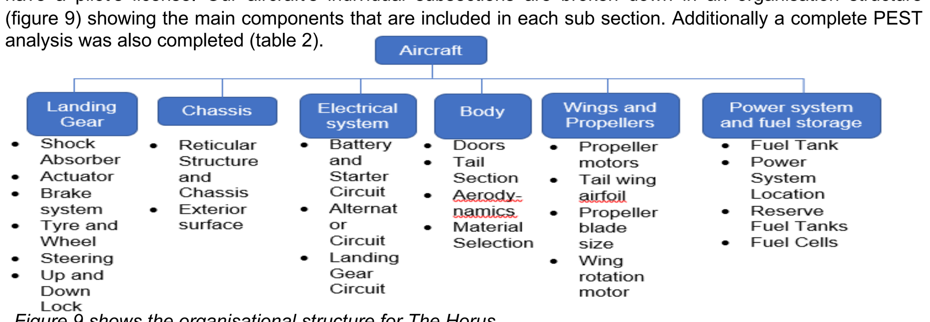


Figure 9 shows the organisational structure for The Horus.

PEST Analysis	
Political Factors	Currently EU law allows for emission levels of 0.50 g/km of carbon monoxide and 0.080 g/km of nitrogen oxide for diesel engines. Conversely, hydrogen powered vehicles are classed as zero-emission vehicles and therefore not subject to restrictions. This reduces restriction on design parameters such as power and therefore greater performance can be achieved. It therefore works towards SDG13 to combat climate change. The current UK conservative government is more lenient to larger businesses than any potential labour government, with a 9% difference in proposed changes to corporation tax between the two parties. However with no clear majority in parliament and differing opinions on Brexit the party is divided politically. This instability could lead to a Labour resurgence at the 2022 general election leading to greater financial restrictions to large companies. The issue of Brexit is also important with the Conservative party intending to leave the single market and customs union. This will allow Britain greater autonomy over its laws though will mean businesses will lose money due to the tariffs present without a free trade deal between Britain and the EU. With Western Europe being a target for sales of The Horus, any increase on import tax will severely affect this vehicles competitive edge against potentially similar products in member states that are unaffected by tariffs.
Economic Factors	There has been an increase in real gross household adjusted disposable income per capita since 2014 in the EU-28. Should this trend continue until sales of our product commence there will be a larger target audience to sell to. Car ownership increased by 670,000 per year from 1997-2007. It took a dip after the recession to 170,000 per year but has been 640,000 on average since 2012. This ownership trend suggest the amount of cars on Britain's will only continue to increase. As such Britain's roads will become busier, meaning a solution to the delays caused by traffic such as our product will become increasing valuable. Individuals earning more than £80,000 will also have more money due to the Labour government not being voted in and imposing their new income tax brackets. Therefore our target audience will have more disposable income to potentially spend on our product.
Socio-cultural Factors	The project will be aimed at the working population of the UK and EU, aged between 18 and 65. Specifically it will be aimed at individuals near large cities, whose daily commute to work is often delayed by traffic and or road accidents and will benefit greatly from avoiding them. The product also targets people who live in remote areas with limited road access as it will prevent them from isolation should roads become inaccessible due to flooding or snow. The target audience will generally be skilled workers due to the cost of our product being relatively high as it is a pioneering design. However this will hopefully change with further days to a wider range of commuters.
Research and Development	Current research into hydrogen fuel cells is being driven by companies in the US and East Asia, with the latter having companies such as Toyota, Hyundai, and Honda that have all competing products on the market. Hyundai in particular have managed to halve the cost of their hydrogen fuel-cell systems since 2014 and expects another 50% decline in the next five years. At this rate of improvement, hydrogen powered vehicles will quickly become much more commonplace as they replace the ever more expensive fossil fuel powered vehicles. This has been done by reducing the amount of platinum used in fuel cells, which acts as a catalyst for electrochemical reactions, by producing ultra-thin platinum films limited to a few atomic layers. The current problem with hydrogen powered vehicles is the same that electrical cars had when first produced, refuelling stations. Companies can't mass produce hydrogen, therefore increasing production and sale cost, until sufficient refuelling stations exist. However counties such as Germany and Japan have invested infrastructure to help promote the usage of emission free vehicles. Companies such as Honda and GM are also working together so different companies share the same platform and therefore can mass produce more quickly. Further research into hydrogen cells will be making them more efficient and cost effective to increase their global usage to help to work towards the climate change targets in the Paris agreement.

Table 2 displays a full PEST analysis for The Horus.

Project Timeline

In order to produce the Horus various steps would need to be taken in order to ensure all the necessary details and components are manufactured (table 3).

Order	Objective
1	Patent Design: • Patent of Key Components
2	Market Research: • Find Target Markets • Develop Questionnaires • Research Financial Backing Opportunities
3	Source Companies for Bought in Components • Find major companies supplying components with correct or similar dimensions • Evaluate prices for both exact and similar designs • Decide whether to opt for exact or similar design
4	Source companies for materials • Research metals and composite companies • Contact companies with design, material and production requirements
5	Source manufacturing companies • Research local manufacturing methods • Evaluate changes to design for manufacturing • Contact companies with design, material and production requirements
6	Build prototype • Transport all components/sub-assemblies to localised factory
7	Test flight • Test aircraft • Market testing for target audience • Improve functionality
8	Design Reveal • Reveal to investors • Reveal to general public
9	Start Pre-orders
10	Start production • Reassess demand and production requirements • Begin production
11	Advertising • Organise potential advert ideas • Contact TV and media companies about advertisement • Contact Influencers about advertising • Create adverts
12	Vehicles available at dealerships • Contact dealer • Arrange distribution of vehicles
13	Release to Public
14	Upgraded Models Available • Release further variations after initial release
15	End of life disposal • Part exchange for new model after 8 years

Table 3 organises the timeline required for the production of this aircraft including its end of life disposal.

Mechanical Summary

Drive:
- Each landing gear (figure 6) has its own motor; this allows simplicity as each gear can be powered separately.
- The motor used is a 10 kW Brushless DC motor allowing a smooth drive phase.
- Steering is via a 24V Brushless DC motor to the front landing gear.
- Shock absorbers of 15 kN mean that the aircraft can land using both V.T.O.L and conventional landing.

Retraction:
- The landing gear is fixed linearly in 4 points to allow for vertical retraction from an actuator.
- A retraction time of 25 seconds means that actuator forces are low reducing overall mass of the aircraft.

Braking:
- 2 brake discs are used per landing gear to reduce maximum pressure needed by the brake calliper.
- In cases of emergency a parachute will also reduce aircraft speed during flight.

Figure 6 displays the complete front landing gear

Civil Summary

A specific cross section of the plane was selected to be analysed.
The cross section was modelled in three sections (figure 7):
The floor beam supporting the internal load (I-beam serial size: 50 x 35 x 0.4). Analysed to check bending and shear forces under ULS loading and the deflection under SLS loading.
The truss which distributes the load to the wing joints (C-beam member serial size 50 x 50 x 0.8). Analysed to check that the deflection is within the limit and that the compression members will not buckle.
The arch supporting the fuselage (I-beam 102 x 102 x 6.2). Analysed to check the bending and shear forces and the deflection under the critical load scenario of cruising at maximum speed and altitude.
The material used for these parts is Al alloy-6082T6 as it is a medium strength alloy which can support the loads but it is cheaper than a high strength alloy.
The material used for the fuselage is Carbon HM fibre as it has a high strength to weight ratio and high corrosion resistance properties.

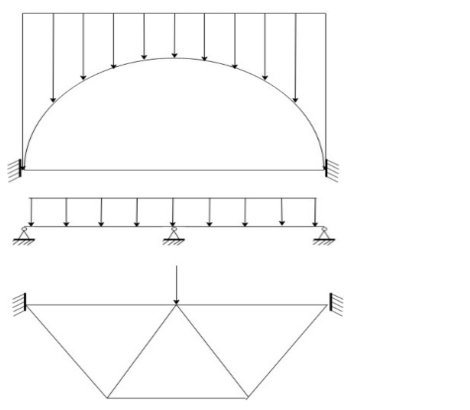


Figure 7 shows the three models that were analysed.

Electrical Summary

The loads, energy systems and control systems of the aircrafts have been simulated. There are 4 key loads that will contribute to the energy usage from the power source. These are the propeller motor, heater and lamp, landing gear motor and PV arrays used on the aircraft. In order for a stable power source, a well-designed energy system and control system was simulated through Simulink and Simscape. The energy system (figure 8) is broken down into a PEMFC fuel cell, PV array, Lithium-ion battery and synchronous generator, each providing power to different systems in the aircraft. There will be 4 control systems, consisting of a generator control system, two fuel cell converters and a PV array control system, used to regulate the output of each energy system.

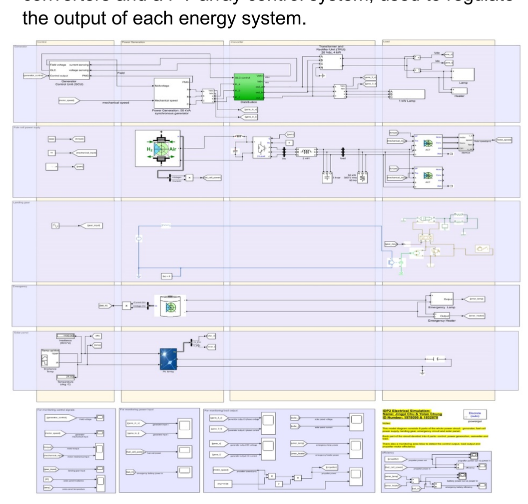
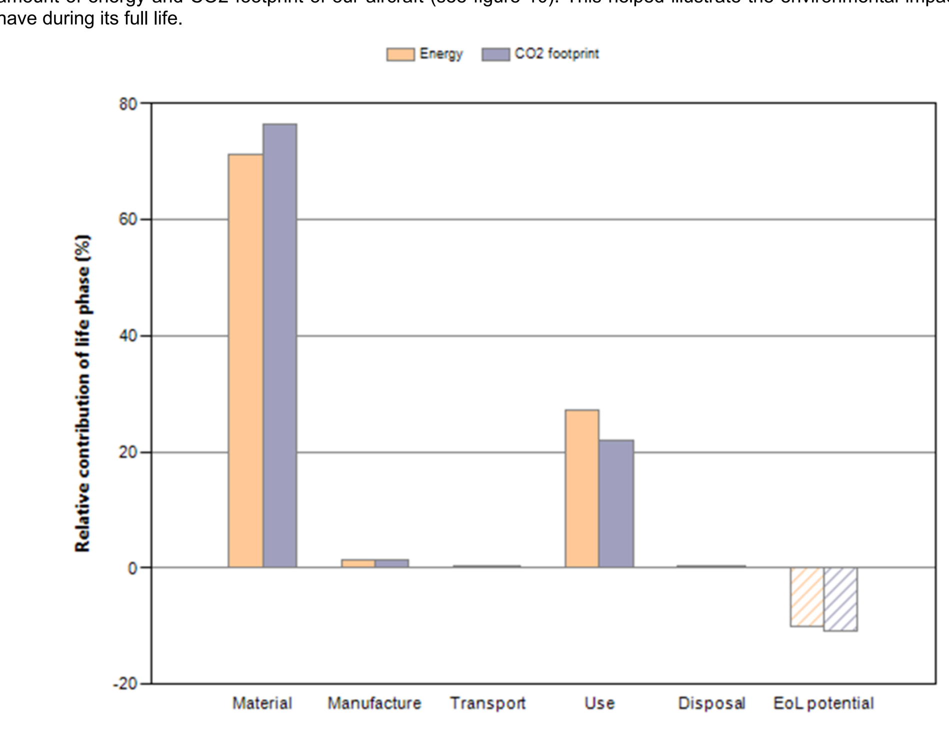


Figure 8 shows the electrical system inside The Horus.

Sustainability

As the main objectives of The Horus is to reduce emissions and help tackle air pollution and climate change, it was important to select the correct materials for our aircraft. A comparison of carbon fibre and aluminium was made for our material selection and we discovered that carbon fibre produced less CO2 and used less energy during its full life cycle than aluminium. Thus, the decision was made to use carbon fibre as our body. After completing the Solidworks model an Eco-Audit was conducted to find the total amount of energy and CO2 footprint of our aircraft (see figure 10). This helped illustrate the environmental impact each aircraft will have during its full life.



Energy details CO2 footprint details

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	3e+05	71.4	2.17e+04	76.4
Manufacture	5.56e+03	1.3	423	1.5
Transport	332	0.1	23.9	0.1
Use	1.14e+05	27.1	6.22e+03	21.9
Disposal	613	0.1	42.9	0.2
Total (for first life)	**4.2e+05**	**100**	**2.84e+04**	**100**
End of life potential	-4.19e+04		-3.1e+03	

Figure 10 displays the Eco-Audit that was conducted for The Horus.

SDG 3 – Good health and Well-Being

The Horus meets SDG-3 as our aircraft uses hydrogen fuel cells as its main power system. The only waste product from hydrogen is water, thus, if our vehicle replaces normal Internal Combustion Engine vehicles then there will be less pollution in the air.
As our flight system is automated, there will be no air collisions; this will reduce the total amount of road deaths. The aircraft can also be converted to carry medical supplies to isolated regions thus providing greater medical care.
The use of The Horus for commuting will make most roads in cities redundant. Therefore, these roads can be removed with trees and large green spaces replacing them along with footpaths and cycle paths. Creating these large green areas in busy cities will improve the mental well-being of people within the city.

SDG 7 – Affordable and Clean Energy

The Horus uses solar panels to generate power whilst in contact with sunlight. The power generated from the photovoltaic cells is stored and used by the electronic components in the aircraft. This increases the shares in the renewable sector and will push for more research in the development of renewables thus increasing employment in this sector and make renewables more affordable and more readily available.

SDG 12 – Responsible Consumption and Production

The Horus uses a negligible amount of fossil fuels during its life, this reduces the dependency and the use of non-renewable resources as an energy source. Thus, this increases the amount of energy harnessed from renewable resources globally.

SDG 13 – Climate Action

The Horus assists SDG 13 as the use of sustainable and renewable resources that are built into the aircraft will create more jobs in the renewable sector. The use of solar panels and hydrogen fuel cells produce much lower emissions than a normal road car. If The Horus ends up being used by a large percentage of the population as a commuting vehicle (as is its purpose) then total emissions will be reduced thus combating climate change.

Health and Safety

The Horus has several critical safety measurements included to ensure safe and efficient commuting. One of these is an automated flight route planning system and an auto pilot system which takes control of the aircraft from take-off at the take-off location to landing at the destination. This ensures that there are no mid-air collisions and that there are no human controlled errors. This system also means that there is no requirement for flight training for the owners of the aircraft. Additionally, if the autopilot system detects a fault or low fuel load then the aircrafts automated flight route planning system will find the nearest safe place to land and proceed directly to it to ensure no damage, injury or loss of life.
Automated pre-flight checks review all the essential aircraft systems before allowing take-off of the aircraft. This means that any error in the system will be picked up before it is possible to become dangerous once the aircraft is in the air. In addition, backup batteries are included for the event there is a failure in the hydrogen fuel cells which provide power to the propeller and flight systems. This means that should a fault occur and power is lost the batteries will provide enough power to land safely without damage, injury or loss of life. Examples of the health and safety analysis conducted includes fault tree analysis (figure 11) and FMEA (table 4).

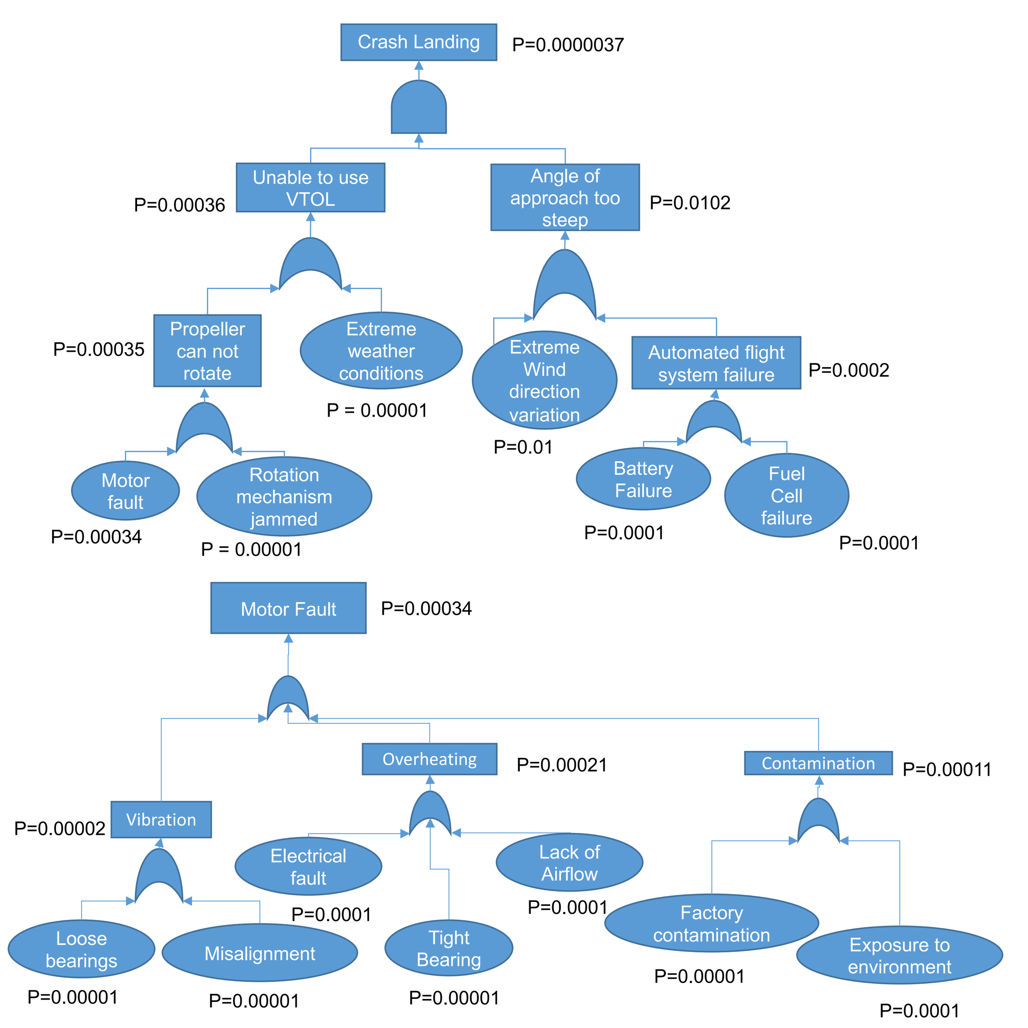


Figure 11 displays the 2 fault tree analyses that were conducted for a motor fault and crash landing for The Horus.

Function	Failure	Failure Mode	Effect
Unfold landing gear in 20-25 seconds	Fails to unfold	Actuator failure	Unable to land smoothly. Seek crash landing location. Land as safely as possible without landing gear unfolded
		No power supply to actuator motor due to wiring fault	Unable to land smoothly. Seek crash landing location. Land as safely as possible without landing gear unfolded
	Unfolds in more than 25 s	Bearings at suspension mount to tight	Delay landing until unfolded. Replace bearings after safe landing
		Supply power to actuator motor too low	Delay landing until unfolded. Diagnose low power issue
Vertical take-off to height of 500 m above ground level in 4 minutes	Fails to take off	Propeller motors fails to start	Unable to take off. Replace or fix propeller motor
		Not enough power to propeller motors to lift aircraft	Unable to take off. Diagnose and fix low power issue
	Does not reach height of 500 m in 4 minutes	Propellers not turning fast enough due to not enough power to propellor motors	Unable to complete takeoff. Land safely, diagnose and fix low power issue
		Excessive weight is being carried on-board	Unable to complete take-off. Land safely and remove weight until below maximum payload weight of plane
Air speed of 100 mph	No horizontal movement achieved in the air	Propellers not turning fast enough due to not enough power to propellor motors	Land safely, diagnose and fix low power issue
		Motors do not turn from vertical take off position due to rotational motor failure	Land safely and replace or fix rotational motor
	Air speed less than 100mph	Not enough power supplied to propeller motor	Land safely and diagnose low power issue
		Propeller angle incorrect relative to desired direction of motion	Land safely and correct issue causing incorrect propellor angle
Wings extend from retracted position before take-off in 30 seconds	Wings don't extend	Extension motor failed	Unable to take off. Replace or fix wing extension motor
		No voltage supplied to extension motor	Unable to take off. Diagnose low power issue
	Wings extend in more than 30 seconds	Power supplied to extension motor too small	Unable to take off. Diagnose low power issue
		Wing extension bearings too small	Unable to take off. Replace wing extension bearing

Table 4 shows the FMEA fault analysis conducted for The Horus