Pearson Edexcel 9DT02 Coursework Marking Training

First teaching in 2017

First assessment 2019

Pearson

Agenda

Overall Objective

- To re-affirm the coursework standard for 2023 post pandemic.
- To return to the coursework requirements as of 2019.

We will look at a whole piece of coursework that fulfils the requirements post pandemic that illustrates what the candidates will need to submit for the 2023 series.

All of the COVID-19 mitigations have been removed and the Quality and Accuracy assessment criterion has been re-instated

Grid One

Identification of a Design Possibility

- To work in a client centred/iterative way, candidates must identify the problems or needs of a client /user group to develop a product that may fulfil their needs. The client / user group could for example be; a target market opportunity, a local business or organisation or an individual client.

- Candidates can explore design possibilities by undertaking market research, conducting identified user group interviews, or responding to a number of identified possibilities and justifying the choice of one.

- We expect that candidates will justify problem starting points from a range of positions. Indeed some candidates will identify a range of problem starting points and others may focus on one and justify it. Alongside the client they need to make a decision on the potential design possibility that they will be working on and produce a preliminary design brief.

- Once candidates have identified the design possibility they need a comprehensive investigation to identify the key information that needs to be researched to inform the design requirements

Non-Examined Assessment – A level Product Design

Gliding

GRID 1

Identification of a design possibility

Context about the sport:

Gliding is an activity in which pilots fly unpowered aircraft (gliders) and attempt to soar by using environmental factors to sustain their flight. The main types of lift a glider pilot may attempt to fly in are thermals, wave and ridge lift. Each of these types of lift can be utilised by glider pilots to gain altitude. The main sporting aspect of gliding comes in the form of competitions, where glider pilots plan cross-country tasks to complete, sometimes nearing 1000km total distance, and race each other round the tasks.

More generally, gliding is commonly accessed through gliding clubs, of which there are 80 clubs in the UK alone. In general, these clubs operate on a volunteers basis where the members that turn up on the day run the airfield. Usually, there are very few (if any) employed members of staff at a gliding club.

Gliding is a day activity. It is dissimilar to powered flying as you typically arrive early in the morning at the club, and leave late evening. You are generally expected to help handle the gliders and help launch others for their flights if you yourself want to fly. Because of the massive ground handling aspect of the sport, there are opportunities to speed up or simplify the operation of a typical day at a gliding club.

Buckminster Gliding Club:

Buckminster Gliding Club is based on Saltby Airfield, a disused RAF airfield active in the second world war. The gliding club was founded in 1971 and now has more than 100 members. It operates 7 days a week (weather permitting) and operates a fleet of 3 two-seat gliders, 4 single-seat gliders, 1 motor glider, a tug aircraft and several ground vehicles. There are also several privately owned aircraft (both powered and non-powered) currently kept at Saltby airfield including 2 private tug aircraft.

The club facilities on Saltby Airfield include; 3 hangars, glider trailer parking spaces, a campsite with static caravans available for rental, a clubhouse, a glider workshop and 4 runways (both concrete and grass). The club has a duty roster where volunteer instructors and members are assigned a day to come and run the airfield. This means that each day the hangar is unpacked and the kit handled by a entirely new set of people to the day before. There are 2 methods of launch at Saltby, winch or aerotow. An aerotow is when the glider is towed behind a powered aircraft. A winch launch is where the glider is pulled in on a cable the length of the runway – similar to flying a kite, it is dragged into the air.

I personally have been a member of the club for over a year, which means I am quite familiar with the day to day operations of the club. Because of the vast member base of the club, there are several club members with 30+ years of experience at gliding clubs all across the country. This means that between the members and myself, any potential points of improvement in the clubs operation can be identified. It is my ambition to expose these points and consider possible solutions and improvements to them.

I will use Buckminster Gliding Club as my client, and will talk to members within the club with lots of experience in gliding. My aim is to manufacture a product that in some way helps the club operate and improves it’s efficiency.

Client Interview

Client Name : Lyn Ferguson-Dalling
Position : Chief Flight Instructor (CFI)
Experience : 30+ years of gliding experience, has been CFI at 2 clubs.

Values:
- Safety
- Efficiency
- Sustainability

Needs:
- Faster start and finish to a day
- More productive use of members time

Wants:
- Cut operating costs
- Increase no. launcher per day
- Maximise use of club aircraft and equipment.

Main identified points:
- Hangar packing
- Towing gliders out
- Obstructions on the runway leading to decreased launch rate
- Lack of manpower
- Decrease expenditure on ground vehicles
- Safety (on ground and in air)

Buckminster Gliding Club and several other clubs across the country are all under pressure (due to current Covid-19 restrictions) to continue to operate and turn a profit. This is proving difficult, as most clubs are lacking their main source of income: experience flights with members of the public. This means now more than ever, clubs are looking to cut costs and increase the amount of flying done per day. This cannot be achieved without simplifying aspects of the day's operation, and decreasing the time taken to commence launching.

Unique shape of Saltby airfield, towing gliders taking too long

What would you say slows down the launch rate the most?
Gliders overshooting the launch point and having to be retrieved by hand/buggy….. Launches have to wait until the landed glider is returned to the launch point thereby slowing down the launch rate.

Hangar packing involves tessellating gliders to fit the maximum number in one small space

Gliders are often very close together and can be damaged in packing.

Having been a member at several clubs, are there any parts of a gliding club's operation in general that you think could be improved upon?
The ability to pack/unpack the hangar efficiently and to have as many gliders as possible in the hangar would be an improvement. I have witnessed a number of methods of 'hanging' gliders in the hangar at other clubs along with other ways to maximise the space in the hangar.

Maximising the use of club members time to improve efficiency

What would you say is essential in the operation of the club? E.g. (speed, efficiency)
Safety is our top priority so anything that contributes to or improves our safety culture would be a major improvement. After safety anything which improves the number of launches achieved and the overall efficiency of the day to day operations would be of real value to the club.

Electric alternatives both reducing cost and reducing maintenance hours for engineers

The club operates several ground vehicles fuelled on diesel and LPG. Do you think electric alternatives to these vehicles are a viable option for the club in the future? Both to save money and maintenance hours?
The introduction of electric alternatives to Diesel and LPG would be of great benefit to the club. Not only will it potentially reduce costs it will also align with our sustainability strategy and inevitably vehicles in the future will need to be electric.

Lack of manpower results in excessive time spent moving kit.

Club generates income through flying so lack of manpower is a direct loss of income

When you are the Duty Instructor, do you ever find there is a shortage of people to help complete tasks?
Yes – we are very slow in setting up the launch point – this can take 1.5 hours which is time we could be undertaking training/flying… Equally the end of the day can be difficult with a lack of manpower to return the gliders to the hangar. Very often the few people left have to undertake multiple trips to take the gliders back to the hangar.

There are several jobs that require doing simultaneously for an efficient start and finish

Freeing up members to complete other tasks will increase efficiency.

On a normal day at the club, what would you say is the most time-consuming or inefficient process in the operation we have to do?
Getting the gliders out to the launch point (and particularly Runway 07) is a very inefficient process with club members having to walk the gliders out to the launch point. A way of getting the gliders out to the launch point which would minimise the use of the manpower that can be utilised for other set up tasks would be a huge benefit.

Club gliders are towed by vehicles 1 at a time

Hangar packing it is very hard to pack the hangar correctly everyday

Are there any potential areas of improvement you can think of in the ground handling of gliders?
The majority of our gliders do not have one man tow out kits – therefore the moving of gliders is manpower intensive. If we could improve in this area it would be helpful. Equally the way we get gliders in and out of the hangar is very inefficient – if we had a way of improving this activity it would be helpful.

Increasing efficiency in the morning would lead to an earlier start and therefore more flights in one day.

What would you say is the most important aspect of the club's operation to help the club make money?
The ability to increase the number of flights on a given day would generate significant improvements in income generation. If we could start the day more efficiently, manage gliders on the airfield with minimum manpower and put the gliders away at the end of the day it would greatly improve our efficiency. Equally if we could manage the launch point more efficiently and increase the number of launches undertaken in a day this would increase income.

Investigation of a typical day at Buckminster gliding club

Morning prep activities:

- Arrive at club
- Morning briefing
- Unpacking hangar
- Daily inspection of gliders
- Daily inspection of winch and tug aircraft
- Tow winch out
- Tow launch point vehicle
- Tow gliders out
- Taxi tug to launch point
- Park and anchor gliders not in use
- Tow winch cables out
- Begin launching

The club tries to fit as many aircraft as possible into the hangar. This involves pushing some in sideways and there is lots of overlap between wings etc.

An image of how the hangar is packed with the current number of aircraft

All ground vehicles and aircraft require pre-flight inspections to find faults before they are moved to the launch point

The club operates an LPG fuelled golf buggy and 3 diesel fuelled vehicles. They are used to tow out the gliders and often require fuelling in the morning.

Fuel ground vehicles?

The launch point vehicle is a shipping container on a chassis with wheels. It's purpose is to provide an indoor space on the airfield. It requires towing by the club land rover

Due to the unique shape of Saltby Airfield, the gliders have to be towed a considerable distance.

Gliders are very light and can be blown over by wind whilst on the ground. The club parks them and secures them with old tyres

The winch has 2 cables which are attached to a flatbed truck and towed out down the runway. This tends to take around 5 minutes.

When on Runway 25, the distance we tow the gliders is 600m

Standard tow out from hangar when operating on runway 25

Hangar for private aircraft

Location of the main hangar

Cycle of events during winch launching:

- Begin launching
- Hook glider onto cable
- Launch glider
- Hook 2nd glider onto cable 2
- Launch glider
- Tow winch cables out
- Repeat cycle

Launch failure?

- Send vehicle and crew to glider
- Tow glider back to launch point
- Retrieve winch cable

Usually 3 people are necessary to tow a glider; 1 to hold the wing, 1 to drive the vehicle and another to walk by the nose.

The winch cable can often land in a field over a fence after a launch failure. To retrieve it often takes over 20 minutes.

Winch location when on runway 25

Launch point location on runway 25

The launch point and winch swap ends when on runway 07

Packing up activities:

- Begin towing gliders back to hangar
- Pull in winch cables
- Tow winch back to hangar
- Tow launch point vehicle back
- Taxi tug to hangar and refuel
- Pack hangar
- Debrief

When operating on Runway 07, the distance we tow the gliders is 1.6km

Area of focus – Ground Handling

At all gliding clubs, ground handling gliders is the most time consuming aspect of the operation. It requires lots of members to participate in moving the gliders. This really does slow the day down (the previous slide illustrates there are several other key jobs to be done to setup a day's flying). If fewer members were required to handle the gliders, other jobs could be done simultaneously and a more efficient start to the day would be possible.

Unpacking hangar

Packing and unpacking the hangar is often one of the most time consuming things in a day.

To both fit all the aircraft into the small space and avoid damaging them, great care must be taken whilst handling them

Some aircraft are slid into the hangar sideways, on 'dollies'.

Wooden chock to stop glider rolling on dolly

These dollies have 4 castor wheels which allow the glider to be moved in all directions without changing it's orientation

It is common for packing and unpacking the hangar to take over 20 minutes

The hangar only has doors at one end so gliders are packed from the back wall to the front doors of the hangar.

Buckminster currently has another aircraft in the workshop, which will also need to be fitted into this hangar

Packing and unpacking the hangar is an essential part of a days operation. It is common for the gliders near the back of the hangar to not be flown as members are not willing to unpack all the gliders before them to get to them. It is common for gliders to get 'hangar rash' (scuffs and cosmetic damage to the aircraft) from being moved on a daily basis.

An area of improvement here could be a braked hangar dolly. Such a dolly could have a hand held controller which triggers a brake on the dolly to stop it instantly. This way, any glider about to make contact with an object could be instantly stopped to prevent 'hangar rash'.

Tow gliders out

As illustrated in this diagram, the tow out pattern for the gliders is quite complex, with several turns and obstructions on each side of the glider.

The gliders are towed by a golf buggy or car, each with a tow rope fitted. As gliders often have 1 central wheel, someone is required to hold the wing of the glider, and steer it on the ground. As the glider is towed by a rope with no compressive strength, another person is required to walk just in front of the wing, to stop the when the tow vehicle comes to a stop. A 3rd person is therefore required to drive the vehicle.

Normally, no more than one glider can be towed by a vehicle at once. This means that each vehicle has to tow a glider out, return to collect another and then tow that out. The vehicles often require re-fuelling with diesel or LPG which the club has to buy in and store on site. Both using this fuel and storing it are expensive for the club, and delays starting launching in the morning.

There is another method of towing out more commonly used with privately owned gliders. If you have a tow bar on your car, glider 'tow out gear' is available which allows you to tow the glider out with your car, and requires no extra people to help:

Tow out gear generally consists of a tail dolly (a fibreglass sleeve which wraps around the tail with a castor wheel), a wing dolly (a fibreglass sleeve which wraps around the wing with a small wheel fitted) and a tow bar. The tow bar hooks onto the tail dolly and attaches to the car. The wing dolly supports the wing and adds enough weight to one wing to stop the other from dragging along the ground. Buying the tow out gear can be expensive, and fuel is still burned in the process. Additionally, you need a tow bar fitted to your car.

An area of improvement here could be an electric tow out device, which both reduces the cost of operating vehicles with engines, and requires less people to tow the glider. If the glider had a wing dolly, only 1 person would be needed to tow the glider. The tow out device could be charged overnight for the next day's use.

Begin towing gliders back to hangar

Gliders can only be towed one at a time. As a result each glider requires one vehicle to tow it out. If operating on runway 07, and all the gliders are required, the club does not own enough ground vehicles to tow them all at once. This means some vehicles have to drop the gliders and drive back to tow another out. We cannot begin launching gliders whilst there are other gliders being towed up the runway. This can result in the time taken to tow all the gliders out being over 30 minutes.

One of the club gliders however has a small hook on it's tail. This allows a second tow rope to be attached via a karabiner. A second glider can then be 'daisy chained' to the first and two gliders can be towed by 1 vehicle.

Each glider still requires 2 people to handle it when being towed, but it does mean a faster start in the morning as fewer trips are required to tow gliders.

A drawback to this method of towing is the increased difficulty in steering the gliders, and stopping them from running into each other. If the towing vehicle has to stop, there is the risk that the second glider can run into the back of the first, which could result in £10000+ worth of damage. Additionally, airfields often have slopes or gradients where the gliders are towed. At Saltby, towing from the 25 end to 07 is uphill. However, 07 to 25 is downhill so the gliders often continue to roll under their own inertia when the tow vehicle slows.

An area of improvement here could be a fixed 'daisy chain dolly'. Such a device would allow any of the club gliders to be attached together and towed. The first glider would be towed normally with a rope, but would feature a small tow bar like attachment to hook over the glider's tail dolly. On the other end of this tow bar attachment, is another end to attach to the tail dolly of the second glider. This would mean the second glider would be towed backwards.

An advantage of this idea would be avoidance of the second glider rolling into the first as the tow bar would have good compressive strength. Another advantage would be any two club gliders could be towed together, speeding up the operation.

Investigation of Design Possibilities

Problems in a day's operation:

- Unpacking and packing hangar efficiently and quickly, without causing expensive damage to aircraft
- Towing gliders while safely using the least manpower possible
- Gliders having to be retrieved from the runway before launching can resume
- Time management
- Lack of manpower at the end of the day
- Gliders packed towards to back of the hangar rarely flown due to inconvenience of unpacking aircraft to get them out

As a member of Buckminster gliding club for over a year, I have been involved in the ground handling of gliders frequently. The issues outlined are heavily influenced by external factors. For example, towing gliders out becomes a lot more dangerous and difficult if it is relatively windy. Packing and unpacking the hangar is more likely to cause damage to other aircraft with fewer members present.

A solution to some of these ground handling points would greatly improve the clubs ability to operate on days where fewer members are present, and days where the weather is more challenging. This would allow the club to gain income on days where it may not have operated in the past.

Design Possibility	Description	Advantages	Disadvantages	Realistic alternative to status quo?
Electronic tow out assist	Electric device designed to replace the vehicle used to tow gliders. Device would hook under tail of glider and tow the glider with an electric motor	❖ Reduce the number of people required to tow glider from 3 to 2 ❖ Reduce expenditure on LPG and Diesel ❖ Small and compact saving hangar space	❖ Would require charging and suitably sized batteries ❖ Difficult to manufacture	I believe this device has real scope for implementation at gliding clubs. It would vastly improve the operation and cut costs
Brake assisted hangar dolly	This hangar dolly would feature a braking system allowing it and the glider upon it to be stopped quickly and effortlessly if needed.	❖ Reduce the risk of damaging other aircraft in hangar packing ❖ Brake could be left on so glider can't move when in hangar	❖ Often it is unclear if damage is going to be caused when moving the glider – you may not always know to use the brake until it is too late	This idea would reduce manpower in packing the hangar, as no one would be required to stop the glider, however efficiency wouldn't necessarily be improved
Glider hanging device	As demonstrated in the picture to the left, this device would suspend a glider from the ceiling of the hangar, creating more ground space.	❖ Increase the number of aircraft in hangar ❖ Simple winch mechanism means glider easily lowered and raised	❖ Gliders beneath suspended glider would need to be moved to lower it. ❖ Training would be needed to use safely	This is a method that is used at other gliding clubs (as seen in picture). It is a good space saver but does not increase efficiency
Hangar packing projector	A projector fitted to the roof of the hangar which projects the outline of the various gliders onto the floor, so they are packed in the same position each time	❖ Speed up the packing process as positions are marked ❖ Less of a chance gliders damaged whilst in hangar	❖ The contents of the hangar varies frequently meaning different types of gliders are sometimes stored	As different gliders and equipment are stored, the projection would have to be changed constantly. It would however ease the process of packing
Glider 'daisy chain' towbar	A linking towbar between two glider's tail dollies so they can be towed together	❖ More efficient towing gliders out ❖ Reduces manpower required	❖ Some tail dollies differ in design so wouldn't be fully compatible with all	I think this would be very useful to the club by saving time and manpower

This image shows a glider suspended from the roof of the hangar using a winch. I took this picture at Midland Gliding Club earlier this year.

Midland gliding club has only got one hangar, so it is essential they fit everything in. Saltby has one club hangar which is larger than Midland's, but Saltby also has to fit all the ground vehicles in with the gliders.

Another image of the hangar at Saltby, demonstrating how close the gliders are to each other in the hangar, and how much care is required to move them without causing damage.

Ground vehicles are also stored in the hangar at Saltby.

Preliminary Design Brief

Problem:

Every day at a gliding club, the gliders have to be moved to the launch point, and towed around on the ground regularly. For club owned gliders, the normal method of towing is with a tow rope, using 3 people. This is a highly inefficient process using lots of time and lots of manpower. Gliding clubs are constantly looking to cut costs and increase profits, as the sport is in decline. The time taken in the morning and the evening to tow the aircraft out, could be used for flying. Multiple trips to and from the hangar are often required to get the aircraft. Additionally, fuel is used to tow the gliders which the club has to purchase and supply to it's vehicles. I have witnessed this problem a countless number of times at gliding clubs across the country, and have missed out on flying due to a slow start/finish to the day.

Preliminary Design Brief:

Therefore, as a response to this problem, I will attempt to design and manufacture a product which reduces the number of people required to tow a glider, reduces expenditure on fuel and is a faster, more simple method of towing the gliders around the airfield. My product should maintain professional-looking aesthetics, whilst functioning in a way that is a better alternative to the current method of towing.

I have elected to produce an Electronic tow out assist which hooks onto the tail of a glider and drags the glider at a walking pace. This would negate any need for a 3rd person to stop the glider running into the tow vehicle, as the tow rope is eliminated from the process. The product would tow the glider at a walking pace, and would require a person to steer the aircraft and another to hold the wing. If the glider has a wing dolly, only 1 person would be required to tow the aircraft. The product would feature 1 electric motor, a lead acid battery and a simple drive mechanism, all encased in a fibreglass cover. The product would be designed to fit any tail dolly of a glider, allowing them to be towed with ease. It would be electric powered, which a charging cable to be plugged in overnight when the product is not in use. It would be very compact and will reduce storage space required for ground vehicles.

Buckminster gliding club would be able to use this product on both their 2-seat aircraft and their single seat aircraft. The club does not have 'tow out gear' for any of their gliders, so the only option available for towing them at the moment is by tow rope. Additionally, these electric devices would be compact enough to be stored in the hangar, taking up significantly less space than the ground vehicles. Overnight, they would need a power source to charge them for the following day, however, this is not an issue due to the availability of plug sockets in most hangars.

My product will be electric powered. It's drive system will be simple, and it will only need charging overnight. This will reduce expenditure on fuel, and any maintenance will be quick and easy

My product is aimed to satisfy or improve upon the following points from my client interview:

My product will lead to a faster start to the day by reducing people needed to tow gliders, freeing them up to help elsewhere

What would you say is the most important aspect of the club's operation to help the club make money?
The ability to increase the number of flights on a given day would generate significant improvements in income generation. If we could start the day more efficiently, manage gliders on the airfield with minimum manpower and put the gliders away at the end of the day it would greatly improve our efficiency.

My product would be quick and simple when towing the gliders, alleviating the risks associated with towing by rope

Are there any potential areas of improvement you can think of in the ground handling of gliders?
The majority of our gliders do not have one man tow out kits – therefore the moving of gliders is manpower intensive. If we could improve in this area it would be helpful.

Due to lack of tow out vehicles and tow out kits, it is not uncommon for gliders to be pushed out by hand. Gliders can weigh up to 800kg so pushing them is a slow and difficult process. This will not be necessary with my product as it will fit gliders without tow out kit.

The club operates several ground vehicles fuelled on diesel and LPG. Do you think electric alternatives to these vehicles are a viable option for the club in the future? Both to save money and maintenance hours?
The introduction of electric alternatives to Diesel and LPG would be of great benefit to the club. Not only will it potentially reduce costs it will also align with our sustainability strategy and inevitably vehicles in the future will need to be electric.

When you are the Duty Instructor, do you ever find there is a shortage of people to help complete tasks? Yes – we are very slow in setting up the launch point – this can take 1.5 hours which is time we could be undertaking training/flying… Equally the end of the day can be difficult with a lack of manpower to return the gliders to the hangar. Very often the few people left have to undertake multiple trips to take the gliders back to the hangar.

With my product, multiple trips to the hangar will not be necessary, as fewer members are needed to tow one glider, so there will be more available manpower for other tasks, such as towing the other gliders

Summary Grid 1

- We do see evidence of an investigation of design possibilities.
- The candidate does explore some of the needs wants and values via a client investigation, and indeed some useful discussion with interested stakeholders.
- The client interaction does evidence some justifications for the design possibility.

This therefore is a level three submission.

Possible Further Evidence to access the higher levels

- **A greater use of target markets/interviews of stakeholders to further explore all possibilities**
- **More detailed research planning that links the design possibility to the research phase to provide real focus for the research.**

- **The candidate gains 8 Marks in this criterion out of 9.**

GRID 2

Investigation of needs and research

Grid 2

- Investigation of needs and research

- In this section candidates are expected to identify needs and identify research that will provide information to help the development of the new product.

- Candidates should/could
- Identify suitable stake holders (Market opportunity, local business /organisation, individual client) and their needs.
- Evidence in-depth investigation of pertinent design possibility in consultation with the client. And the needs of the situation.
- Undertake an effective identification, justification and investigation of the design possibility.
- Undertake an exploration that links to the design situation and addresses the identified needs in the investigation
- Undertake focussed research including considerations of form function and sustainability.
- Look at the work of others and existing product analysis to provide further iterative triggers.

Analysis of the User Needs, Wants & Values

Needs, wants & values	Analysis
Safety	My product will be used for the movement of aircraft on an airfield. This in itself is a dangerous activity as airfields are often extremely busy. The product must therefore provide a level of manoeuvrability that matches or exceeds the current methods of moving aircraft.
Efficiency	To increase efficiency, my product must have a suitable battery life allowing it to function without charging for extended periods of time. To be better than petrol or diesel alternatives, my product should require less work an maintenance, and less care, and simply be plugged in during the night and be ready to use by morning. This will help the operation speed up, as less time will be allocated to maintaining ground equipment.
Sustainability	To help reduce the club's running costs, this product should be relatively simplistic in it's operation and use, to allow easy, fast and cheap work to be done on it if ever needed. It should be cheap to make, cheap to run and cheap to repair. It's electronic motor will save the club money being cheaper than fuelled alternatives, helping the club cut costs during what has been a challenging financial year.
Faster start and finish to the day	My product will free up club members to help with other tasks in the morning and evening, allowing the club to speed it's operation and make the most of a flyable day. To make my product useful to the club, it must also be quick and easy to switch between aircraft being towed. This would decrease the time taken to hook aircraft up and speed the start and finish of the day.
More productive use of members time	As a vast majority of a day at gliding clubs is spend moving the aircraft around, it's where most time is lost. Other tasks are often not completed or delayed due to lack of manpower. My product will have to be less labour intensive than current methods and will change how club members spend their time at gliding clubs.
Cut operating costs	Similar to the sustainability value, my product must help the club cut operating costs. By requiring fewer people, the club will be able to operate on days where not many people can make it. In the past, days have often been cancelled due to lack of man power. With my product, the club will be able to operate when less members are present, making the club money from the flying.
Increase no. launches per day	Increasing the launch rate is always about saving time. More prevalent now in winter, the days are short so for the club a faster start and finish increases the time left for flying and for more launches. Additionally, my product will speed up the operation during the day by helping move gliders around the launch point more efficiently.
Maximise use of club aircraft and equipment	The club often leaves certain aircraft in the hangar as they are too much effort to get to the launch point. My product will allow any member to get any of their desired aircraft out of the hangar and to the launch point. This will help the club use all of it's aircraft and allow members a better selection of gliders.

Values:
- ❖ Safety
- ❖ Efficiency
- ❖ Sustainability

Needs:
- ❖ Faster start and finish to a day
- ❖ More productive use of members time

Wants:
- ❖ Cut operating costs
- ❖ Increase no. launcher per day
- ❖ Maximise use of club aircraft and equipment.

Follow up questions for client:

Follow up questions for client:

- ❖ What is your initial impression of the preliminary design brief?
  - Very Good
- ❖ Are the aesthetics of the product important to the club? (e.g. looking professional to the public)
  - Yes – looking professional will add confidence in its capability and use
- ❖ What would you say is a minimum period of time for the batteries to last? (e.g. 2 full days of operating)
  - Initial design 2 days operation so that 1 full day will be achievable after ageing
- ❖ Are there any additional features you would like the product to include?
  - Would it be possible to have changeable tow bars for gliders, Motorgliders, tugs?
- ❖ Do you think this product would be beneficial to the club?
  - Yes
- ❖ What size does the product have to be? (e.g. smaller than the buggy so multiple could fit in the hangar)
  - As compact as power requirements and traction capabilities permit
- ❖ Will the product need to be resistant to the weather? (Water resistant etc. could be stored outside?)
  - Must be showerproof – will be stored in the hangar
- ❖ Is it important that the product fits all gliders at Saltby, or just club aircraft?
  - All aircraft
- ❖ Can you think of any issues with this product or issues it may cause when in use?
  - One man operation with wing dollies could produce manoeuvring problems

Analysis of the needs of the prototype

Needs of prototype:
(extrapolated from previous slide questions)

- ❖ Must be able to tow all aircraft at Saltby
- ❖ Must have a professional appearance
- ❖ Must be able to operate for 2 days without charge
- ❖ Must be able to take a range of tow bars to tow other aircraft
- ❖ Must be compact and easy to store
- ❖ Must be water resistant
- ❖ Must be sufficiently manoeuvrable
- ❖ Must feature an emergency release
- ❖ Must be able to be charged from a wall socket

There are several different types of aircraft at Saltby, all with different configurations for being towed

→ Perhaps some sort of tow ball fitment, where a variety of tow bars specific to different configurations of aircraft can be interchanged

→ Alternatively, an adjustable tow attachment may do the same job, taking up less space. Adjustable 'jaws' used to hook onto different tow fittings on the aircraft

→ Perhaps something similar in nature to this:

Having a professional appearance will help the club make a better first impression to visitors

→ A variety of finishes will be available for whichever materials are best suited to the product. Perhaps bearing the club's logo etc.

Being able to operate without a nights charge is essential, as the product will be operated by the untrained members, who may forget to plug it in

→ A sufficiently sized battery paired with an efficient motor should be tested to see if they are adequate for this

→ Additionally, the battery must also be able to be charged relatively quickly.

Very important as there are never any aircraft we always get out, it varies greatly.

Due to lack of hangar space, it's important this product is compact

→ The motor and battery combination must be arranged in the most compact form possible

→ Any drivetrain components must also be arranged in this manner.

→ Having these parts being packed in with less exposed areas could also help with water resistance

As gliding is an outdoors activity, we often end up being rained on with all the kit out

→ As the product will be electronic in nature, this is even more important. The finishes used on materials will have to protect them from water

→ To protect the internal electronics, perhaps some form of sealant could be used to prevent water from entering

→ Alternatively or additionally, the electronics inside could be encapsulated in their own protective water-proof boxes.

It is essential that the product allows as much control as current methods

→ If being used with a wing dolly, the lack of someone steering on the wing may cause problems

→ To counter this, my product must have a good range of motion on the steering axis

→ It must also have little resistance when pulling the handle to turn it

If something is going wrong, it's important the aircraft can be released from the tow quickly

→ Expensive damage can be caused on the ground

→ Some form of a pin attached to a pull cord may be the answer here

There are several wall sockets in the hangar, which would be used for charging.

→ This would also allow the product to be used at other clubs without any modification

Scale of production for the prototype:
As my product will be relatively complex and almost exclusively custom, it will take a large period of time to manufacture. This means that one off/job production is probably the most suitable method for my prototype. For me, it will also be relatively expensive to produce so when scaled up to being marketed, the product will likely have to be sold at a relatively high price. Additionally, impacting this price will be the time it takes to produce the product, likely raising the price again. It is important I make sure that my product is still cost effective for both me, and the consumers.

Scope of market:
In the long run, my product could be offered to all 80 gliding clubs in the UK. Some larger clubs may require 3 or more of these products, where as smaller clubs may only want 1. The market for this product is relatively small, however, if it is a success in the UK, it could potentially be offered through mainland Europe where Gliding is a much bigger sport than in the UK, and is a bigger market.

Research plan

Research Area	How can I find information on this?	Relevance to product
Existing similar products	Could be found online, or in shops such as B&Q for products suited for more common purposes	Utilising any information from researching into existing products could give me ideas into how to improve my product. Additionally, seeing how different designs tackle similar tasks will allow me to see what approach would work best for my purpose
Battery/motor combinations	Online (mostly in specifications for products)	Seeing what other manufacturers have chosen to power their products will help me narrow the selection of a battery/motor combination for my product. I could do this by looking at the function of the product, it's towing speeds and weight limitations and it's maximum duration. This will all help me find the best suited combination for my product.
Design styles and themes linking to aviation	Online (e.g. documents relevant to design of aircraft)	In seeing what themes and ideas aircraft have been shaped around, I may be able to take the same themes and ideas and design my product around them. This would help make the product look suitable on the airfield, and aesthetically pleasing.
Ergonomics	Online, or personal experience from utilising similar products	Analysing ergonomics of products is essential to making my product as user-friendly as possible. Any information found could give me ideas to design my product around, meaning user experience would be a factor in all stages of design
Anthropometrics	Online (e.g. studies on similar actions/products)	Knowing anthropometric information surrounding similar motions/products will give me baseline data on aspects of my product. I may be able to determine certain dimensions about my product to make it comfortable to a range of users by analysing this information.
Relevant Standards	Online (e.g. Government website)	Knowing which relevant standards will apply to my product, will allow me to manufacture it to those standards, in turn making it safer to operate and more reliable.

Research into similar existing products

Electric pallet trucks:

How do they work?
These pallet trucks function in a similar way to how I see my product functioning.
They feature an electric motor which drives one main wheel. This wheel has a tyre for traction. They are steered by this wheel which is directly connected to the handle. The handle features the throttle to control the speed, and other controls for lifting heavy loads.

How do they link to my product?
The main thing I take away from this design of pallet truck, is the control handle and driving wheel. While my design may feature multiple driving wheels, the principle is the same. A handle which bears the throttle, and when moved side to side steers the assembly. Additionally, the electric motor and battery setup may be similar to the combination I will use.

How do they differ to my product?
These are designed to operate on smooth warehouse floors. Saltby airfield has been around since WW2, so the surface of the concrete is covered in stones and has several cracks and holes. My product then will need to have bigger, grippy tyres with sufficient weight over them to be able to pull the heavy loads I am intending to.

Electric trailer mover:

How do they work?
These trailer movers feature a simple battery and electric motor, which drive the rear wheels. There is a tow ball attachment fitted towards the rear of the machine, and throttle and on/off switch are positioned on the handle which is once again used to steer the device. These movers generally have bigger heavy duty tyres for the rough terrain they operate on.

How do they link to my product?
A particular note of importance with these designs, is the fact they have 3 wheels in a tricycle arrangement. This may be something I could utilize, rather than a Segway-like 2 wheel setup. Other than that, the large tyres and tow ball attachment are all things that could be incorporated into my product. These trailer movers may be better suited to move heavier things than gliders, so the motor is larger.

How do they differ to my product?
The main difference here is in size. My product should be much more compact. A 2 wheel design may help to keep my product compact, however the 3 wheel design would seem to provide more stability. Additionally, my product would not need a motor as powerful so that would save space and allow me to make the design smaller and more compact.

These 4 categories of existing products will be analysed in detail on the following slides.

Powered aircraft hangar tugs:

How do they work?
The drive system is very similar to the other products mentioned. Where they differ is the methods used to attach to the nose-wheel of powered aircraft. Some 'pinch' the nosewheel with 2 prongs that slide into holes in the nosewheel cowling. Others rest the entire nose gear assembly on them and 'chock' them back. My product would likely use the first method.

How do they link to my product?
As these are custom suited to aviation, they have many of the safety features my product will have to incorporate. They can be stopped very quickly and easily, they all have easy releases and move at a sensible speed to avoid damage. These are all properties that my product must include to be safe on an airfield. Gliders typically weigh less than powered aircraft however my tug device will be used to tow both.

How do they differ to my product?
These are all designed to tow the nose gear of powered aircraft. Gliders do not have nose 'gear' as such, and are more commonly towed from the tail. This means my product will need to have several different methods to attach aircraft, including the 'pinch' method outlined before, as all of the glider tug aircraft at the club are towed in this manner.

Electric jockey wheel:

How do they work?
Commonly found on caravans, these jockey wheels are designed to fit to the front of a caravan and help move it around without the use of a car. They feature a simple electric motor which drives one wheel, and a pole which goes through the jockey wheel post on a caravan. The wheel is fully steerable by the handle on its right. The product only works on concrete.

How do they link to my product?
The aspects they will share in common are simply the electric motor setup, the drivetrain setup and the battery. The design is powerful enough to move a caravan and yet extremely compact. Both are qualities that will need to be included in my product. The motor and battery combination may be very similar to the combination I will use in my product as it is powerful enough to move a glider at the correct speed.

How do they differ to my product?
My product should feature 2 or more wheels for better stability and grip on the ground surface. The one wheel design would not work as my product will be designed to stand by itself and not be made to be attached to another frame to operate.

Specific Research 1: Electric pallet trucks

Hyster PC 1.5 Compact Lithium-Ion pallet truck:
https://www.hyster.com/emea/en-gb/product-range/product-overview/pallet-trucks/PC1.5/

Technical features and specifications:

- 0.75Kw drive motor
- 48V 10Ahr lithium-ion battery – optional large battery with 3-hour fast charger
- Performs well on gradients
- Spare battery enables continuous operation with just a 6-second battery exchange
- Ergonomically designed operator handle, with all controls in easy reach
- LCD display for battery life and on-board diagnostics. Operators get a re-charge alert
- Durable steel frame and protective covers
- Maintenance free components: brushless drive motor and lithium-ion battery
- Easy to service and maintain. It takes 60 seconds to replace the drive wheel for example

A spare battery is not something I had considered. If I implemented a similar system on my product it may help the product last 2 days of operation

Some form of battery level warning system may be a useful feature on my product

Things to take away from this product:
Many parts of these pallet trucks are more heavy duty than elements I'd include in my design. However, there are some aspects that may be important to consider in my design. The handle design may be useful in helping me design the handle for my product. I will need to incorporate some of the same controls as these pallet trucks on the handle to control the speed of which my product tows aircraft.

Additionally, the easily removeable battery and subsequent spare, is not something I had considered for my design. A spare battery that could be charged whilst the other is in operation could help the product operate for several days without stopping to charge. This would overcome the main disadvantage of using electric power over fuel – the range.

Furthermore, the LCD display indicating battery life and on-board diagnostics could be included in my product in some form. A simple battery life indicator could be included on the handle or elsewhere to stop someone from towing an aircraft with my product, if it will run out half way through.

Aesthetics:
For it's purpose, I think this product has relatively good aesthetic value. It's plastic shrouds cover most of the internal framework and it's simple steel construction provides an un-complicated user friendly appearance. The colour scheme is once again relatively simplistic but still enhances the aesthetics. The finishes on the materials are mostly shiny, gloss like finishes which also enhance the aesthetic value.

Cost:
The product has no listed price anywhere online, so looking at similar products of the same specifications, my extrapolation of the price is in the area of £2000-£3000. This is significantly more expensive than my product should be (preferably in the region of £50-£150)

Customer:
This product is aimed at companies who operate warehouses, or large storage facilities. It is ideal to move large quantities of products around a warehouse floor, and therefore would be aimed at companies with lots of stock and several staff members. This means it is possible it is used by multiple people in a day, so it must be easy to use.

Environment:
The product, when in use, is relatively good for the environment as it is battery powered and produces no emissions. In terms of recycling and waste, it's mainly metal construction can be melted down and recycled however the battery and plastic parts may be harmful in the long run.

Size:
Designed for large loads, this product's frame is much larger and more heavy duty than my design will need to be. The electronics and drivetrain are arranged in quite a compact manner, however in general this product is more heavy duty than I would ever need on my design.

Safety:
There are very few safety issues concerning the operation of the product itself, without load. It moves at a slow speed and features no exposed moving parts.

Function:
As mentioned, the product is used for moving pallets of cargo around warehouse/shop floors. The 2 forks slide underneath the pallet and gently lift it. The truck is then steered via the handle and slowly moves the cargo to the desired location.

Material:
The product is largely made out of a strong, heavy steel frame. The electronics are covered by a plastic shroud and the handle is constructed out of metal box section and tube. This allows the product to be strong enough to lift heavy loads.

Specific Research 2: Electric trailer movers

Multi-Mover M18:
https://www.multi-mover.eu/product/multi-mover-m18/

Technical features and specifications:
- 0.9kw, 90A electric motor
- 2 x 12v 26Ah lead acid batteries
- Push and pull up to 1800kg
- Air tyres, width 15 inches
- Solid rubber swivel castor wheel (200mm)
- Ergonomic tiller head with emergency stop button
- Potentiometer for continuously adjustable maximum speed to 5km/h
- Tiller head can fold together for compact storage
- Gross axel weight 250kg
- Battery display
- Error display
- Minimum speed 0.5km/h
- Emergency stop switch on housing
- Height adjustable tow ball from 45cm to 60cm height
- Operating time: 1-2 work days

Things to take away from this product:
The tricycle wheel arrangement on this product may be something I can consider on my design. A 2 wheel design would be inherently unstable without gyroscopes etc. A castor wheel at the front/back of my product may allow it to maintain stability when towing, without someone holding it. The only drawback to this, is it does make the product much less compact.

The handle design on this product is once again very similar to the previous product. This style of design seems both ergonomic for the user and easy to use. An emergency stop button is featured on the handle. Some form of emergency stop/release could be included on the handle of my product.

The large, wide tyres are definitely an aspect I will need to consider with my design, as it will need to have traction on both grass and concrete, whilst towing loads of over 500kg. A castor wheel may also pose a difficulty when used on grass, as its narrow profile may sink in to the grass.

I had not considered this for my product; If necessary, some form of folding could help the product be as compact as possible. E.g. a telescopic element on the handle.

The gross weight of this product id 250kg, which is quite heavy for easy manoeuvring on an airfield. My product can be lighter as It will not need to be able to tow such high weights.

Aesthetics:
This product's aesthetics are very simple. The box steel is all painted the same colour, with only the wheels and handle being different colours. It conveys an extremely functional look to the product, very much linking to form follows function. It presents as if it is a very heavy duty product, which has very little in the way of it's functionality

Cost:
This product has been priced at £3000. It's physical weight and size may contribute to the price, however the powerful electric motor and large batteries may make up most of the cost. My product will not need to move as much weight, and will therefore require less expensive parts and less expensive construction

Customer:
This product is suited for both private customers and companies. For anyone who owns a large trailer E.g. a boat on a trailer, this product can help them move the payload around easily without extra manpower. This means the product should be easy and intuitive to use, as it is suited to private use, where anyone can go and buy one.

Environment:
This product is mainly constructed out of steel. This means it is easy to recycle as the electric elements can be removed and the metal frame melted down. It's impact on the environment is minimal due to the electric motor and long lasting batteries.

Size:
For towing large and heavy trailers, this product is quite large and very heavy. This allows it to have good traction on the ground and a wide footprint left by the tyres. My product will be significantly lighter and smaller, but should still maintain sufficient traction on the ground to tow aircraft on both concrete and grass.

Safety:
Once again, there are very few safety concerns with this product. Other than the wheels, all moving parts are contained, and the product features 2 emergency stop switches

Function:
This product operates in a very similar way to the previous product, and to how I imagine my product working. A trailer is attached to the tow ball, and the product is controller through the throttle on the handle.

Material:
The product is constructed out of steel for strength, and the weight helps it gain traction on the ground.

Specific Research 3: Powered aircraft hangar tugs

Best Tugs Alpha A2:
https://www.besttugs.com/pages/a-2-info

Technical features and specifications:
- 1179kg weight capacity
- 56.7kg weight
- Torque control from on-board computer
- Maximum amp draw of 20 Amps
- Digital battery status read-out
- 14” standard tyres
- Auto chock technology
- Auto brake technology

Things to take away from this product:
The layout and design of this product is important as it has been designed specifically for this purpose. It’s professional appearance and ergonomic design are both aspects that can be taken and considered in my design. It features many of the design elements that are essential to my design, it is compact, relatively lightweight, easy to use and charges overnight.

Instead of a 3 wheel setup, perhaps with one castor wheel, this product features a 2 wheel layout with a support stand for when not in use. This may help my product be more compact, as instead of a bulky 3rd wheel, I could install a small stand which the product could be leaned on to.

The towing mechanism for this product is quite specific to powered aircraft. While my product may be used to tow powered aircraft on occasion, it’s main focus is gliders. This means the tow attachment will be slightly different to the forks on the Alpha A2. My product may feature multiple towing mechanisms for a range of aircraft.

Aesthetics:
The Best Tugs alpha has clearly been designed with aesthetics in mind. This being said, the form of the product is carefully designed around it’s functional parts. The carbon fibre cover can be finished in custom paint designs as per the users request, and the black bar where the forks attach, can be finished in a custom anodized colour

Cost:
Being a very specialised and handmade product, the Best Tugs Alpha A2 is priced at around £3000 for the base model. This product features heavily with computerised technology which raises the price significantly.

Customer:
This product is very much aimed at private customers who own their own aircraft. Powered aircraft weigh much more than gliders so naturally they often need a powered vessel to tow them out of the hangar.

Environment:
This product once again is largely built out of metal alloy, which can be melted down and recycled easily. The carbon fibre shroud however cannot be recycled along with the electronic components.

Size:
This product is very small in comparison to others analysed. It is specifically designed to occupy a small space in an aircraft hangar.

Safety:
This product is designed to tow aircraft sometimes costing over £300,000. It therefore has several safety features which allow it to stop very quickly, and safeguard against user error. The ‘Auto brake technology’ is designed to automatically apply the break when the user lets go of the throttle. This means the aircraft is always protected when being towed.

Function:
The Best Tugs Alpha is designed for use in the aviation industry, this makes it very similar in function to how my product will be required to operate. It features two ‘forks’ which clip onto the nose wheel of aircraft. These forks are attached to a sway bar which regulates the steering. The controls are on the handle and a motor drives both wheels.

Material:
Best Tugs has used carbon fibre to create the shroud around the electronics. Carbon fibre is extremely strong and lightweight. The rest of the frame is constructed out of a metal alloy, which provides the necessary strength to tow heavy loads.

Specific Research 4: Electric jockey wheels

Aluminum motorized jockey wheel trailer mover:
https://www.vidaxl.co.uk/e/8718475911012/aluminium-motorised-jockey-wheel-trailer-mover-12-v-350-w?gclid=CjwKCAiA9bmABhBbEiwASb35V3U31wEB7eCmQKJOVPDIetkSo_SmfS6N_0xJfjjDYL4qML4Bc45tVxoC-3oQAvD_BwE

Technical features and specifications:
- Overall size: 83cm x 84cm x 25cm (L x W x H)
- 12V motor, 350W
- Towing speed: 6.5m/min
- Gear ratio 326:1
- Maximum load: 2270kg
- Maximum jockey wheel load: 272kg
- Suitable for use on inclines of maximum 5 degrees
- Recommended battery: 12V 24Ah lead acid battery
- Easy to operate
- Non-slip rubber wheel
- Power mover with clamp
- Automatic brake function
- Forward and reverse function
- Ideal for trailers, boats, caravans, campers

This information may be extremely important. If the towing speed is suitable, this gear ratio may help me to determine how fast my product will tow

An element I had not considered. There is 50ft of elevation between either end of the runway at Saltby, and many other sites have far steeper inclines. My product therefore will need to operate on inclines.

Things to take away from this product:
The motor and battery combination, paired with the gearing are all valuable pieces of information. My product will need to operate in a similar speed bracket to this one, meaning a similar drivetrain combination. As I will be using a motor of a similar size, it would be very interesting to see how this one drives the wheel.

The gearing will provide a 'ball park' for my product, allowing me to centre in on the range of speeds I intend for my product to operate within, without any trail and error or uncertainty. This product is almost a template for the electric components I intend to use, so the information it provides is valuable.

The height adjustability of the jockey wheel is not something I had considered implementing on my product. Naturally towing different things will happen at different heights, so some sort of height adjustment feature on the tow attachment on my product may help it tow certain aircraft.

Aesthetics:
This is an extremely basic product, in terms of aesthetics. Everything is exposed including the motor, which is pleasingly blended into the wheel housing. Everything else is clearly there for a purpose, and this product very much builds on the idea of form following function. It does however, not look unprofessional or in my opinion, unpleasant.

Cost:
These jockey wheels are priced in the range of £200-£230 generally. This is a much more reasonable price than any of the other products analysed, and a much similar price to what I'd expect my product to be valued at.

Customer:
Mainly suited for use on Caravans, this product is very much aimed at the private consumer. Someone who owns a trailer or caravan that is moved on a regular basis without the use of a vehicle. It's low price makes it accessible to a wide range of customers and ease of use helps it's sales.

Environment:
Of all the products, this is the least environmentally damaging. It features a cast metal frame, which can easily be recycled and the other parts can be reused.

Size:
As the smallest of the products, this is naturally the most compact. It's no-nonsense design helps it keep the size down which allows it to be stored in car boots, and in caravans which are often very crowded. In terms of size, my product should aim to be between this and the Best Tugs Alpha.

Safety:
This product features no obvious safety issues, it's simplicity means everything is easily accessible should there be a problem and it does not move fast enough to cause any damage. It is user friendly and features an automatic break just in case.

Function:
The jockey wheel is designed to slide directly into the place of the standard jockey wheel on trailers. The old one is simply removed from it's hole, and this one is slid in. It is then clamped in and is free to operate. It is perhaps the most simple product to use, however differs from the others as it requires a separate, 3rd party frame to operate.

Material:
This product's frame is made of a metal alloy, so it is very strong. It needs to resist bending due to the manner it operates, so strong bar construction techniques have been implemented.

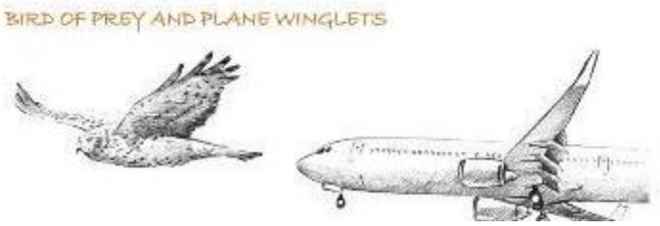
Design styles and themes

Biomimicry:
Biomimicry is effectively engineering in nature's style. Aspects from nature, such as plants and animals, are taken into account when designing a product. In aviation, this is particularly relevant.

Most water-going and airborne creatures are 'aerodynamic' in shape, to maximise their efficiency in movement. As a result of this, aircraft have adopted several similar contours and shapes as some animals.

As per the picture to the right, Airbus are researching and considering aspects of an albatross' wing in flight for their newest aircraft. They are also researching materials similar to that of shark skin, due to their drag reducing properties.

In the aviation industry, most pieces of equipment is designed heavily with only the functionality of the product in mind, rather than the form. This is very much linked to Biomimicry, as Animals and plants have evolved to perform specific functions, and their form is a reflection of those functions.



Aspects to consider in my design:
My product is very functional in nature – similar to aircraft. It's shape will most likely be defined by the layout of components. This means, my aesthetics and design elements will have to be shaped around the functional components, similar to the previously mentioned existing products. Innkeeping with the emergent aeronautical design styles however will be an important part of my product. To both appear professional and appealing, my product should be designed with the form of aircraft in mind. This means considering styles and themes like Streamlining and biomimicry. An example company that does this, is Best Tugs (as already mentioned in existing products). Their Tugs are unlike any competitors in the aircraft-like shrouds and cowlings placed over them:

Streamlining:
Streamlining is obviously a very important design style in aviation. The very nature of aircraft means they have to be streamlined and aerodynamically optimised.

Streamlining (or 'Streamline Moderne') was a form of Art-Deco, which became popular in the 1930s. The main design focus for streamlining was around aerodynamic design. Streamlining therefore very much included smooth corners, and flowing forms. Buildings and vehicles often appeared as if they had been sculpted by the wind. Besides buildings, streamlining design was often found in trains, telephones, buses, aircraft and many other things.

Streamlining was first developed by industrial designers, who removed all decoration and ornament from the Art-Deco style, and replaced those elements with aerodynamic lines, developed by scientific minds in the context of speed and movement.

In aircraft, aerodynamic streamlining increased efficiency, range and flight characteristics. This then, meant not only did Streamlining have a distinctive visual style, it also increased functional properties of vehicles. Many elements of streamlining are still found in aircraft today, such as drag-reducing engine cowlings and 'wheel pants' on many light aircraft.

Smooth, drag-reducing cowling

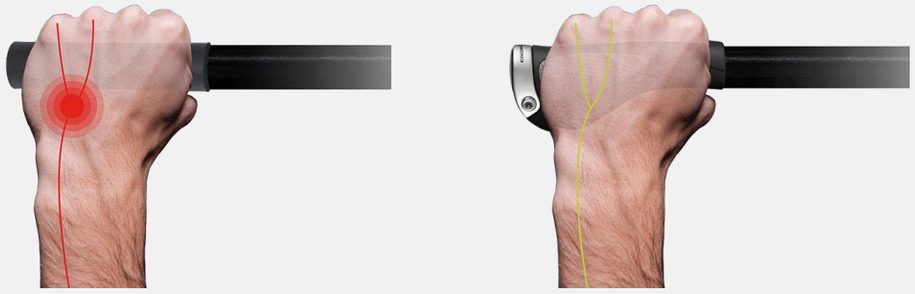
'Wheel pants'

Ergonomics in design

Ergonomics of control handle:
My product will be controlled by a handle, designed to be pulled by the user. Although motorised, the user will need to be able to both apply steering force to the handle, and simultaneously operate the controls. To accomplish this, the height at which the handle comes to and the design of the controls should be carefully considered.

As a result of this, my products handle should be ergonomically shaped to allow the user to apply force and grip without injury or strain to their hand.

Research shows, numb fingers, painful hands, wrist discomfort and forearm discomfort can all be results of utilising handles for extended periods of time. My product therefore should be designed to reduce stress to these areas to allow a user to operate it for longer, more comfortably.



The image on the left shows a main pressure point when force is exerted on a regular, tubular handle grip. This point of pressure is unsupported and can therefore lead to compression of nerves and strain on the hand. The image on the right shows the effect of placing a support under the stressed area. The pressure is distributed across the hand and the grip, and reduces strain on the nerves and hand.

My product therefore, should include ergonomically designed grips which help to distribute any force applied to the handle. These grips however must also allow the user to operate the throttle easily.

Additionally, my product's handle should be at a height which allows the user to comfortably place their hands on it without substantial bending of the wrist.

As shown in the images above, significant bending in the wrist can lead to more nerve compression, sometimes eventually leading to carpel tunnel syndrome. By keeping the wrist straighter, the nerves are not compressed and the hand is more comfortable. It is therefore important that my product should allow the user to grip it similarly to the image on the right, at the correct angle. Perhaps an adjustable length handle could allow the user to adjust the height of the handle according to their own height.

Ergonomics of throttle control:
The main control that will need to be operated on my product will be the throttle. Although not operating at high speeds, it's important the speed can be controlled to a high degree of precision to aid the manoeuvrability of my product.

There are several types of throttles that would be suited to my product. The most common, twist throttles, generally operate by twisting the whole handle to change speed. An alternative would be thumb throttles, small levers positioned near the thumb which can be pushed to increase speed.

Left: Example twist throttle.
Right: Thumb throttle

Twist throttles:
Twist throttles are generally better for rough terrain, as you can rest your hand on the whole grip/throttle, giving better stability.

You get a better control over speed using twist throttles, as they have a greater range of motion.

Twist throttles can be better for people with arthritis (quite common in gliding!) and reduce any pain from moving just one finger repeatedly.

With full-twist throttles, users comment their wrist tires from the movement. This is reduced with half-twist throttles but not eliminated.

With full-twist throttles you must maintain the degree of twist to keep speed. This can strain the wrist leading to injuries over extended periods

Twist throttles can be more dangerous when moving the product around, as accidentally twisting the grip could lead to unintended acceleration. This could be very expensive in gliding.

Thumb throttles:
Thumb throttles eliminate any wrist injury as the user can maintain the proper grip angle as mentioned earlier.

Thumb throttles are smaller, allowing for ergonomic handles to be used without modification.

They also reduce strain over long periods of time as the user does not have to hold their whole wrist at an angle, just their thumb.

That being said, the thumb can also easily tire over time, especially if full throttle is being used for long periods.

As a thumb throttle sticks out from the handle, it's much more likely to be damaged than a twist throttle. It could be knocked when being stored in the hangar for example.

As a thumb throttle sticks out from the handle, it's much more likely to be damaged than a twist throttle. It could be knocked when being stored in the hangar for example.

When going over rough terrain, the thumb is difficult to keep steady. Additionally maintaining a speed in the middle of the throttles range of motion is difficult.

Anthropometrics in design

Above:
Example aircraft tug. Note the steep angle of the towing arm to allow the user to pull with ease

Below:
Another example, note the user is dragging this aircraft backwards. His arms are straight and the handle seems to come up to a good height

Anthropometric data analysis:
The table to the right shows anthropometric data regarding the handle height of shopping trolleys, collected for a study. This information is relevant to my design, as the handle will have to be adjustable to a range of heights to allow the user to operate it at the correct angle.

In shopping trolleys, the user often has their hands placed slightly above their elbows on the handle. This therefore results in the average height of a shopping trolley handle being above the mean height of a person's elbow.

My product however, should be more similar in shape to the image of the man with the pallet truck. His hands fall lower than his elbows in this case, maintaining a straight arm and straight back. Although electronically assisted, my product will be designed to be pulled or 'dragged' by the user. This means stress on the user's back and arms could be expected over long periods. Achieving a straight back, and straight arms, means most of the pulling force comes from a user's legs. This reduces any likelihood of back injury in operation, or strain on arm muscles. Additionally, keeping a straight arm will reduce any compression on the wrists, allowing for the hands to land at the correct angle on the product.

Operator	High Elbows Standing (Cm)	Hand-Held Diameter (Cm)	Operator	High Elbows Standing (Cm)	Hand-Held Diameter (Cm)
1	105	6	16	104	6
2	106	7	17	102	6
3	107	5	18	103	7
4	103	7	19	102	5
5	103	5	20	102	5
6	102	6	21	105	7
7	105	6	22	107	6
8	107	7	23	106	6
9	105	5	24	103	7
10	108	5	25	104	5
11	104	6	26	104	6
12	106	5	27	107	6
13	106	7	28	107	5
14	103	6	29	106	7
15	107	5	30	105	5

Subject	Age (yr)	Height (cm)	Weight (kg)	Speed (m/s)
1	34	169	68	1.43
2	31	172	67	1.34
3	30	179	70	0.89
4	32	182	78	1.34
Mean (SD)	31.8 (1.7)	175.5 (6.0)	70.8 (5.0)	1.25 (0.24)

Anthropometric data analysis:
The table above was taken from a study to determine a persons "Self-selected luggage-pulling speeds". The information was gathered by a selection of people, all a range of heights and weights, pulling the trolley to the right with a 25kg mass. What can be seen by the results is that a person's height or weight generally has little effect on the speed they are comfortable pulling things at. This means, my product can have a universal maximum towing speed which is suited for all users. This study suggests an average towing speed of 1.25 m/s (2.8 mph). From experience, my product's maximum speed should be described as a 'brisk walk'. This allows the user to tow the aircraft quickly but maintain full control and good stopping distance in the process. The average walking speed of an adult is around 3 to 4 miles per hour. This study tells us that is reduced when pulling an object, so some experimentation into the effect of an electric motor may be warranted here.

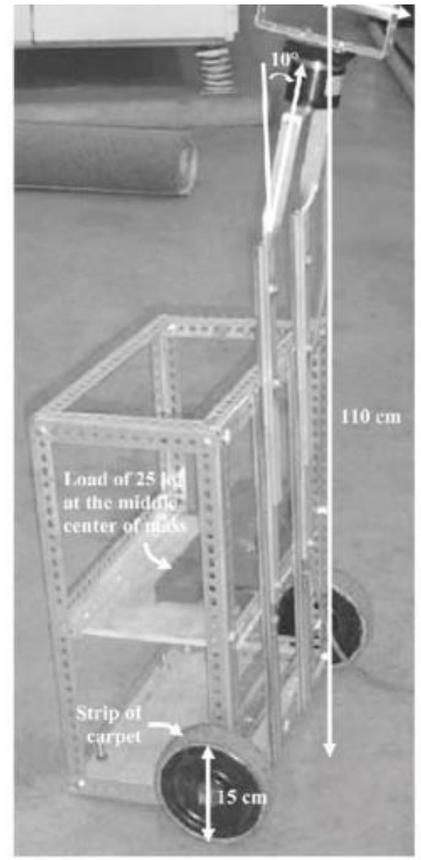


Fig. 1. Luggage prototype with the configuration of 110 cm handle height, 90° handle rotation, 10° pole angle, 15 cm wheel diameter, and carpeting. The load of 25 kg was placed at the middle center of mass of luggage.

Relevant standards

The CE mark is a indicator that a product has been manufactured to conform with health, safety and environmental protection standards set by the European Economic Area (EEA). It is often found on products not sold in the EEA, however it simply serves as a manufacturers declaration that the product has been manufactured to EEA standards. When a manufacturer places the CE mark on a product, it ensures the validity for the product to be sold throughout the EEA.

RoHS (Restriction of Hazardous Substances) is a standard that restricts the use of 10 harmful substances in electrical products. It was implemented by the EU in 2003 to help increase the reuse/recycling of products. Without the harmful substances, a lesser impact on the environment is achieved. It also promotes collection and recycling of electrical and electronic equipment free of charge to the user.

The BSI (British Standards Institution) Kitemark is a product and service quality trade mark used in the UK. It is most often used in products where safety is essential, e.g. crash helmets or smoke alarms. In recent years however, the Kitemark has been used in a range of products, including electronic devices. To obtain such a certification, the product must be assessed by BSI to ensure the product meets relevant British, European or international specifications and standards. Not only does the Kitemark ensure a level of quality, it ensures a level of compatibility with other equipment.

Standard	Year	Description
BS 1362	1973	Specification for general purpose fuse links for domestic and similar purposes (primarily for use in plugs)
BS 1363 Parts 1 -5	1995 - 2008	13 A plugs, socket-outlets and adaptors.
BS EN (IEC) 60309, Parts 1,2, 4	1999 - 2007	Plugs, socket-outlets and couplers for industrial purposes.
BS EN 60320, Parts 1, 2	1999 - 2009	Appliance couplers for household and similar general purposes.
BS EN 60335, Many parts		Specification for safety of household and similar electrical appliances

The table above was lifted from https://www.hse.gov.uk/electricity/standards.htm#power , in reference to relevant standards for electrical appliances

There are obviously several British standards which apply to products with an electrical nature, and some of those listed will certainly apply to my product. Ensuring my product meets said standards is essential for safe and continuous operation.

The plug socket standards will be of particular relevance to my product, as any form of charging will be through a plug socket. I will have to ensure my charging solution is within all of these standards before using it in an aircraft hangar

Summary Grid 2

- We do see some good and indeed relevant research.
- The ergonomic evidence cited will impact the specification.
- The analysis of the potential towing system will impact the specification and the ideas.
- The research that looks at existing products could trigger potential iterations of the design proposals.

Possible Further Evidence to access the higher levels

- **The candidate would benefit from annotation that illustrates how the research might influence the design possibilities.**
- **The work does becomes too descriptive especially in terms of the materials research.**
- **A more detailed interaction with the client or interested stakeholders would provide greater focus and relevancy.**
- **The work might also need to focus somewhat on the potential materials and processes required.**
- **Further research on the environmental conditions that the artefact might encounter could be relevant**

This is a level 3 submission but at the top of that level, or borderline level four. 11/12 marks out of a possible 15.

Pearson

GRID 3

Refined Design Brief +
Specification

Grid Three

- Specification
- A refined design brief and specification must be produced.
- At best these will reflect the research and analysis previously undertaken and take into account changes or renegotiations that have taken place between stake holders/client and designer in the research.
- This narrative is imperative if the candidate is to fully justify the performance requirements
- The specification must have technical measurable and realistic elements again mimicking commercial activity

Refined design brief

As my previous slides dictate, my gliding club and most gliding clubs in the country require a better, more cost efficient way to move their aircraft around on the ground. In response to this therefore, it is my intention to manufacture a product that will save time and move aircraft more easily than current methods, and reduce expenditure on fuels and maintenance. I have elected to produce an electric, battery powered tow out device.

This tow out device must be designed to be compatible with all the aircraft at Saltby. This could either be accomplished via one, universal fit tow attachment, or several separate detachable attachments. It is essential however my product be designed for ease of use in hooking up the aircraft, as current methods are extremely quick and efficient. My product should also be designed to accept standard tow bars already used at the moment. This is important as lots of private glider owners have their own 'tow out kit' as described in earlier slides. My product therefore will need to feature a tow ball so it can replace the traditional use of a car in this case.

It is essential my tow out device be designed with a professional appearance, as that would attract more customers and inspire more trust in it's function and reliability to club members. To fit in with the elements of streamlined, aerodynamic design on airfields, my product should be designed with design styles such as streamlining and Biomimicry in mind. To this effect, my product should appear almost as if it had been sculpted in a wind tunnel, with smooth flowing lines and curves. The aesthetics of my product should in no way hinder it's performance, however it is imperative it present as if it had been mass manufactured.

My product is required, by the client, to be able to operate for 2 days without stopping to recharge. In terms of design, a large battery could be included, or 2 smaller batteries that can be quickly and easily swapped if necessary. In theory, 2 interchangeable batteries could run the product for an indefinite period of time if one is kept on charge whilst the other is in use. However, this does increase the chance of one battery becoming lost (quite a regular occurrence at a gliding club). I should design my product with ease of use in mind, and adding a swappable battery also increases it's complexity and decreases it's user-friendliness.

My product must be compact and easy to store, as specified by the client. This is not only important at Saltby, but all gliding clubs as space is often a virtue in the hangar. My product therefore should be designed to be as compact as possible, significantly reducing the space taken up by petrol powered vehicles. This therefore suggests my product should be kept to the essential components being fitted as close together as they can function, and then covered by a very sleek shroud manufactured out of a polymer or a composite such as CFRP or GFRP.

The client has specified that my product must also be waterproof, which is important at all gliding clubs due to the wet grass it will be towing on, and any rain that passes through on a day. Therefore, my product should be designed with a waterproof, weather resistant shroud that covers the electronics, which is sealed round the edge with some form of rubber gasket or sealant.

It is important that my product is designed to be as manoeuvrable when towing aircraft as current means. Therefore my product should have a wide range of motion in it's steering, and feature a throttle with a lot of movement for better speed control. Additionally, the force required to turn the product and the glider should be quite low, as several members of gliding clubs are relatively old.

My product should be designed with an emergency release for the glider, in case anything is going wrong during the tow. This release should be easily accessible and mounted on the handle. The emergency release should feature a yellow handle/knob (in gliders the release handle is always yellow). This therefore would mean it's use would already be known to any glider pilot operating the product. The release could simply be a retaining pin, mounted to the tow attachment, connected to a steel cable which runs up to the handle, and when pulled, moves the retaining pin and jettisons the glider on tow.

It's important my product be able to be charged from the wall, without any special power adapters etc. Additionally, it may not always be near a wall socket in the hangar, so a long charging cable may be necessary.

Specification (of prototype)

Purpose/Function:

- **1.1** My product must function in a way that replicates standard glider towing methods. This is important as it's necessary that a user be able to recognise and utilise the product without any prior training or instructions in it's function. This will allow the product to operate at a wider range of gliding clubs.
- **1.2** Being electric powered, my product should also be cheaper to operate than the petrol powered alternatives. This is essential as one of the key selling points of this product is it saves time and money. As most gliding clubs are having financial difficulty post-covid, this is especially relevant.
- **1.3** Additionally, my product must feature an electric motor and battery combination which both provides enough torque and power to move all weight ranges of gliders in clubs across the country. This is also important in making sure the product is able to operate at a range of sites.
- **1.4** It is important my product be able to tow aircraft on both concrete and grass (with the exception of wet grass as it is likely the club would not operate if the grass and ground is very wet). Lots of gliding clubs have only got grass runways, therefore my product must be able to cope with these surfaces.

Form:

- **2.1** To present as a professional, high quality product, it is necessary that my product provide aesthetics to that effect. This is important as most gliding clubs are looking to 'remake' themselves in the image of the 21st century to attract younger customers and make gliding more mainstream.
- **2.2** As well as looking professional, my product should also look tough and durable. Gliding clubs often operate on quite rough/rugged terrain and in harsh conditions, so it is imperative that my product instils a feeling of confidence in the user with regards to it's reliability.
- **2.3** As already stated, it is important that my product be compact to fit in small or crowded storage spaces. This therefore dictates that my product should be no larger than: 1.2m in height (with a collapsible handle) and have a wheelbase of over 1.2m. The length of my product will be different for different tow attachments for the aircraft, but each attachment should be removeable from the product to allow it to be stored more easily.
- **2.4** Additionally, it is important my product does not look 'home made' in any way, so it presents as a product and not a 'good idea' that gliding clubs can replicate rather than purchasing it.

User Requirements:

- **3.1** Most importantly, my product should be easy and simple to use. As, on a daily basis, it will be used by any member of the gliding club, it must not be complicated in it's operation at all, and should be intuitive enough to use without any prior training. This is very important at a gliding club as several members swap roles throughout the day so being easy and simple to use will prevent any confusion over the products function.
- **3.2** My product should also be easy and convenient to charge, from any socket at the club. This will help the product be sold at other clubs as there will be no special charging requirements stopping a potential customer from purchasing it.
- **3.3** My product should also be simple and easy to work on, as in the event anything does go wrong it is important that someone with little technical training can diagnose faults and change parts. This would be a good selling point for gliding clubs as often a select group of people are the only ones that perform technical maintenance on equipment, so being user friendly would help with member workload.

Performance Requirements:

- **4.1** My product must be able to operate on gradients. Several gliding clubs are on hills or have inclined surfaces/runways, therefore my product must be able to cope with these gradients to make it suitable for use at other clubs. It should be able to operate on 5% gradients regardless of the surface.
- **4.2** The product should be able to function for 2 days of continuous operation before requiring a charge. This is important as it is possible someone forgets to plug the product in to charge overnight, and therefore it will not be fully charged the following day. It must therefore still be able to operate.
- **4.3** Gliding clubs operate in a wide range of temperatures, as they fly all year round. My product therefore should be unaffected by temperature and continue to function on any day. It should be able to operate between -10 degrees C up to 35 degrees C.
- **4.4** My products' maximum towing weight must be over 700kg, as some of the heaviest gliders flying in the UK weight 700kg. It should be able to tow these aircraft with relative ease.

Material and Component Requirements:

- **5.1** To provide a strong and durable base for the components and for attachment points for tow assemblies, my product will mainly have a metal based frame. Further analysis on costs, weights and strengths of metals will be required to find the suitable material to construct my product out of.
- **5.2** To cover the electronic components, my product will need a thin shroud/cowling. This could be manufactured out of a range of polymers or could be made out of composite materials such as Carbon Fibre or Fibreglass.
- **5.3** Any materials chosen for the product will need to have a good range of finishes available for it, to aid in the aesthetics of my product.
- **5.4** My components must be suited for their purpose in this product, as in suited for outdoor use and operation. This is important as continuous use over a range of different weathers can take it's toll on some components, but it is imperative my product be unaffected.
- **5.5** All materials chosen must also have good weather resistance, and be unaffected by continuous outdoor use. This will give the product a much longer life-span.

Scale of Manufacture and Cost:

- **6.1** In the manufacturing of my products, job production will be used. Each product will be manufactured one at a time and can be tailored to each gliding clubs needs. This would result in a high overall price, however the products would be made to a very high quality and standard. The products could be altered to fit any aesthetic requirements of a club, E.g. their logo on the shroud, and could be modified to tow any unusual aircraft found at their site.
- **6.2** The cost of manufacturing the product will likely be relatively high, as the most expensive parts are the motor and battery. Both of these together can be found in the region of £150-£200, and therefore the manufacturing cost of the entire product I estimate will be around £350-£400. This however is assuming all new parts, which would probably be the case for the batteries as they degrade over time. The motors however could be sourced as second hand, as that would reduce my products impact on the environment and therefore help it be more environmentally sustainable.

Summary Grid 3

We do see some evidence of a final re-worked design brief, which is comprehensive. And a number of the specification points are measurable. It is a pity that some of the materials mentioned do not feature in the research as this would show the linkage between the clients needs, the stakeholder dialogue and the specification.

This small oversight illustrates a slight lack of perception.

This is a level three submission and is awarded **7** marks out of nine

Possible Further Evidence to access the higher levels

- **The candidate needed to try to build further client/stakeholder interactions into the writing of the specification.**
- **There were missed opportunities to explore further materials/processes and then be more specific in regard to possible materials etc.**
- **An analysis of existing systems turning circles, manoeuvrability could have aided the writing of the specification.**

GRID 4

Design Ideas

Grid Four

- Design Ideas
- In this section it is expected that a range of design strategies are used to produce a range of design ideas that address the specification criteria from the previous section.
- Design strategies include elements such as 2D, 3D, subsystem details, inspiration materials, work of other designers and cultural historical influences.
- Candidates should be thinking like a commercial designer and apply their knowledge of technical skills and materials and back it up with the research they have carried out previously and any additional research.
- It should be obvious that the work has taken into account the needs established prior to this section.
- Annotation should illustrate the candidates knowledge and understanding of technical elements such as materials, processes and techniques that are relevant to the identified design area.
- Iteration should/could occur in this section – and beyond (you may see linear or cyclical designing.) However, the client/stakeholder input should be apparent.

Design Idea 1 (frame + components)

Luca MacGregor #1

1 Wheel Setup:

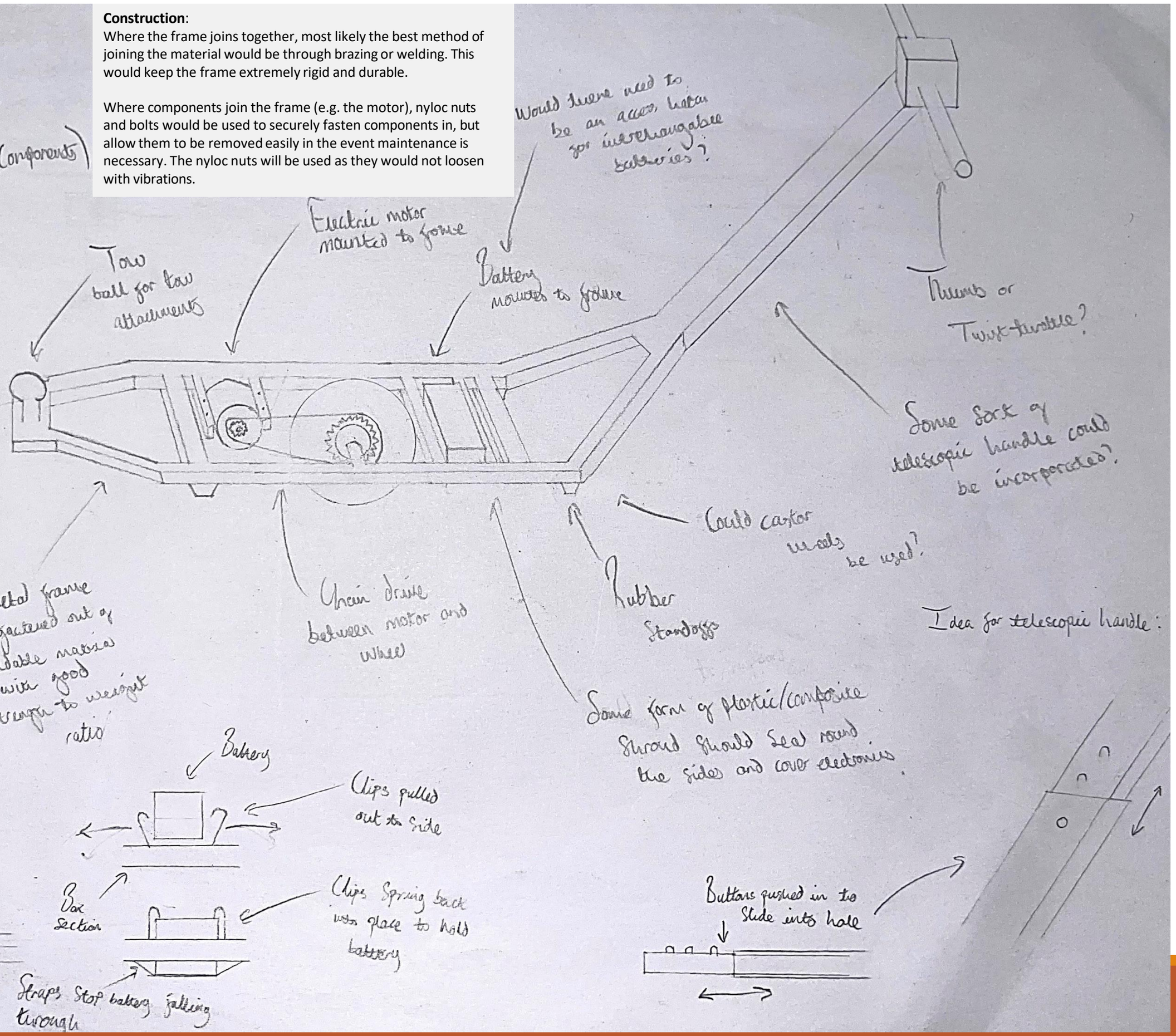
(Frame + Components)

Overview:
This idea is based around a one driven wheel arrangement. It takes a narrow streamlined form with all of the internals contained within the frame. It features a chain drive power system where the motor is geared to the main wheel through a chain and sprockets. The tow attachments would feature at the back of the product with the idea the weight over the back would balance the force the user would apply on the handle.

Material:
The frame would be constructed out of mild steel box section, for strength and weight (to help the product have traction on loose surfaces). Mild steel is both inexpensive and relatively easy to work with. It is however a ferrous metal therefore would require a finish in corrosion-resistive paint to prevent the formation of rust.

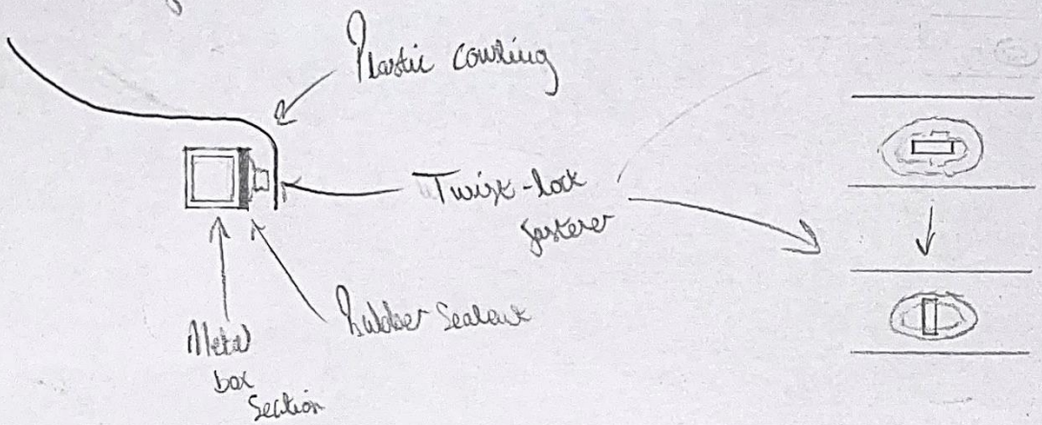
Construction:
Where the frame joins together, most likely the best method of joining the material would be through brazing or welding. This would keep the frame extremely rigid and durable.

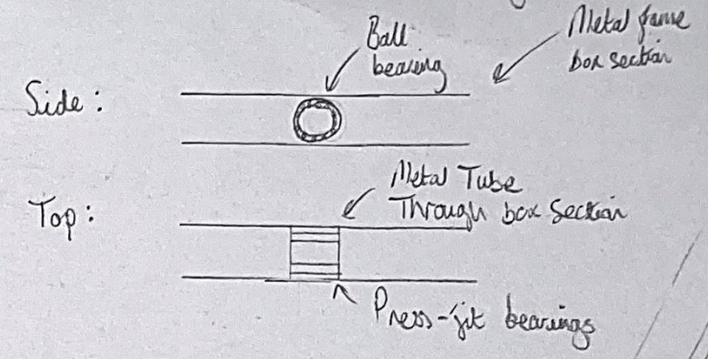
Where components join the frame (e.g. the motor), nyloc nuts and bolts would be used to securely fasten components in, but allow them to be removed easily in the event maintenance is necessary. The nyloc nuts will be used as they would not loosen with vibrations.



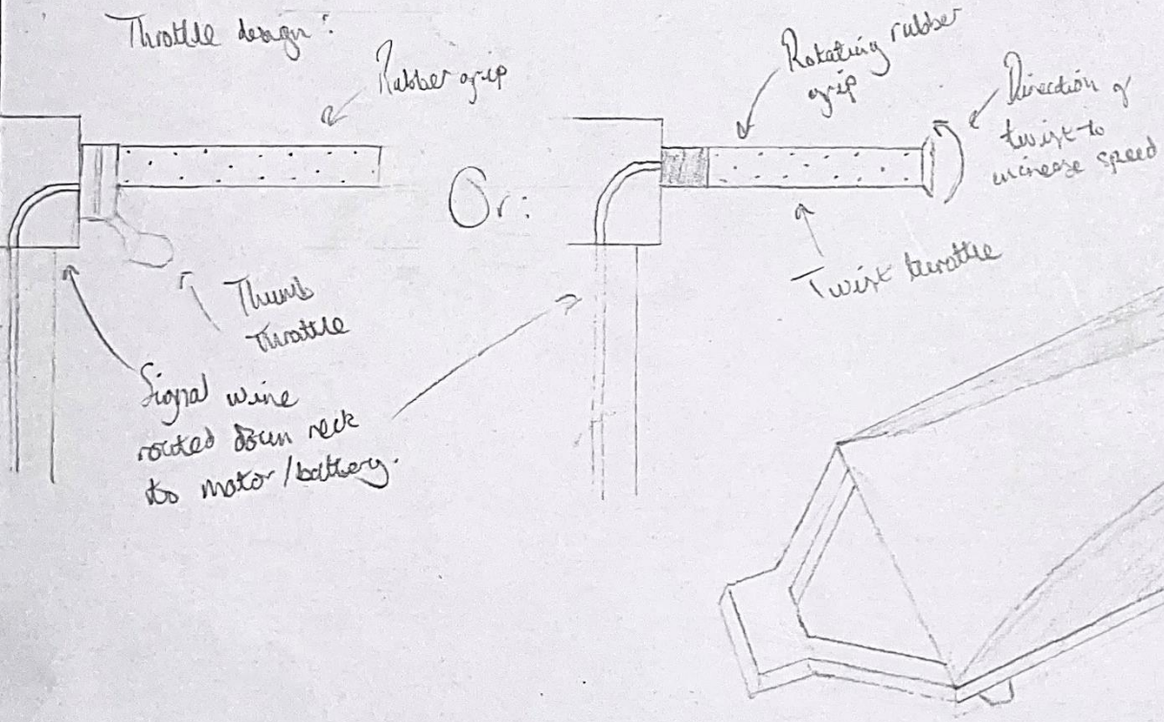
Luca MacGregor #1A

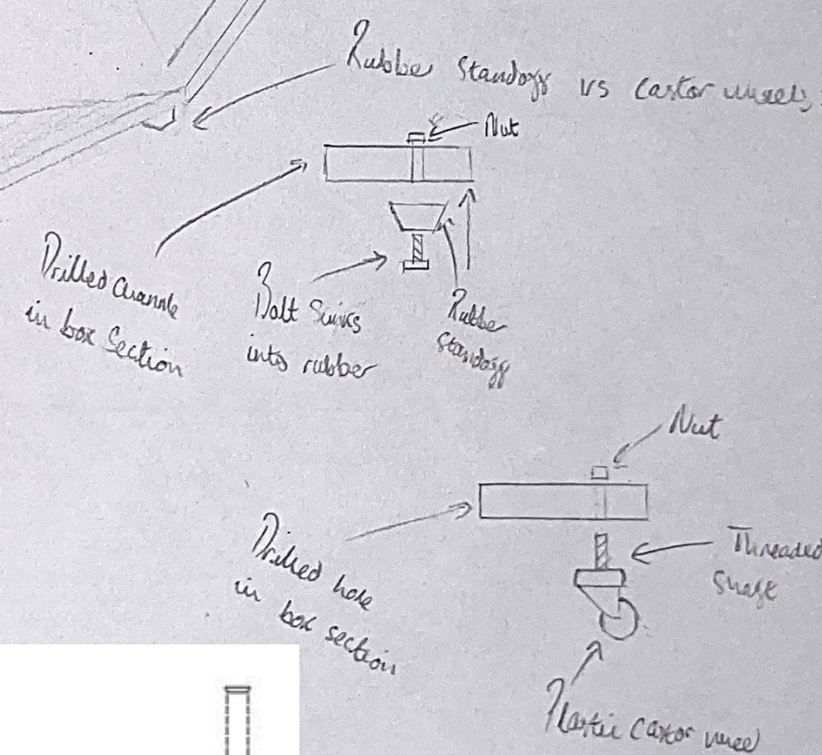
Graphics on cowling:
The large white surface area of the cowling lends itself to a wide range of possible graphic designs. For example, in gliding, neon patterns and strips are often used to aid visibility of the aircraft in flight. For my design, something similar could be applied in the same style as gliders. Additionally, the graphic design styles used on airliners should also be heavily considered, as they are also suited for enhancing large, streamlined white surfaces.

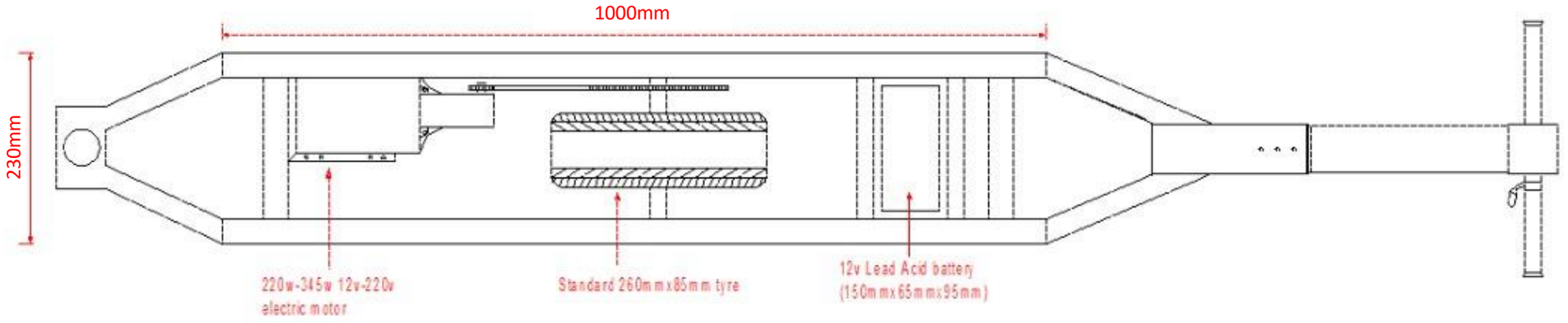




Design influences:
This design is very much focused on the theme of streamlining and aerodynamics. The plastic cowling would be moulded with smooth flowing lines and gentle curves to create a product that looks at home on an airfield. The lines and shapes of the cowling very much lend themselves to many design elements of gliders.







Techsoft 2D design rendering:
This is a scale 2D CAD rendering showing the actual dimensions of the product and it's components. The dimensions of the components were found online for similar spec components to the ones I will require.

Design Idea 2 (frame + components)

Luca MacGregor #2

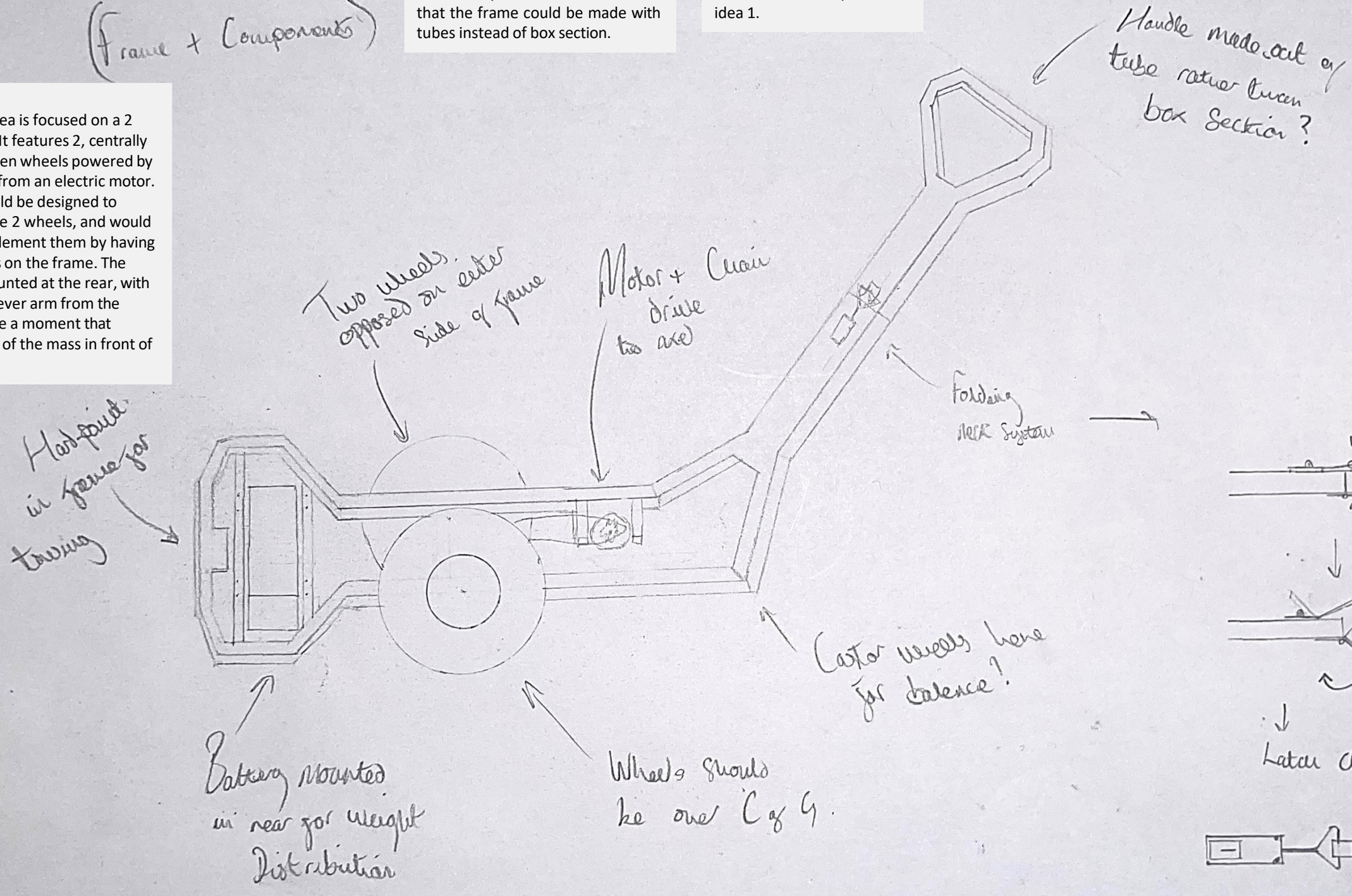
Two-wheeled Setup:

(Frame + Components)

Overview:
This design idea is focused on a 2 wheel setup. It features 2, centrally mounted driven wheels powered by a chain drive from an electric motor. This idea would be designed to balance on the 2 wheels, and would possibly supplement them by having castor wheels on the frame. The battery is mounted at the rear, with a significant lever arm from the pivot to create a moment that balances that of the mass in front of the wheel.

Material:
The frame would likely be constructed out of mild steel box section, however, as this design has 2 wheels, it will have increased traction over idea 1, and therefore could be constructed out of a lighter material: e.g. aluminium. Additionally, it could be considered that the frame could be made with tubes instead of box section.

Stability:
In comparison to idea 1, this design would have increased longitudinal stability, and would therefore not be prone to tipping to the left or right. Lateral stability however is unaffected as compared to idea 1.



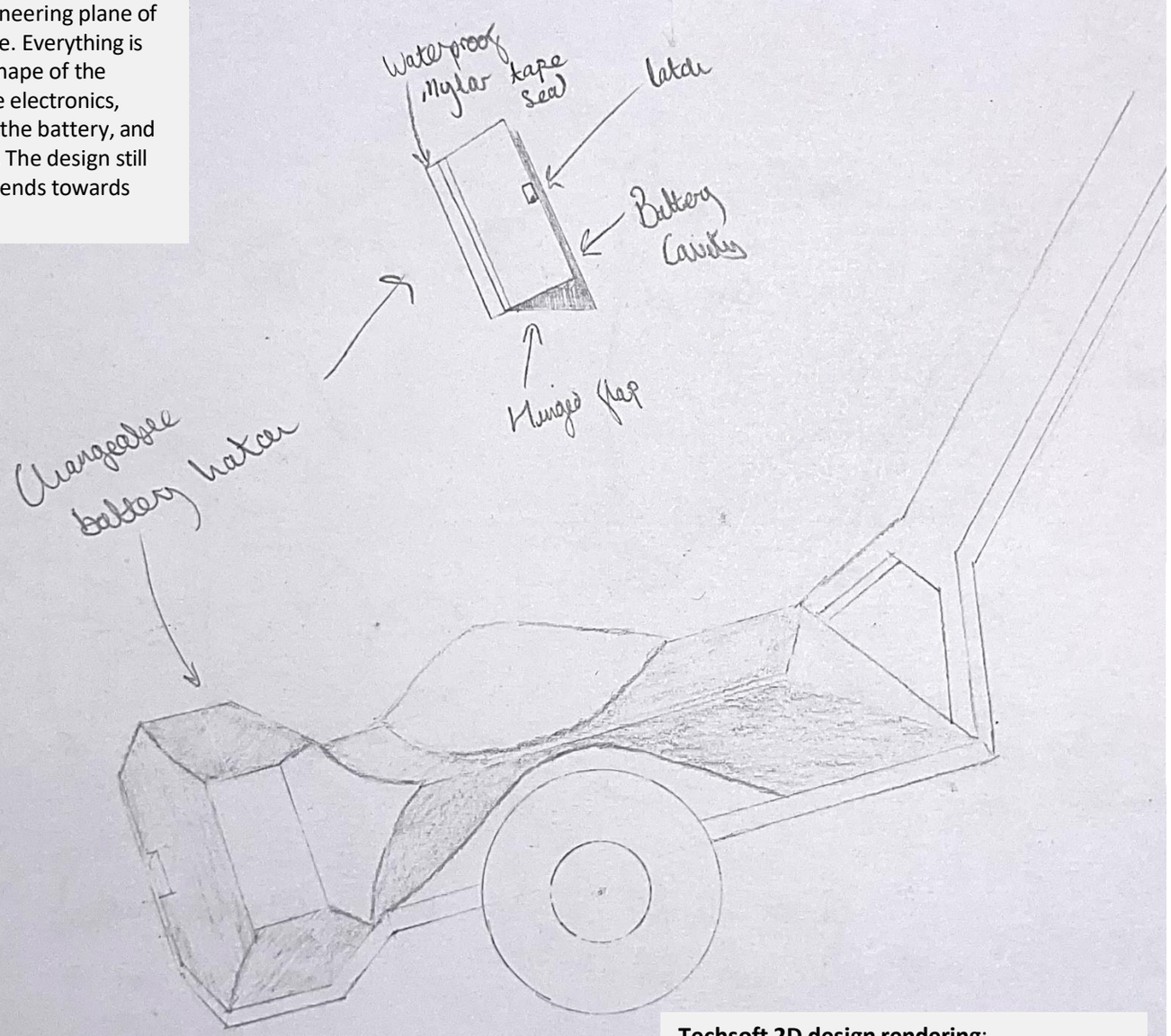
Luca MacGregor #2A

Two-wheeled Setup:

Plastic Cowling:

Design of cowling:
The shape of the fibreglass cowling on this design, flows over the components to provide a very sleek and snug fit. It features 2 wheel arches on either side and a raised flat section to house the battery. Similarly to design idea 1, it is designed to be attached on the side of the metal frame.

Design influences:
This design is more centred on an engineering plane of thinking, as compared to an artistic one. Everything is functional, and it's form follows. The shape of the cowling is sculpted by the layout of the electronics, hence the raised flat section to access the battery, and the wheel arches to house the wheels. The design still very much draws on streamlining but tends towards favouring design around the internals.



Techsoft 2D design rendering:
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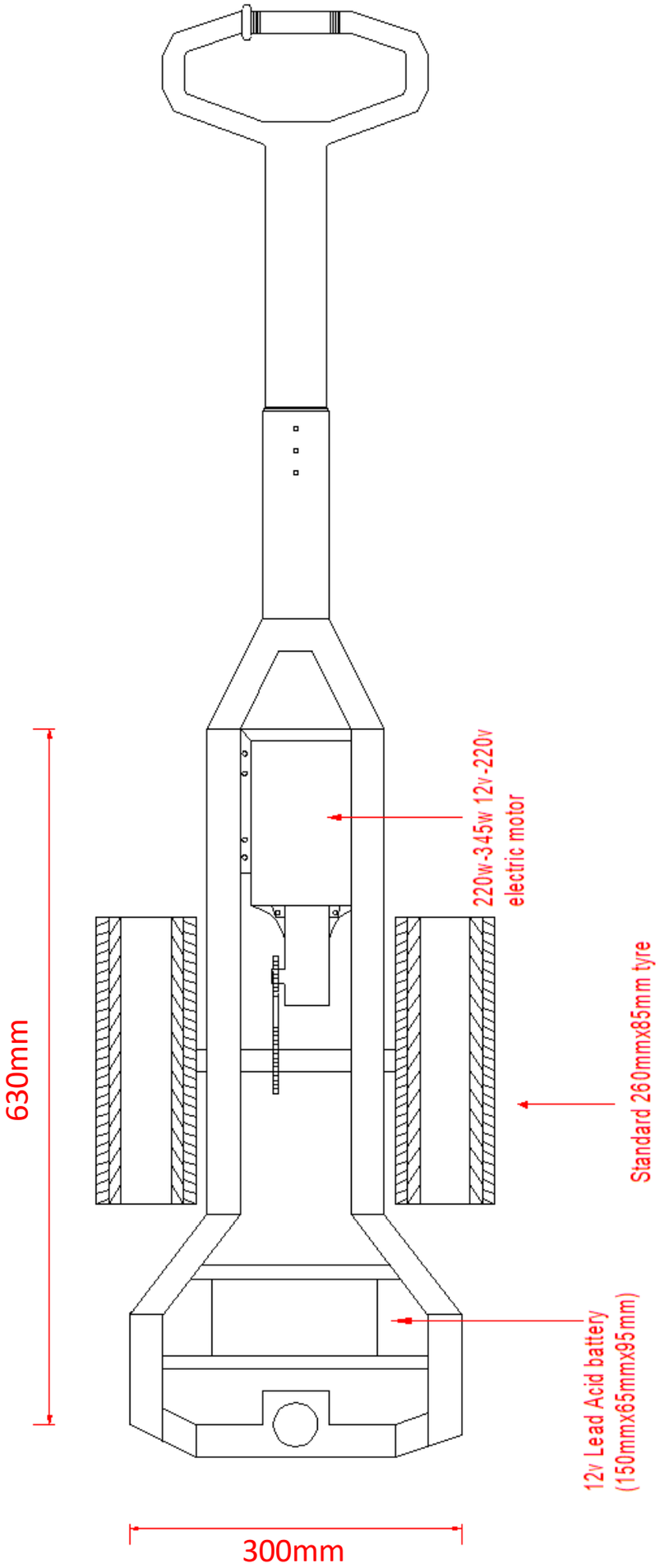
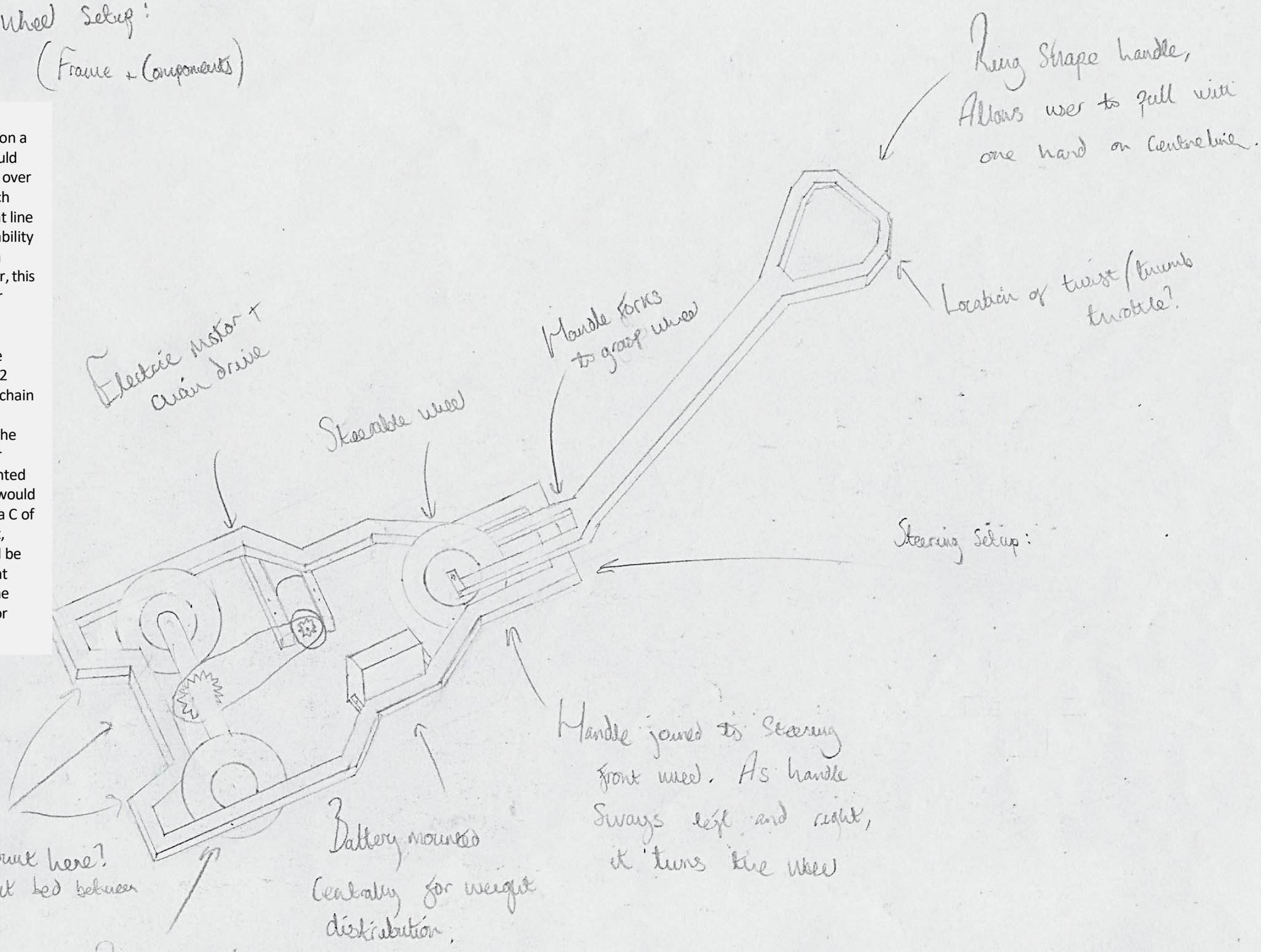


Design Idea 3 (frame + components)

Luca MacGregor #3

3 Wheel Setup:
(Frame + Components)

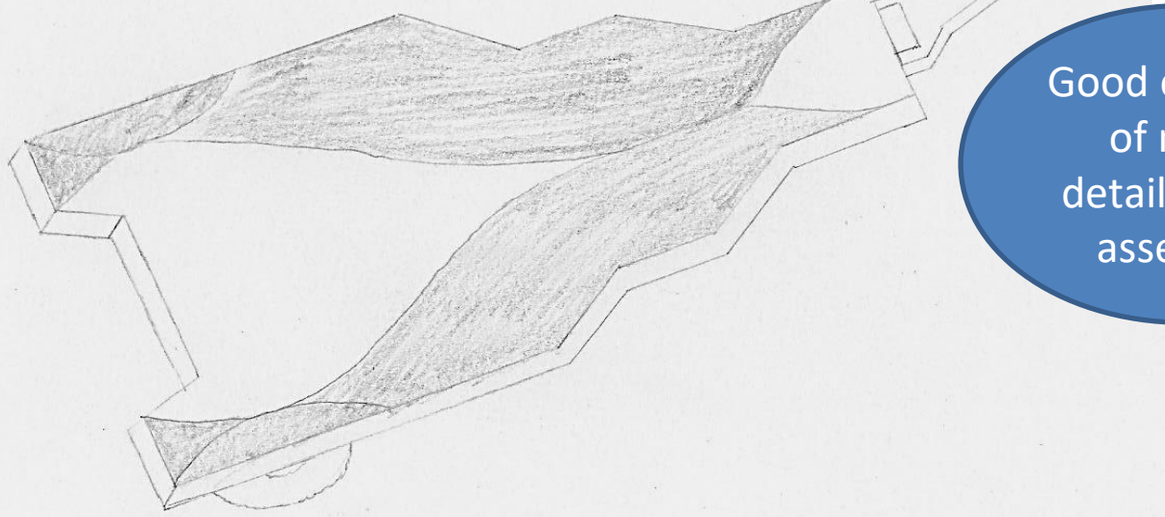
Overview:
Obviously, this design is based on a 3 wheel tricycle setup. This would have greatly improved stability over both design ideas 1 and 2, which would make towing in a straight line much easier. To aid manoeuvrability however, this design features a steerable front wheel. However, this setup is certainly not as agile or manoeuvrable as the previous design ideas.
In this idea, the rear wheels are driven in a similar sense to the 2 wheel setup; on an axel with a chain drive.
An advantage of this design is the motor and battery and all other electronics are able to be mounted forwards of the rear axel. This would mean the product would have a C of G forward of the towing mount, meaning significant force could be applied at the rear and the front wheel still be in contact with the ground. This would be useful for heavier aircraft.

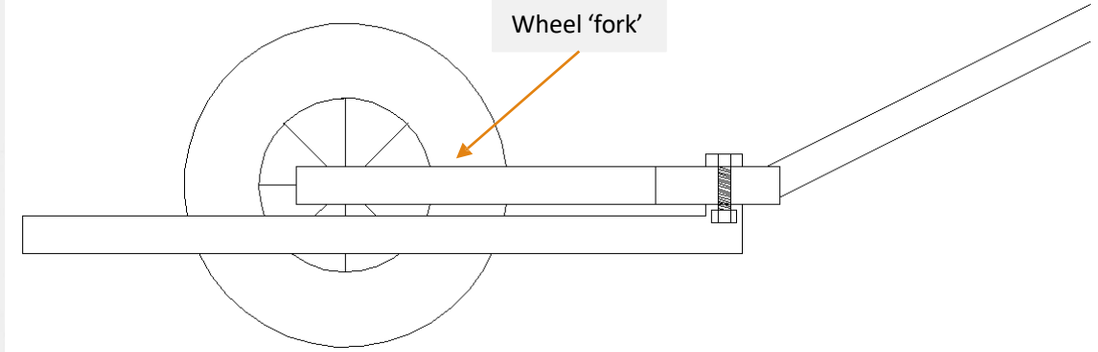


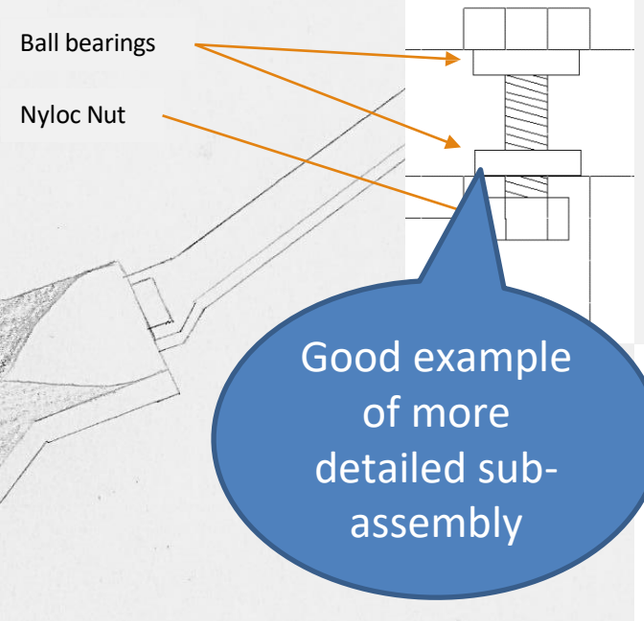
Luca MacGregor #3A

3 wheel setup:
(Plastic cowling)

Design of cowling:
The shape of this fibreglass cowling still leads into ideas of streamlining and aerodynamics. Everything is concealed within the fibreglass shell. There are no external components, alluding almost to the idea it has been shaped in a wind tunnel. Due to the shape of the fibreglass, on this design I do not think that an accessible battery flap is a realistic option. A disadvantage therefore is that to change the battery, the user would have to remove the cowl completely.

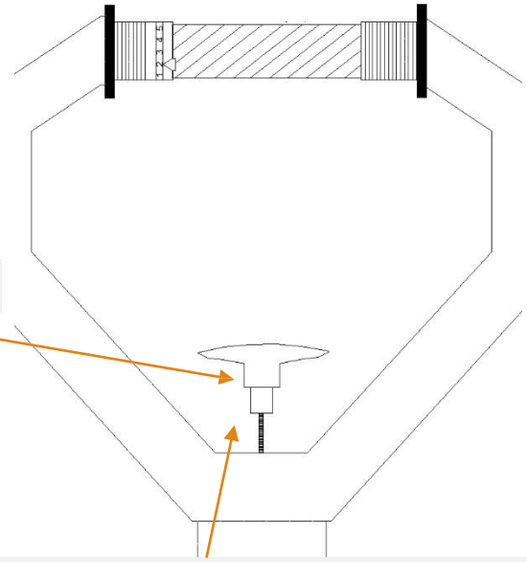


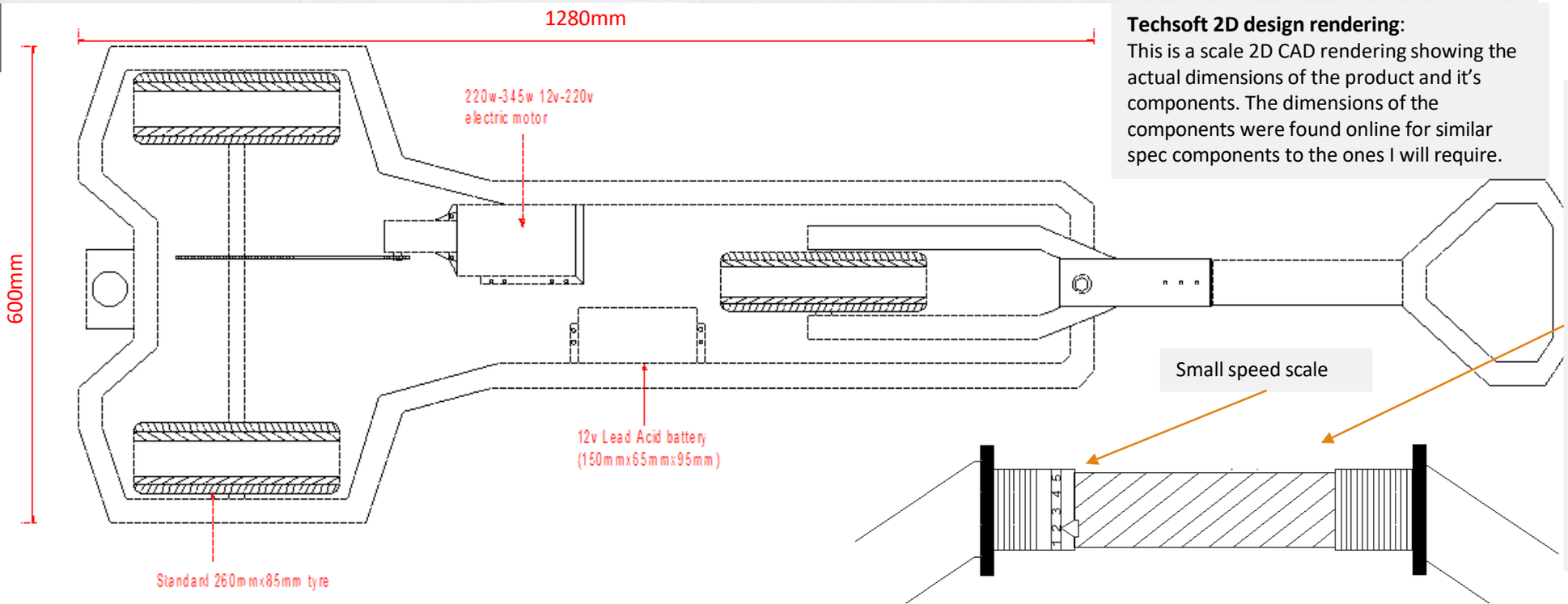




Expansion of steering mechanism:
This design features a steerable front wheel, which helps give the stable tricycle design manoeuvrability. As shown above, the steerable 'fork' which the wheel is mounted to is bolted to the steel frame. To allow sufficient movement with minimal friction, the bolt passes through 2 ball bearings.
As the frame of the 'fork' itself is mounted on top of the main frame, the wheel can reach greater angles of turn before it is blocked by the frame.

Good example of more detailed sub-assembly





Techsoft 2D design rendering:
This is a scale 2D CAD rendering showing the actual dimensions of the product and it's components. The dimensions of the components were found online for similar spec components to the ones I will require.

Expansion of handle design:
The handle on this design would also feature a twist throttle, where the signal wire is routed internally through the metal box section frame. Featured on the throttle, is a small scale from 1-5 with a needle to indicate to the user what power setting they are using. This could be helpful as a standard power setting for towing could be found in testing and labelled on the product.

Additionally, this design features an emergency release in the shape of a T-handle mounted at the base of the handle. Attached to the handle would be a length of steel cable which would either mechanically detach the aircraft on-tow or electrically disable the tow out device. The handle would be coloured either yellow or red as in gliding those are the standard colours for release/emergency jettison respectively.

Design Idea 4 (frame + components + cowling)

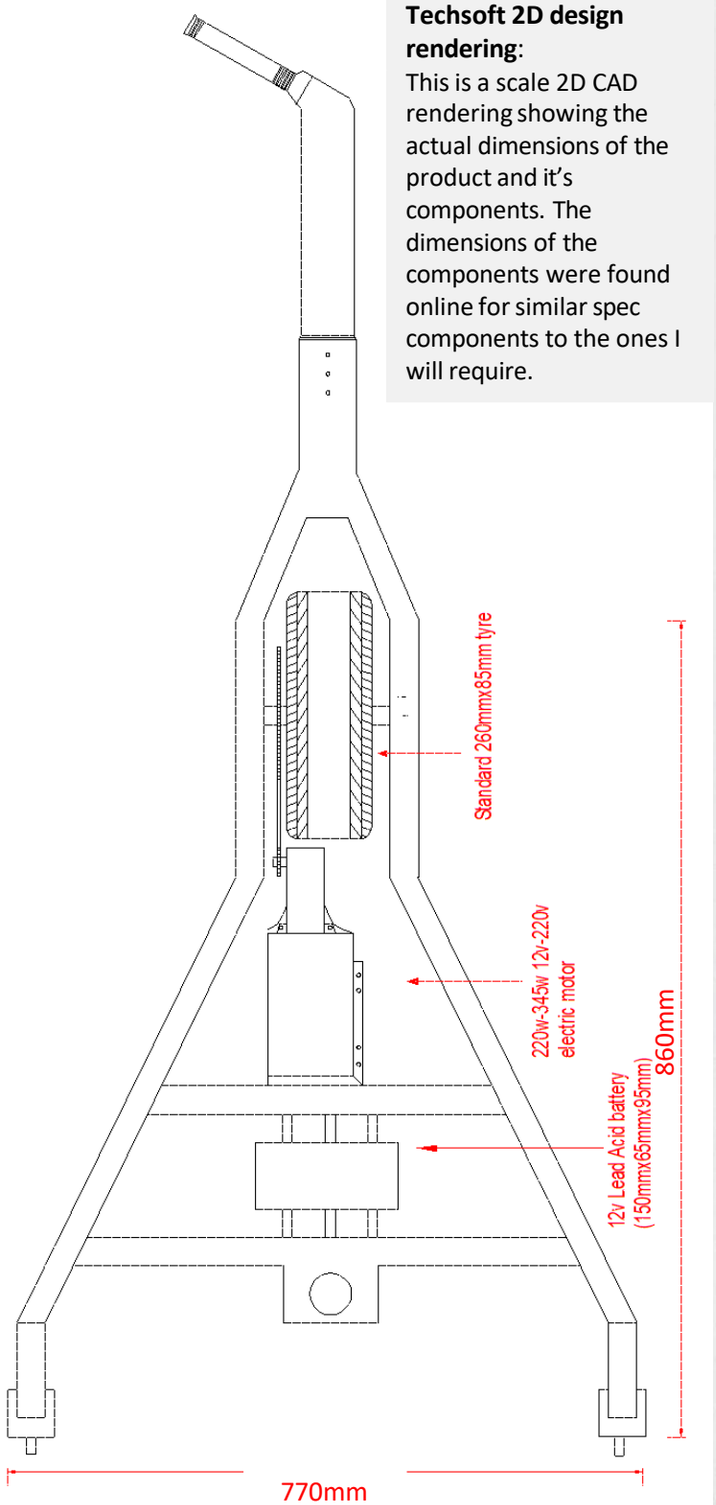
Luca MacGregor #4

Tripod Setup:

(Frame + Components)

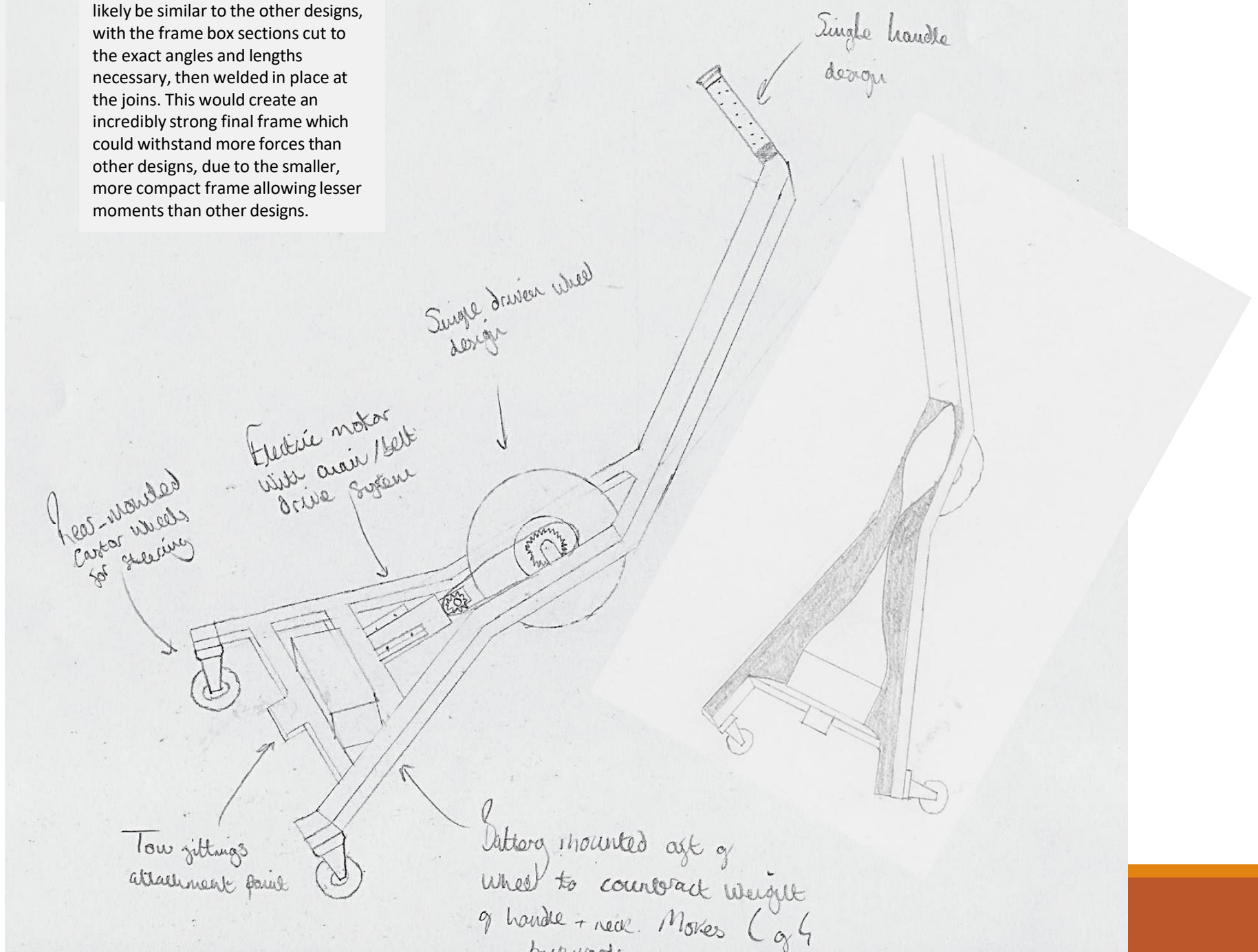
Overview:
This idea differs from the others due to it's tricycle layout but with the front main wheel being driven, and the rear wheels free castoring. This results in a design which should be extremely manoeuvrable. When towing, the main load will be applied over the rear wheels which should increase stability around the yaw axis.

Materials:
For this design, either tubular or box section steel pipe would be used. The usage of tubing however may increase manufacture time and complexity. This design is inherently smaller than the others, and will in turn be lighter. To achieve the same weight over the driven wheel therefore for traction, heavier/stronger metals could be used in the frame, however this also may increase the difficulty of manufacture.



Techsoft 2D design rendering:
This is a scale 2D CAD rendering showing the actual dimensions of the product and it's components. The dimensions of the components were found online for similar spec components to the ones I will require.

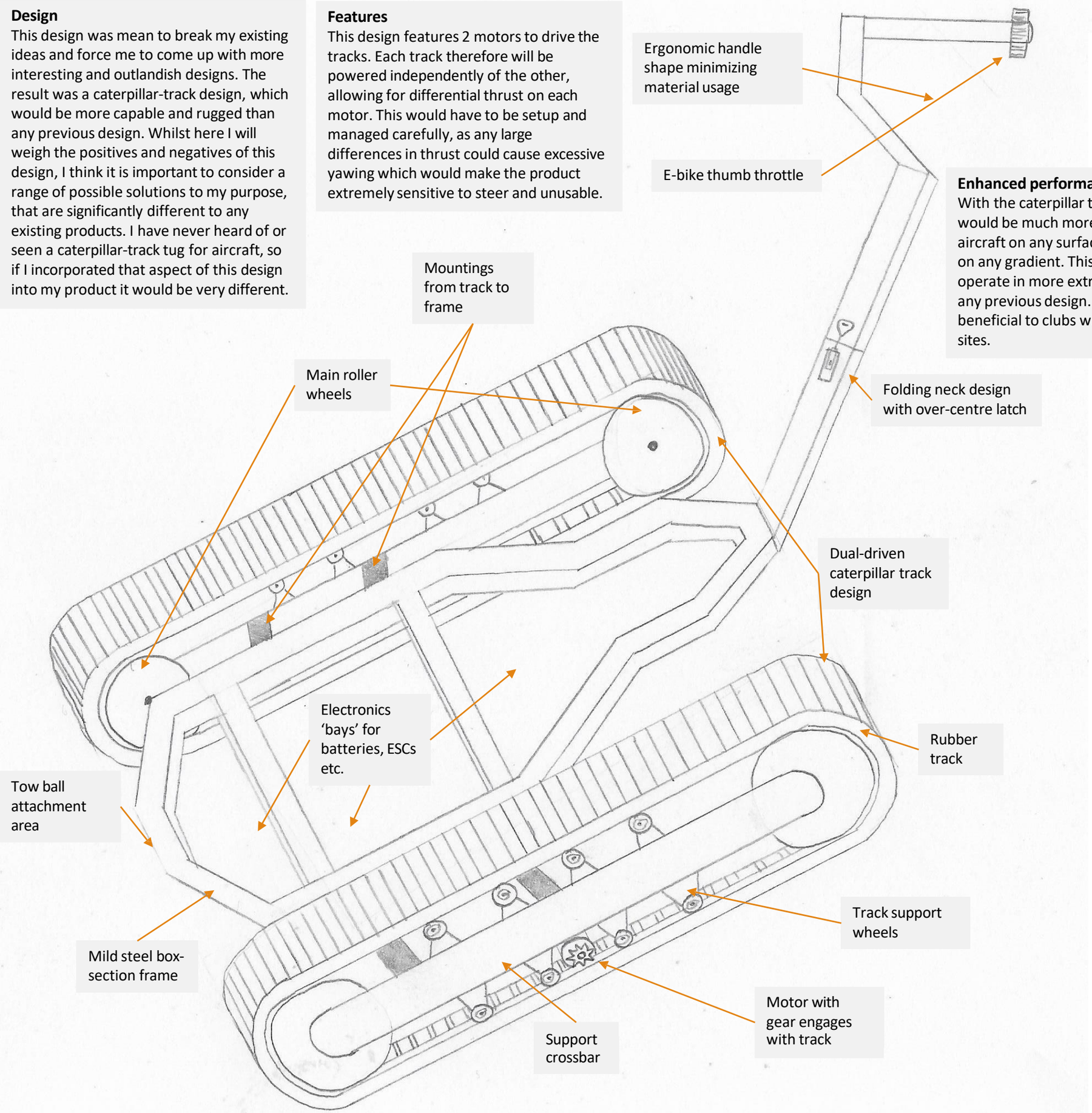
Construction:
The construction of this frame would likely be similar to the other designs, with the frame box sections cut to the exact angles and lengths necessary, then welded in place at the joins. This would create an incredibly strong final frame which could withstand more forces than other designs, due to the smaller, more compact frame allowing lesser moments than other designs.



Design Idea 5 (Alternative concept)

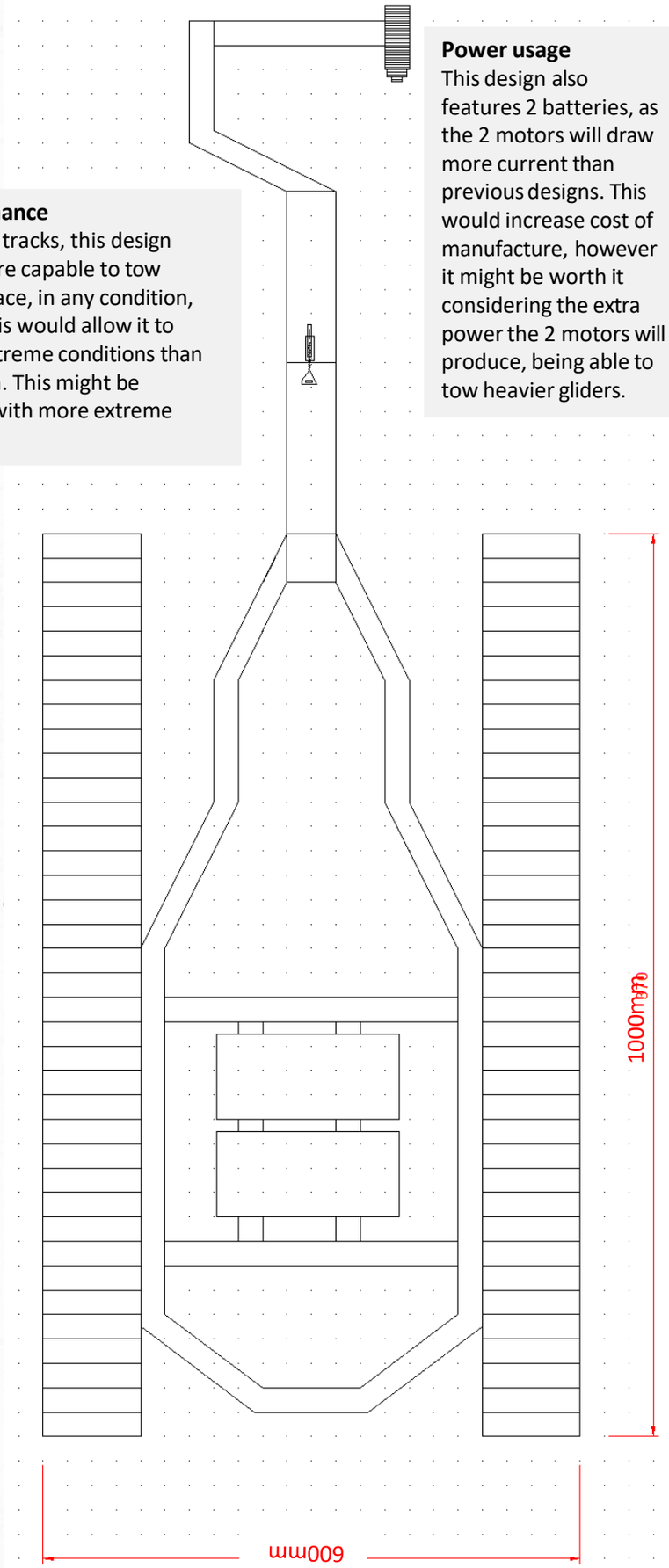
Design
This design was mean to break my existing ideas and force me to come up with more interesting and outlandish designs. The result was a caterpillar-track design, which would be more capable and rugged than any previous design. Whilst here I will weigh the positives and negatives of this design, I think it is important to consider a range of possible solutions to my purpose, that are significantly different to any existing products. I have never heard of or seen a caterpillar-track tug for aircraft, so if I incorporated that aspect of this design into my product it would be very different.

Features
This design features 2 motors to drive the tracks. Each track therefore will be powered independently of the other, allowing for differential thrust on each motor. This would have to be setup and managed carefully, as any large differences in thrust could cause excessive yawing which would make the product extremely sensitive to steer and unusable.



Enhanced performance
With the caterpillar tracks, this design would be much more capable to tow aircraft on any surface, in any condition, on any gradient. This would allow it to operate in more extreme conditions than any previous design. This might be beneficial to clubs with more extreme sites.

Power usage
This design also features 2 batteries, as the 2 motors will draw more current than previous designs. This would increase cost of manufacture, however it might be worth it considering the extra power the 2 motors will produce, being able to tow heavier gliders.



Analysis of initial ideas

Initial idea 1

Advantages

Streamlined – This idea is the most streamlined of all as it's slender and sleek form allow a very aerodynamic cowling to be fitted.

Simplicity in manufacture – This idea is most likely the easiest to build due to it's simple, rectangular based frame and centrally mounted wheel.

Good access for maintenance – This idea would have lots of excess space within it, making maintenance and access to components very easy.

Disadvantages

Stability – The one central wheel would result in a general lack of stability which could impact user friendliness.

Traction – with only one driven wheel in the centre, the main weight of the towing load would not be over the wheel so it may not have enough traction to tow heavier aircraft.

Loading – on some glider tow out kits quite a substantial load is applied on the tow bar to lift the glider's tail off the ground when towing. This would cause this product to rock backwards.

Initial idea 2

Advantages

Traction – With 2 driven wheels, this idea would have excellent traction and grip when towing.

Size – This idea features a collapsible neck design which would quickly reduce it's size making storage easier

Space for components – With it's large frame, this idea would feature ample space for components with room to spare

Cowling – This product maintains a mostly rectangular frame making manufacturing the cowling less challenging.

Disadvantages

Stability – Like idea 1, the wheels on this product are centrally mounted, so that would make it difficult to use.

Power – Using only a single motor to drive both wheels, this idea may require an additional motor to turn both wheels effectively under heavy loads.

Length – This idea although spacious, is not the most compact it could be whilst still being easy to maintain and manufacture. There is wasted space in the design which could be eliminated.

Initial idea 3

Advantages

User friendliness – This idea features a steerable nose wheel which would make operation of the device extremely easy.

Stability – This idea features a much more stable tricycle design, which increases stability and ease of use.

Weight distribution – the weight of this idea would be equally distributed across all wheels improving traction and stability.

Form – although big, this idea is sleek and still streamlined to fit the target aesthetic.

Disadvantages

Complexity – This idea is more complex to manufacture, which would result in an increased production and final cost.

Power – Much like idea 2, this product may require 2 electric motors rather than 1, especially due to it's increased weight.

Size – This idea is the largest of the ideas, and despite being streamlined would be the least compact.

Initial idea 4

Advantages

Compact – This idea is by far the most compact design, allowing it to be stored in smaller spaces.

Stability – With it's tricycle setup much like idea 3, this idea would be inherently stable yet manoeuvrable with the castor wheels at the rear

Tow fixings – The height of the rear platform on this design would allow the tow fixing to be mounted higher up, similar to the height of a tow bar on a car. This would mean the standard tow equipment would not require modification

Disadvantages

Steering – Although this design would be manoeuvrable, the rear wheel steering may prove to be tricky to master for a user. Front wheel steering would be easier to control

Handle design – With the single handle design, it may be difficult for a user to apply pushing/pulling forces to the handle without operating the throttle when being moved around manually.

Accessibility – Being so compact in it's form would possibly mean a difficult assembly and tricky to get at components in the future.

Initial idea 5

Advantages

Power – This idea would be more powerful than any before it, allowing it to tow a wider range of aircraft

Traction – The caterpillar tracks would have much more traction than any wheels, so the extra power could more easily be delivered to the ground.

Durability – As this design features gearing instead of a belt drive system, it would have increased durability as gears are much less likely to wear and break than a rubber belt.

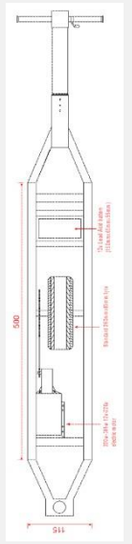
Disadvantages

Complexity – The tracks themselves would be very tricky to manufacture, and mixing differential thrust to steer the product would also be exceedingly tricky.

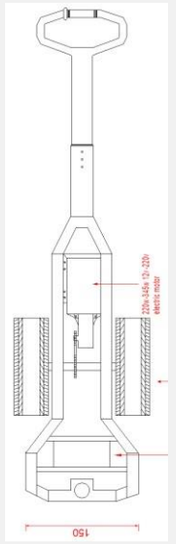
User friendliness – As this product would have to have differential thrust steering, it would likely be very sensitive to steering inputs. This might make using it much more difficult, and possibly even cause damage.

Cost – As the tracks are so complex, the cost of sourcing components/manufacturing them would be very high.

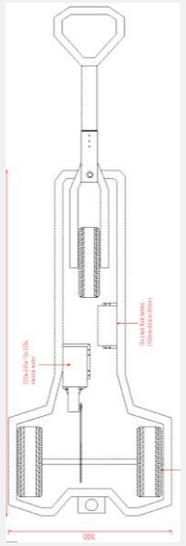
Initial idea 1



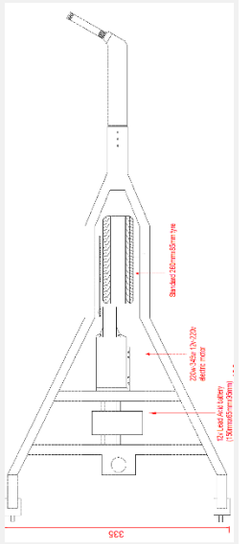
Initial idea 2



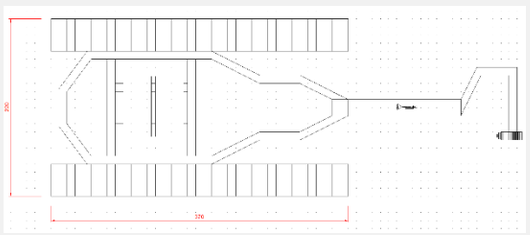
Initial idea 3



Initial idea 4



Initial idea 5



Initial ideas against specification + Client

Specification Point	Initial Idea 1	Initial Idea 2	Initial Idea 3	Initial Idea 4	Initial Idea 5
"My product should be able to tow aircraft on both concrete and grass"	With it's single central wheel, it is unlikely that this idea would have the required grip to tow on grass	The 2 driven wheels would have enough traction to tow on grass	Like idea 2, this idea also has 2 driven wheels which would have the grip to tow on grass	This idea also has 1 driven wheel, and would also likely be too light to tow on grass	Absolutely would tow on any surface
"To present as a high quality product, it's necessary my product produces aesthetics to that effect"	The cowling design on this idea is sleek, streamlined and fully hides the internals	This design also features a fully covering cowling design, which flows to fit the streamlined design	Despite it's bulkier form, it still conveys a professional appearance that fits the context of the design	The most compact of the designs, it's similar cowling still retains a professional appearance	Product may not look professional as tank tracks have never been professionally done on a tow vehicle
"My product should be no larger than: 1.2m in height and have a wheelbase of over 1.2m"	Main length: 1m, handle height adjustable	Main length: 0.63m, handle height adjustable	Main length: 1.28m, handle height adjustable	Main length: 0.86m, handle height adjustable	Main length: 1m, handle height collapsible.
"My product should be easy and simple to use"	While easy in basic operation, the act of balancing the product on it's main wheel may prove difficult	The towing weight at the back should counter the weight of the handle and force from user	Completely stable, steering mechanism very straight forward and intuitive	Steering with the rear wheels may be challenging. The castor wheels would need to be relatively stiff	Differential thrust steering may be tricky to manage
"My product should be easy and simple to work on"	Ample space for maintenance	Like idea 1, there is plenty of free space for maintenance	The most spacious of them all, this design would be the easiest to work on	Less spacious but with the removable cowling it should still be easy to preform maintenance	Complexity of drive system and tank tracks would likely be hard to work on and expensive to repair
"My product will have a metal based frame"	Mild steel box frame	Mild steel box frame	Mild steel box frame	Mild steel box/tube frame	Mild steel box section frame
"All materials chosen must also have good weather resistance and be unaffected by outdoor use"	Steel frame prone to rusting – will be finished in all weather paint. Fibreglass cowl weather resistant	Steel frame painted for rust protection – fibreglass cowl finished in car paint	Steering assembly made with stainless steel bolts to improve rust resistance	Castor wheels will be disassembled and painted to improve corrosion resistance	All materials will be painted and treated to be successfully used outdoors
"My product must be able to operate on 5% gradients regardless of the surface"	Single motor may not provide enough power for heavier aircraft	Single motor	Single motor	Single motor	Dual motor design would provide enough power to tow heavy aircraft up gradients
"My product must be able to function for 2 days of continuous use before needing a charge"	Efficient single motor setup	Single motor setup	Single motor setup	Single motor setup	Would require 2 batteries due to dual motor design

Client Feedback

What are your first thoughts on the initial designs?
I think all the designs would be able to operate at Saltby without issue. Designs 1 and 4 may have difficulty operating at more challenging sites e.g. the Mynd, as they only have 1 main wheel.

Which design do you prefer at this stage?
Designs 3 and 4. I like design 3 due to its steerable front wheel. I think this would make it's use very easy at Saltby. While design 4 only has one powered wheel, I like the idea of how manoeuvrable it is. If these two designs were combined, I think the final result could be very useful to gliding clubs.

Is there anything you think could be added to improve these designs?
A second motor as seen in design 5 would be necessary if the product is to tow all aircraft at gliding clubs. Some heavy 2 seaters take quite a lot of force to move and we wouldn't want a situation where we can't tow them if they battery is dying etc.

Do you think any of these designs wouldn't function well at a gliding club?
I think Design 1 would have real difficulty towing aircraft at any club. To balance it on the main wheel might be unachievable with the tail of a heavy aircraft weighing one side down. I also think when power is added the design would have a tendency to tip up, making it much more challenging again for the user to operate. On top of this, only having the one wheel might mean it does not have sufficient grip to operate on grass, especially if it is damp or raining. We do operate in wet conditions fairly often, so it would have to be able to cope with that situation.

Do you think Idea 5 has scope at a gliding club?
Whilst I think it is an innovative solution to glider towing, I worry that maintaining it would be more tricky than other ideas e.g. finding spare tank tracks + the wheels inside them. I do think the two motors is a good idea, and the use of 2 batteries also as we have many spare on any day at the club, so they may as well be used.

Client's thoughts at this stage
As seen from the table above and my client feedback, it is clear that my final design will have to feature 2 motors. This indicates to me that not one initial idea is fully suitable to be put in to production, so my final design will likely be a combination of several of the best design aspects of my initial ideas.

Summary Grid 4

The candidate does evidence a range of design ideas and we do see reference to the specification. The evidence of sub-system design is present although it does lack real detail at times.

We do see some technical annotation regarding joining but less in terms of relevant materials and processes.

The question here is does the candidate display an in-depth understanding of materials processes and techniques?

Level 2/3 A sympathetic award would be 7 marks but 6 would be more accurate out of nine.

Possible Further Evidence to access the higher levels

- **The candidate needed to try to build more detailed client/stakeholder interactions perhaps with a two way narrative that enabled discussion to take place and ideas can be examined in terms of context and detail**
- **There were missed opportunities to evidence the range of relevant materials and processes.**
- **The sub-system design needs a more detailed approach so that we can see how parts of the design interact with each other.**

GRID 5

Development of Design Ideas

Grid Five

- Development of Design ideas
- The definition of perceptive!
- Candidates should demonstrate the application of an iterative approach to design development. This is informed by the application of knowledge of materials and the needs, wants and values of the client/end user.
- Modelling/simulation should be used to test appropriate features including proportions, scale, function, sub- systems.
- Modelling/simulation can be achieved through the use of traditional materials, or 2D and/or 3D computer simulations. This modelling should be annotated and justified, and have supporting annotation that draws some kind of conclusion that could be returned to the client and be valuable in terms of the final design.
- Ongoing developmental changes are informed by technical application of research, experimenting, and client/end user feedback in order to improve, refine and realise a design.
- Folders shouldn’t feel as though the centre is following a formula – what is needed to test aspects of the particular design and are they met?

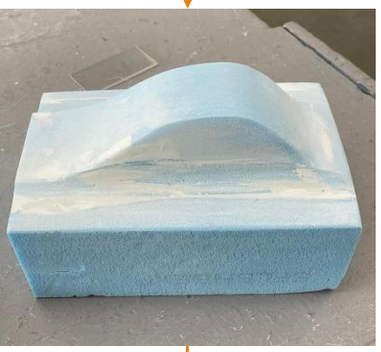
Manufacturing a fibreglass mould

Rough cut of mould:
Initially, my first stage of manufacturing this mould was to create a very rough outline of the shape I intended to make. I cut the foam block to size with a band saw and cut the curve with a craft knife. I then sanded the curve and sides to make sure they were flat and level. My next step was to glue two blocks either side of the curve to later become a radiused edge.

What I could improve on:
Next time when making the rough shape, I would use a hotwire bow. This would allow me to more easily create complex shapes accurately and would reduce the workload later with fine sanding.

Rough sanding and filler:
With this stage, I focused mainly on rough sanding the shape I desired into the foam. The blocks I had glued on were significantly reduced and the curve shape was further developed. Once I had the shape I was after, I used multipurpose filler to seal and fill all the remaining defects in the foam. Adding the filler also sealed some of the pores in the foam which allowed for a smoother finish of the foam when I fine sanded it.

What I could improve on:
I found when sanding with glasspaper, no matter how careful I was there was always a tendency for the edge of the paper to dig into the foam and create a small hole. Next time, I should fold the edges of the paper up to create a radius.



Final filler:
The aim of this step in mould making was to completely fill all of the holes and seal the mould. Lots of filler was applied, and gently sanded down until it was level with the mould. At this point, the mould was smooth all over and nearly ready to take the sealant I would be using.

What I could improve on:
Due to the holes previously mentioned, a lot of filler was required. This took a long time and could be reduced if I implemented the sanding technique mentioned earlier.

Final sanding:
This quick stage was a fine grit glasspaper gently across the surface of the mould. Once completed the mould was smooth and ready to be sealed. The filler was completely flush with the surface and all corners were radiused.

What I learned:
The actual shaping of the foam by hand was relatively easy and did not cause too many problems. For the final product however, it may be advantageous to use a hotwire cutter to shape the foam more accurately and ensure it is even on both sides. Then, fine shaping and smoothing could be done by hand with sandpaper.

How it links to my design:
In all of my designs so far, featured is a lightweight fibreglass cowling to cover and protect the internals. When manufacturing my product therefore, it is important I understand how to create a suitable mould for the fibreglass, and how to use it to create parts.

In this section of my development, I have chosen to manufacture a relatively complex shape mould, scaled approximately 50% of the size it would be for the actual prototype.

What I want to achieve:
My intentions with this development are to learn and practice the following:

- Creating a suitable foam mould
- Preparing the mould
- Laying up fibreglass
- Prepping for paint
- Painting + finishing

From practicing these processes, I can determine what methods will work best for my prototype and get some experience with using them. This hopefully will result in a better quality product.

Second mould:
For my developments, I found it would be useful to create 2 moulds. One would be used to test different techniques and processes, and the other to mirror what I would be doing on the final design.
The images in this slide are of the mould that represents what I will be doing on my final design, and on subsequent slides the smaller one represents the ‘test bench’ mould.

Preparing the mould

Sealing the mould:
To seal the small holes in the foam, I decided after researching different methods that covering the mould in a thin layer of PVA would be appropriate. To do this, I mixed the PVA with a small amount of water to ensure it was thin enough to retain the shape of the mould. I then very lightly applied the PVA glue with a paintbrush, evenly distributing it over the whole useful surface.

Drying process:
The mould was then left in a dust free environment to dry. As the PVA was so thin, it's natural tendency was to draw itself level as it dried creating a smooth, pore-free surface. The fact the PVA also moved to find level meant that any brush marks from applying it in the first place were removed. I did not find any issues with running or dripping of the glue.

Secondary mould

Results:
When dry, the final result was a glassy smooth finish which was suitable for fibre-glassing. The disadvantages to this sealing process is it has to be conducted very carefully, as if there were to be an imperfection in the glue layer, it would be practically impossible to fix it when dry.

My thoughts:
In my opinion, this option is best for my product. PVA glue is readily available in school and very cheap. It is also easy to use and has no undesirable properties. In later developments, it had no reaction with the paint or the fibreglass and proved to be a useful sealant for the mould.

Sealed mould

Other tests:
I also investigated applying a non-stick surface to the mould, using Clingfilm. It was suggested to me by someone with previous fibre-glassing experience. As seen in the image below, the Clingfilm was applied when the PVA was still wet, to ensure it was stuck down securely.

End result:
When applying the Clingfilm, I found it very difficult to effectively 'wrap' the small section of the test piece I was using. The film always had wrinkles in it which would've shown in the fibreglass part.

Additionally, being a non-stick surface, the film was very hard to stick down to the PVA. This meant on a more complex shape (such as the mould I will be using), it would be unlikely the Clingfilm be able to stick down over curves and corners.

When dry however, the Clingfilm did serve it's purpose as it was extremely easy to remove from the mould. This would mean if I were able to apply it correctly, I would easily be able to remove any part on the mould.

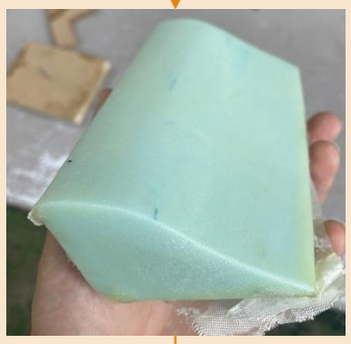
What I learned:
In summary to this idea, I have decided to reject it for use on my final product. While it does yield the intended result, I find the process too temperamental and too risky to be attempted on the mould. I will simply have to carve the foam mould out on the final part and settle for a 1 use only mould.

Laying up fibreglass

Simple mould:

Shaping and initial layup:
First I cut the fibreglass sheet to size with lots of excess material around the edges to be sure it fits when contoured to the mould. I then mixed up the resin and soaked the first layer of fibreglass in it, off the mould. Once saturated, I took the glass sheet and draped it over the mould. I used a credit card to 'squeegee' out as much resin as possible and get rid of any air bubbles. This also removed any wrinkles in the glass.

Second layer:
After the first layer was on tight and the resin still wet, I cut a second sheet of glass and soaked it in the resin. I then draped it over the first layer and used the same credit card to contour it to the mould and remove as much excess resin as I could. The resin I was using was relatively fast setting so it was important I proceeded quickly.



Drying + layup difficulties:
Once the second layer was applied, I left the mould in a dust free environment to dry. I only applied 2 layers to this mould to test the minimum number I would want for my final product.
On this mould, laying the fibreglass was relatively easy, with no difficult curves or contours, the fibreglass was able to cling tightly to the surface without any intervention.

Trimming excess + clean-up:
Once dry, my first task was to trim off the excess fibreglass still hanging over the edges. I did this using a sharp razor blade and scissors. It was challenging to get close to the mould without accidentally cutting into the fibreglass and foam core. I elected to leave a few millimetres of excess to be sanded off instead of cut down all the way.
After the excess was trimmed and sanded, I took a fine grit sandpaper to all the edges to remove any roughness.

Hollowing the mould:
Seeing as the Clingfilm experiment in the previous development was rejected, I have decided to simply leave the lightweight foam core inside the fibreglass component. Subsequently, this means I had to hollow out the foam which was very easy with a knife and sandpaper. I left ~10mm of foam underneath the fibreglass to improve the strength of the fibreglass component.

Complex mould:

Differences in initial layup:
Between this and the simple mould, the intricacies of this form were much more difficult to shape the fibreglass around. Using the same technique as before, soaking the fibreglass sheet in resin and then applying it to the mould, it became very tricky to get the glass round the corners without cutting it. In particular, the section where the glass basically has to go round a 90 degree bend was very challenging. As part of the mould, I incorporated a bigger radius corner on one side to see if that would be easier to glass, and it was.

Differences in next layers:
The second layer was easier to apply because it could more easily stick to the already wet first layer. However, because of the time constraints using the quick-setting resin, I found I did have to use scissors to cut the glass and overlap it in one section, however it did not have a significant effect on the final finish once sanded down.
On this mould I decided to do a third layer which improved the overall strength of the cowling, and when scaled up for the final design I believe it will be important to have more layers.

Clean-up:
Similarly to the 1st mould, the excess glass was trimmed and sanded back to be flush with the foam. Any rough patches were sanded down, including 1 air bubble. I think the reason this air bubble formed is due to the steepness of the transition from vertical to horizontal on one side of the mould. The air bubble was likely a result of the fibreglass being pulled away from the radius when the excess resin was being removed with the credit card.

Result:
In my opinion, this mould did not come out to as high a quality finish as the simple mould (as to be expected). The side with the steeper corner proved extremely difficult to get around which resulted in me cutting the glass on the 2nd layer and the formation of the air bubble. Additionally, the pictures show a slightly yellowed finish which is a result of me using a slightly incorrect resin mix.

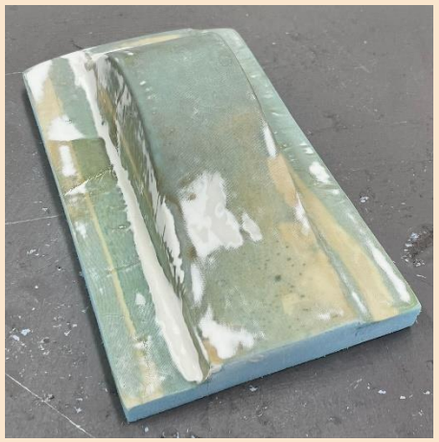
What I learnt:
From these moulds (the 2nd in particular) I have gathered essential information which will help me design and manufacture my final product. For example, the cowling on the final design will feature no abrupt edges, as per the theme of streamlining, and any curves will be smooth and continuous to make the layup easier. Furthermore, I will use the proper measuring equipment to measure and mix the resin to prevent the yellowed finish as seen on the complex mould. From the moulds, I have decided my final product will have a minimum of 3 layers to retain it's strength as it will be considerably larger than these developments.

Prepping for paint

Profiling the mould:
To ensure the surface of the fibreglass was level and smooth, I coated each mould with simple wood filler. This ensured that any low points in the finish were filled in and when sanded back they would be level. I used wood filler because it's easy to use and requires very little work to sand back.

Sanding down the mould:
Initially I used a coarse grit sandpaper to take back the bulk of the filler. Once I started to reach the fibreglass below, I switched to a finer sandpaper. With this paper I scaled the filler back until most of it had been removed and the surface was level. I noticed there were still undulations in the surface, and it was important that the surface which was to be painted was as smooth as possible, as any imperfections would show through the paint.

More filler + final sand:
To remove these smaller imperfections I applied more filler to the areas required and sanded them back as described above. I then moved to the finest grit sandpaper I could find and spent a long period of time gently going over the surfaces, to ensure they were as smooth as possible with the desired shape.



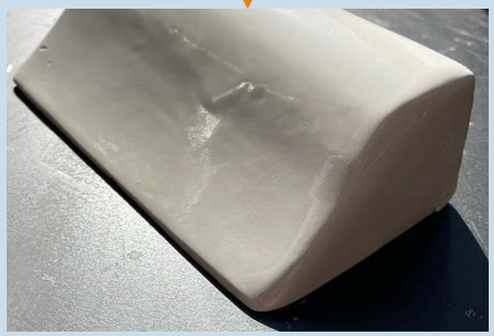
Painting + finishing

Final sand + fine detail:
I first used the finest grit sandpaper I could find to make sure the surface was as smooth as it could be. I then used a damp cloth with a small bit of alcohol to remove any loose dust particles from the surface of the part. Once dry, the piece was ready to be primed.

Priming:
To prime both parts, I used Halfords white primer which is designed to work with it's car body paint (what I used to paint the parts). The first coats of primer were extremely thin with a 15 minute interval between them. I initially did 3 coats. The primer was beginning to fill the weave of the fibreglass and create a level surface, however I could've used Halfords own 'filler primer' which may have filled the weave in fewer coats.

Further sanding + priming:
When the first coats were dry, I then took to them with a very fine grit sandpaper and gently sanded them back to help fill the weave. Once sanded, I once again wiped the surface with the damp cloth and took it back to the spray booth where I repeated this prime, sand, prime, sand sequence a few more times.

Paints:
I chose to use car body paint to finish the fibreglass. In gliding, a gel coat is used to get a smooth white glossy finish on aircraft. To get the same finish, several coats of white paint and lacquer were applied. Car body paint was chosen due to it's durability, weather resistance and gloss finish.



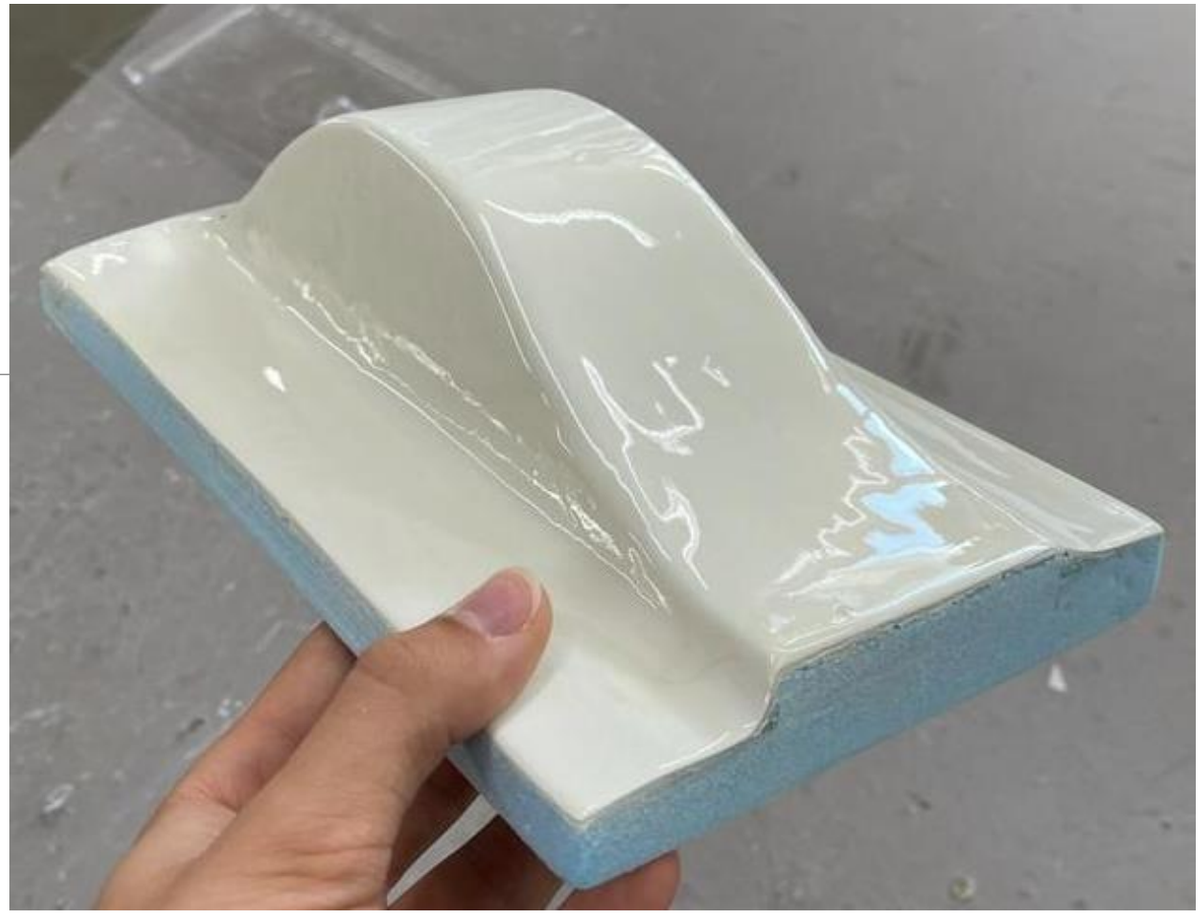
Initial coat:
The first coat of white paint went on very well. It was applied very thin and appeared to fill in some of the fibreglass weave. I left 15 minutes between each coat and the image on the left is the result of the 3 first coats. Already the part had a glossy, smooth finish. I decided that the simple mould would be done with as little paint as possible to see what the minimum paint required was for the desired result.

Further coats:
On the simple mould, I applied another 3 coats until I was happy with the finish. The paint had completely filled in any of the fibreglass weave that was still showing after the sand, so the result was a completely smooth surface. I put 9 coats on the more complex mould, which had the same effect. There was no discernible difference between the finishes after different numbers of coats.

Preparing for lacquer:
To prepare the parts for the lacquer, I used an extremely fine grit wet and dry paper, soaked in soapy water to remove the gloss finish already added by the paint. Once done I dried the parts off and was sure to wipe off any loose particles of dust.

Applying lacquer:
Like painting them, I applied 3 coats of the lacquer on each mould with 15 minutes in between coats. I did find the lacquer was thicker than the paint so had a tendency to run on the sides of the complex mould. It did not effect the finish once subsequent coats were added.

End result showcase + analysis



Chemical reaction + erosion:
When the finishing process was complete, I noticed 2 areas on the complex mould where sections of the foam appeared to have eroded away. These sections were not effected until I applied the lacquer, therefore I must conclude the lacquer I was using had a chemical reaction with the foam. This was further supported by the fact there was no reaction on the simple mould, as no foam was left exposed. On my final design therefore, I should be sure that all of the foam that is visible is covered by fibreglass to prevent this reaction.

My thoughts:
I am extremely pleased with how these 2 developments turned out, from start to finish. The finishing process was very straight forward and it resulted in a mirror-like surface which resembled a glider's gel coat perfectly. Furthermore the surface was hardened so it would not chip or scratch easily. My final product therefore will utilise the same methods demonstrated in the finishing process, which hopefully will result in as good a quality finish as seen above.
Additionally, thanks to using Halfords own paint, I was able to cut the cost of finishing these product significantly, as using gel coat is an expensive and potentially dangerous process. This will help the cost of manufacture for the final product meet a sensible selling price for gliding clubs across the country, making it a cheaper alternative to current solutions (as per my specification).

MIG welding initial tests

Why MIG welding?
To manufacture my frame, I elected to use MIG welding due to it's simplicity and ease to learn, and the strong joins it produces. This would allow me to join together my metal frame easily and quickly, making sure it also can withstand any stresses it will endure in it's lifetime (e.g. pulling a glider) without failure. Our school workshop did not originally have a MIG welder, so one was purchased for the purposes of completing my product. This therefore meant that I would have to learn to MIG weld, along with the Staff as no one had previously attempted it.

The setup
We set the welder up to run on a CO2-Argon mix which was specified as the best arc gas for welding mild steel (what I had chosen to produce my frame from).
I selected mild steel as it is strong and very suitable for welding. Additionally, the mild steel box section has an appropriate strength to weight ratio for my purpose, as it will allow the product to be light enough to be dragged when not under power, whilst being heavy enough to give traction to the wheels.
We also used a standard auto-darkening welding mask and wore protective gloves and aprons when welding.

Initial attempt
My initial attempt at the welding process was to simply 'tac' 2 pieces of material together. Other than checking our setup worked as intended, this initial attempt gave me a better understanding of the process and how I should proceed. The first attempt proved successful as the metals were strongly fused by the weld 'blob'. See image to the right

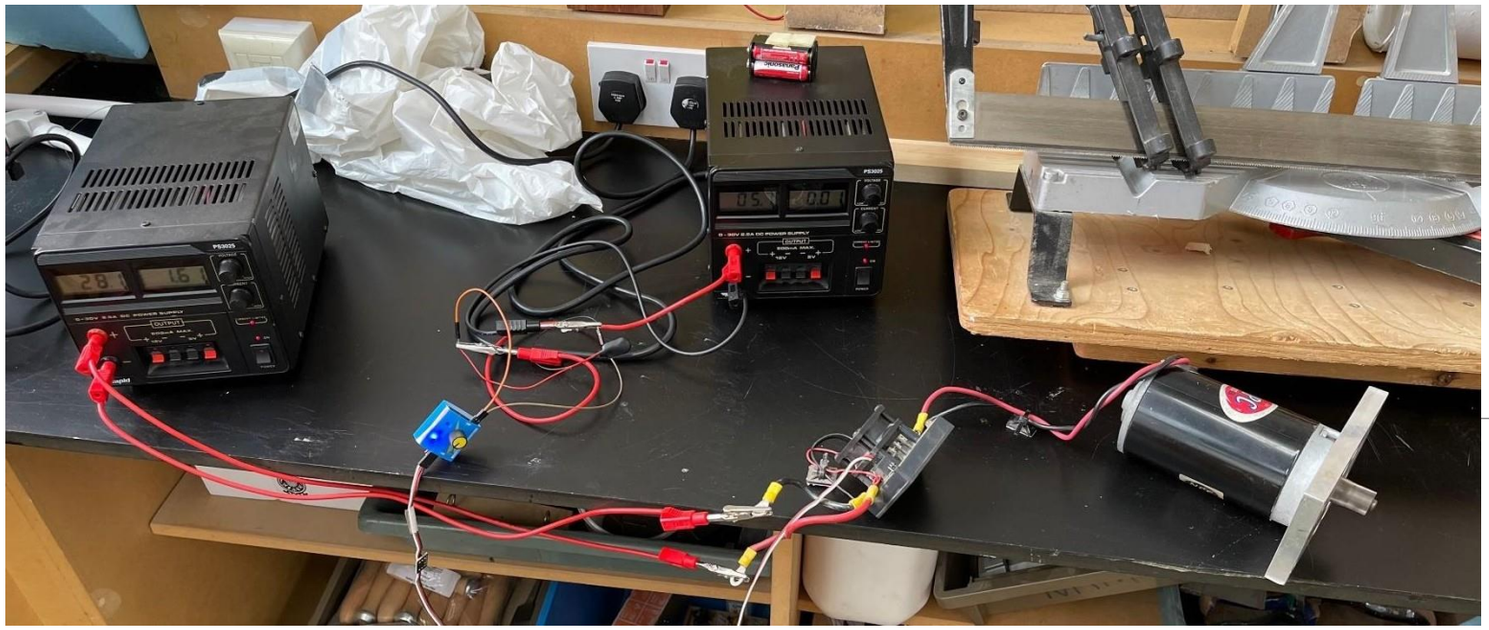
Attempts at continuous welds
The next logical step was to try a continuous weld. As the image to the left demonstrates, the first attempt was rather irregular in it's shape and distribution of material. One problem I encountered was the welding mask went so dark when the arc formed it was very tricky to see where the work was or where the weld was going. Additionally, I also found some areas had patchy deposits of material rather than the linear flow of welding rod I was looking for.

Next attempts
Having altered the darkness of the mask and changed both the welding voltage and wire feed speed, I attempted many more continuous welds, fine tuning the settings each time. The image on the left shows the effect of altering the darkness of the mask; the weld on the left is markedly crooked whereas after the mask was adjusted I could see the work much better, resulting in the straighter more uniform weld on the right. This process was repeated several times until I was happy with the settings, producing a weld I deemed strong enough and uniform enough for my product. The image below captures my most successful attempt before moving on to welding the frame.

Welding table
I also created this sheet metal surface on which to weld on. It provided a level, grounded surface to work on.

Fine tuned settings
As the image to the left depicts, after multiple iterations of trialling new settings, I found a combination which resulted in the best and easiest weld for the material I was using. Additionally, the other attempts gave me the opportunity to practice my welding technique, which improved over the cycles. I ended up using a motion where small concentric circles were made by the welding gun in the direction of movement. This resulted in an increased penetration of the weld, and the 'rippled' appearance as seen in the image.

Selecting and testing electronics



Motors and ESCs
I was able to acquire 2 powerful NPC robotics DC motors and 2 appropriately sized electronic speed controllers to pair with them. The motors ran on 24V power, at 4000rpm delivering 0.73hp each. When geared down, these motors would produce a significant amount of torque at the lower speeds, which would be sufficient for my product. To test this combination, I connected each motor to it's speed controller, which I then connected to a simple PWM signal servo tester. I powered both the motor and the servo tester off 2 powerpacks and tested to see if I could control the speed of the motors through PWM waves. The test was a success and I also discovered the ESCs had a reverse function which could be used with the servo tester. This was important to my product as it proved that any PWM throttle could be used to interface with my motors.

Batteries:
As the motors are designed to run up to 24V and the batteries I was planning to use were 12V, I had to use a step up transformer in the form of a coil to allow the voltage to be correct for the motors. I was able to source this transformer from an existing product, and took it for use in mine. See image to left

Pictured above:
An example 10Ah 12V glider battery

Glider batteries:
Gliders use lead acid/lithium ion batteries. My product should be designed to use these batteries as they are readily available.

Throttle:
For the throttle, I selected a PWM E-bike thumb throttle. This was because it could be easily mounted on the handle, and as it relays PWM signals, it will interface with the ESC very easily. This throttle also runs on 12V, which is suitable to the batteries I have chosen.
I selected a thumb throttle over a hand throttle due to the design of the handles in my design ideas. I reasoned that gripping a moving surface would make the operation of the throttle quite tricky, and a better way would be to simply have a fixed throttle, that was operated independently of the hand grip.

Summary Grid 5

The candidate does evidence the ongoing development of the product in some ways (body styling) and we do see some good modelling to test aspects of the proposal especially in terms of materials and processes. We see little evidence of the research influencing the design thinking, apart from the exploration of glass fibre moulding and very limited detailing evidenced in the sub-system design work. This does illustrate that this is a level 2 submission. However, the evidence of real client narrative seems to be an omission where a perceptive, iterative approach does not seem to be in evidence.

The award therefore is a level 2/3.

Award 6/7 marks out of nine

Possible Further Evidence to access the higher levels

- **The candidate needed to show evidence of a more substantive client narrative that then clearly impacted on the design thinking.**
- **The candidate would have benefited from more detailed sub-assembly design work to illustrate all final proposals.**

GRID 6

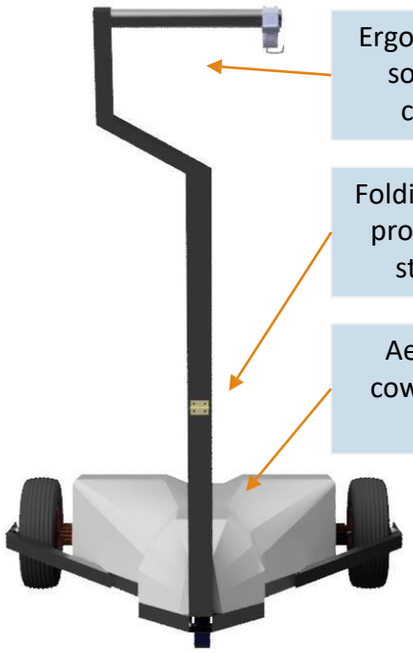
Final Design Solution

Grid Six

- Final design solution
- In this section candidates are expected to provide comprehensive manufacturing details to enable a third party to manufacture the design solution.
- It should include detailed drawings of the finished designs full cutting lists of the materials and components required and any part drawings where appropriate.
- This section should also include details of manufacturing processes and where sustainability and environmental decisions are being made.
- Evidence in this section is likely to include a graphical representation of a final design with working/component drawings and a breakdown of major manufacturing stages.

Final Design – Orthographic View

Front View

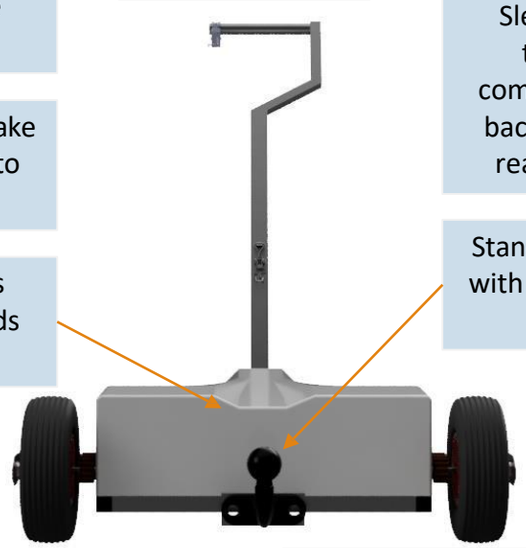


Ergonomic handle designed so user can apply force centrally up the neck

Folding neck design to make product more compact to store when not in use

Aerodynamic fibreglass cowling protects + shields electronics

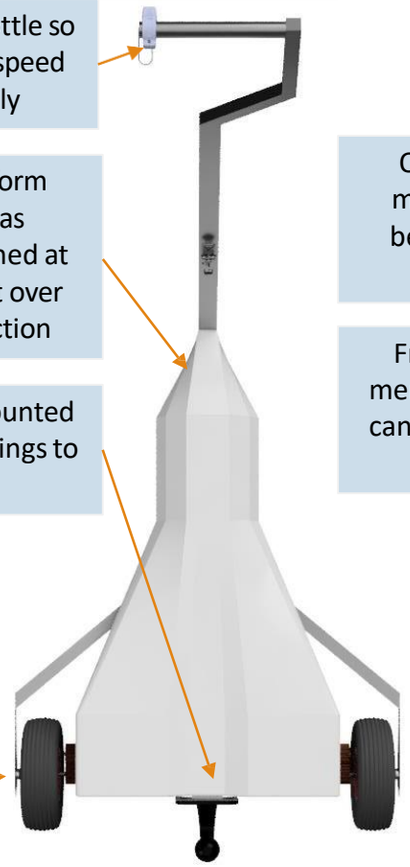
Rear View



Standard tow ball mounted with universal mountings to rear of frame

Wide wheelbase allows better distribution of power when towing

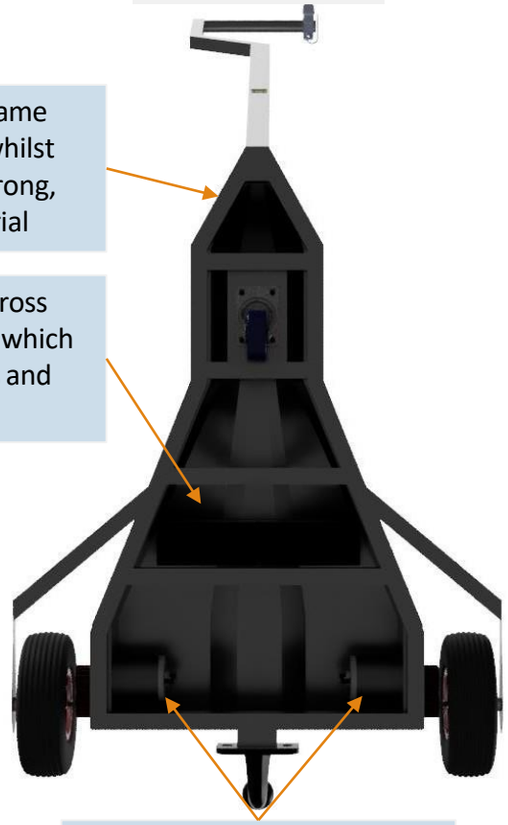
Top View



Electronic thumb throttle so user can control the speed of the device easily

Sleek and slender form tapers to a point as components positioned at back to exert weight over rear wheels for traction

Bottom View

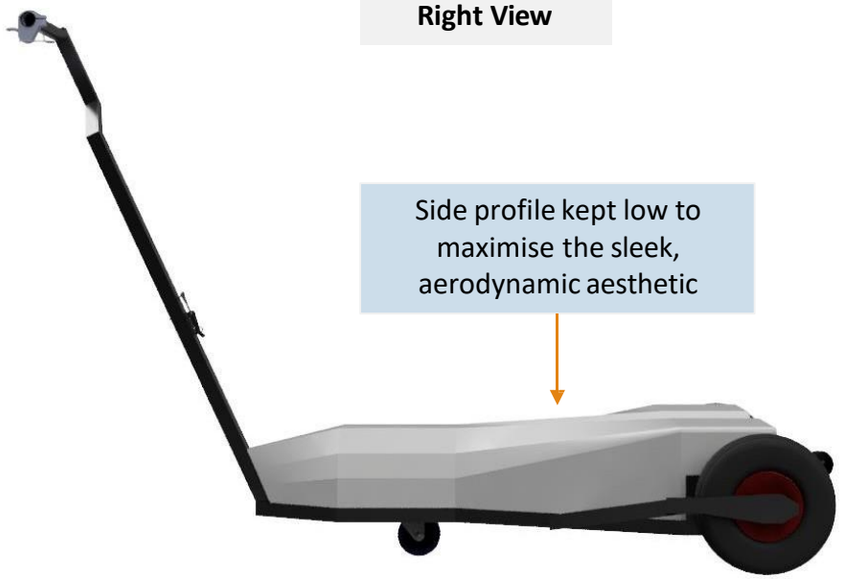


Open mild steel frame maximises space whilst being extremely strong, using little material

Frame divided by cross members into 'bays' which can store electronics and components

2 large DC motors to provide power and torque

Right View



Side profile kept low to maximise the sleek, aerodynamic aesthetic

Left View

Materials

My design features the following materials in it's composition:

- Mild Steel – used for the entire frame of the design
- Polystyrene – used as a foam mould for the cowling
- Fibreglass – Used to manufacture the cowling
- MDF – Used miscellaneously as brackets + braces
- Acrylic – Used as a splash shield for the underside of the design

Design

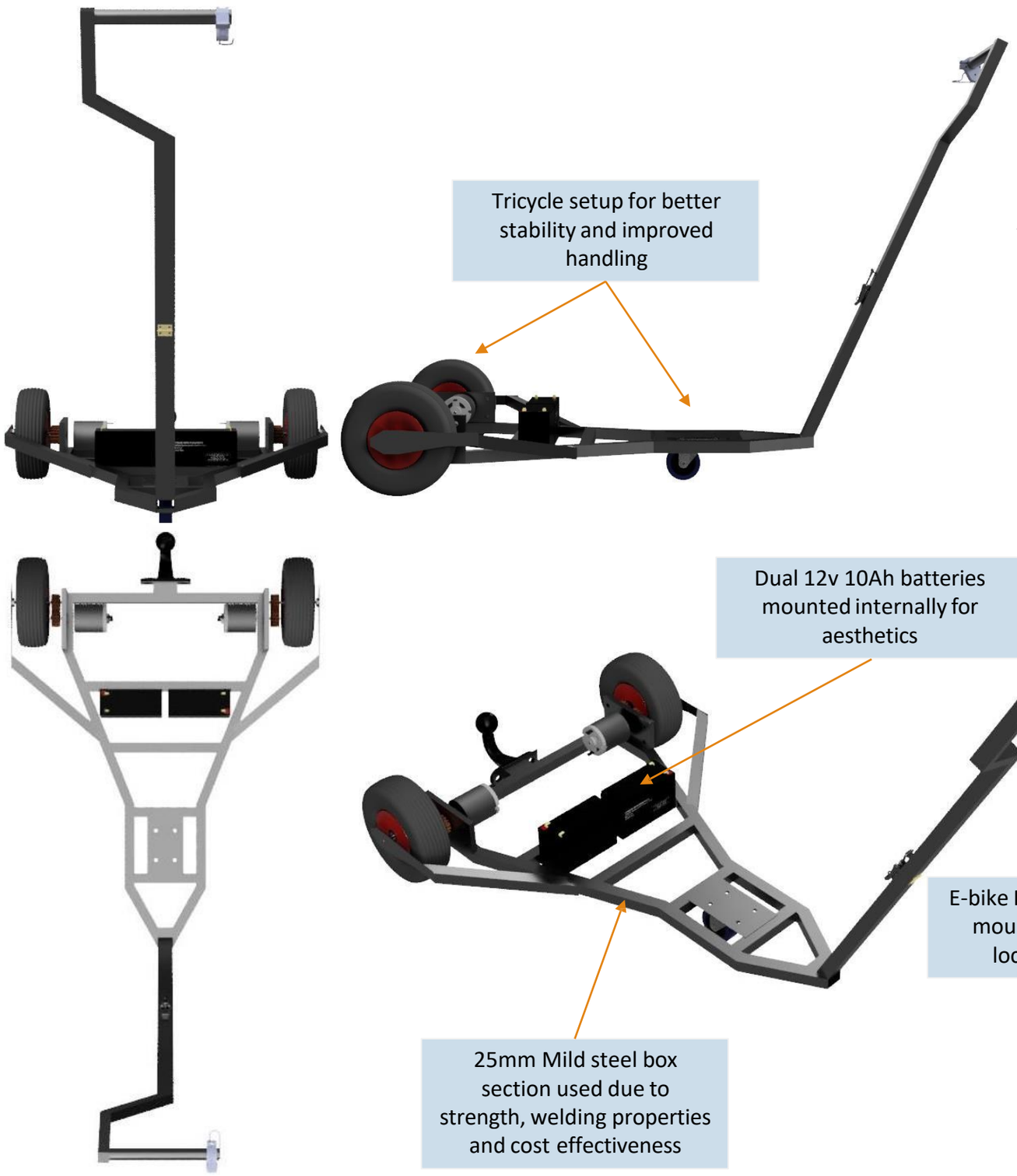
My design is a combination of several best aspects of my initial ideas. It is designed to be more user-friendly, and capable than any of my design ideas so far, drawing also on client feedback. It is designed around the specification, and will also improve upon existing glider tow methods.

Features

This design features 2 driven wheels at the rear, and 1 free castor wheel at the front. The rear wheels are much larger in diameter, and are air-inflated rubber tyres. Each rear wheel is driven by it's own electric motor, which drives the wheels through a set of gears. Due to the open and spacious frame, the design is split into electronic 'bays', which each will house different electronic components. The mild steel frame will be welded to 1 piece, making it incredibly strong and extremely durable. Additionally, the fibreglass cowl will be hollowed out on the inside to allow sufficient space for internal components to be mounted.

Final Design – Orthographic Frame View

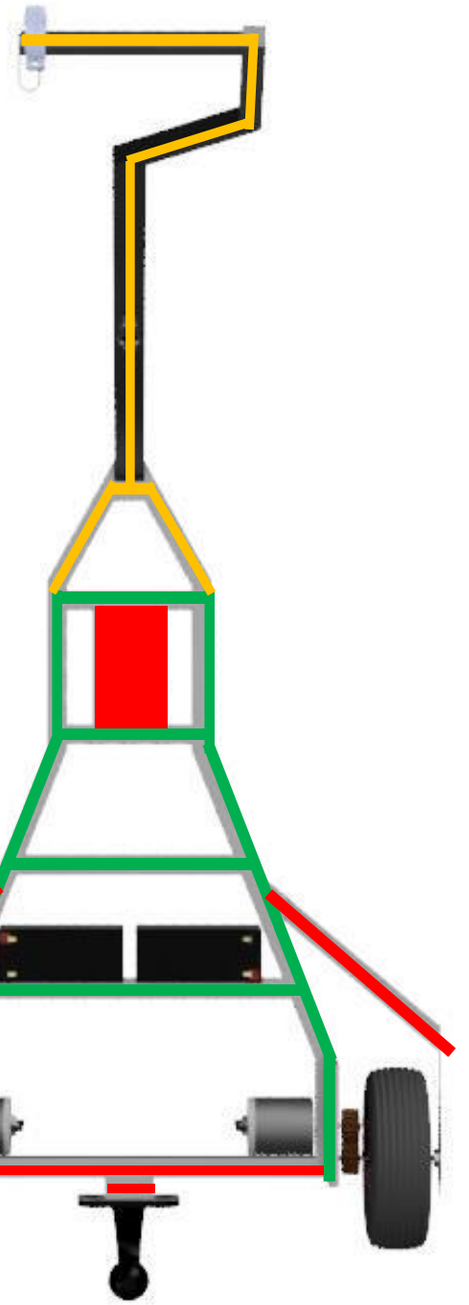
Front View



Manufacturing

It is clear that the frame must be manufactured in a particular order to achieve the best results. To this end, I will first cut and weld the 'main body' of the frame, and then weld the extremities after. To indicate this, I have drawn lines on the image to the right to show which order sections I will do first.

- **Green** – weld first
- **Amber** – next welds
- **Red** – final welds

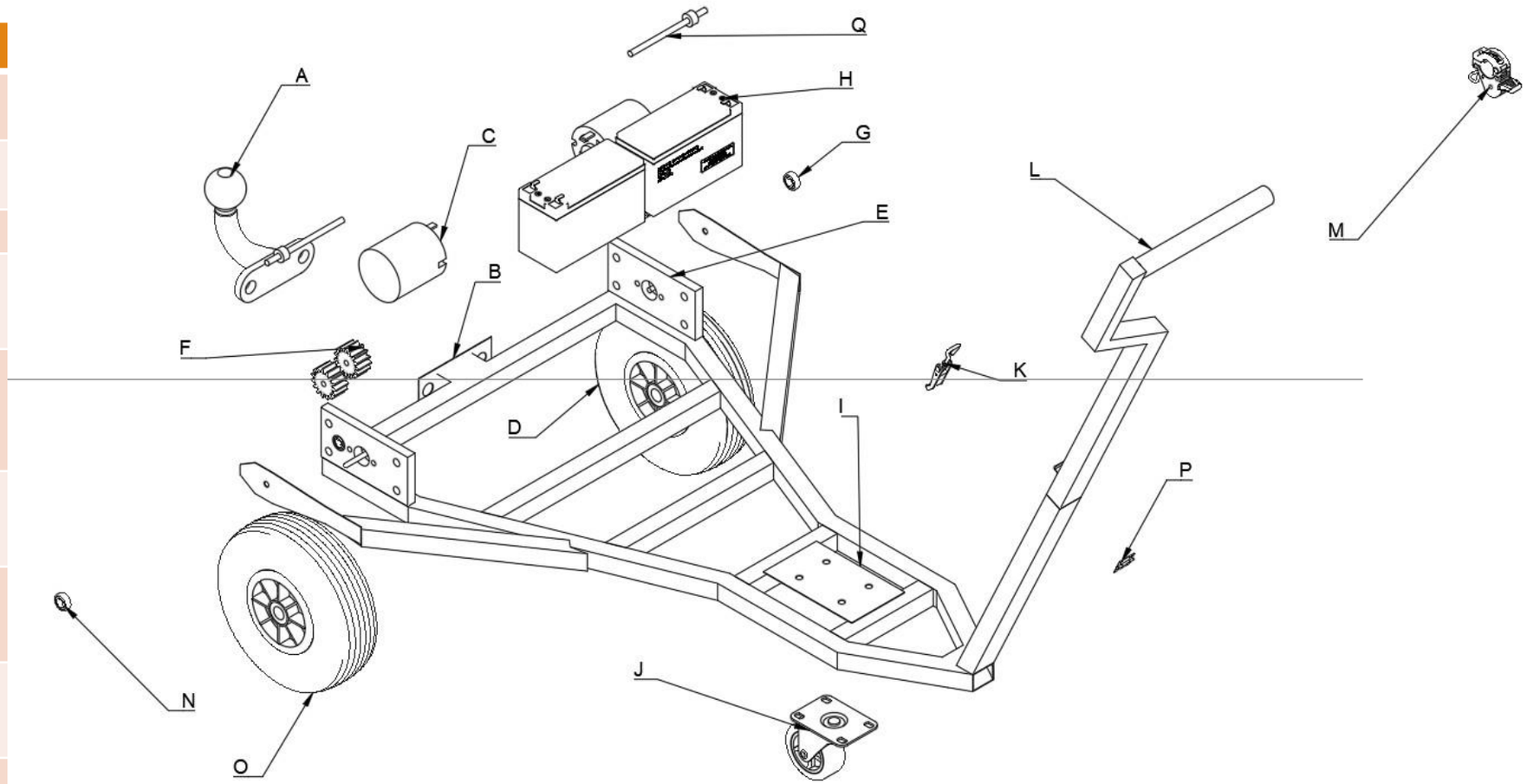


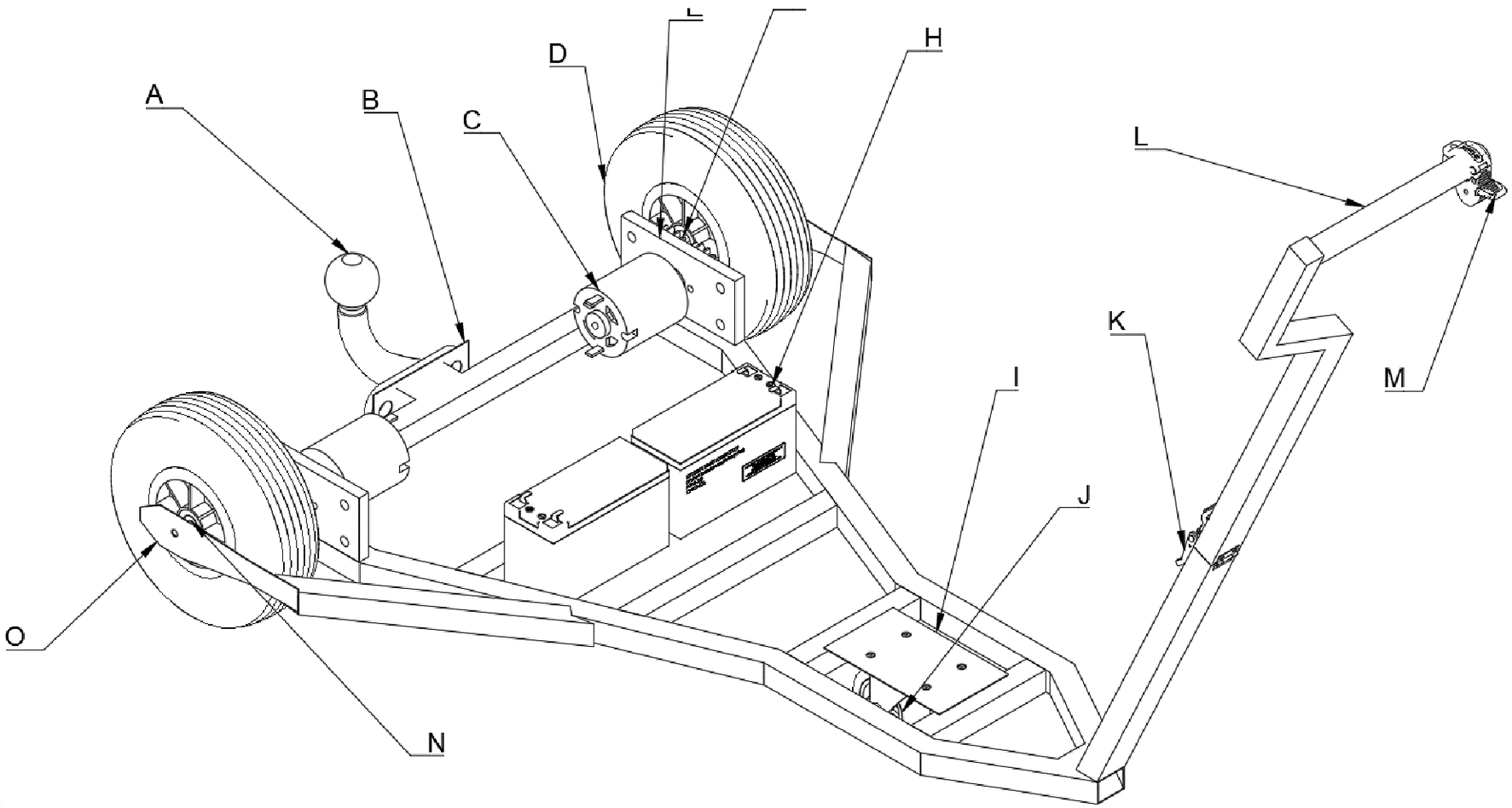
Space usage

As can be seen from the isolated frame of my design alone, with the essential components mounted in place there is a large amount of free space available for any other electronic components. I have tried to keep the heavier components towards the rear of the frame. This will mean the weight distribution of the product and the C of G is closer to the rear wheels, allowing them to have more traction when towing. This will help my product tackle heavier aircraft. The free space towards the front of the frame therefore will be used for the small throttle circuit, and electronic speed controllers. There is a clear acrylic sheet along the bottom of each frame 'bay', stopping water from entering and damaging the electronics.

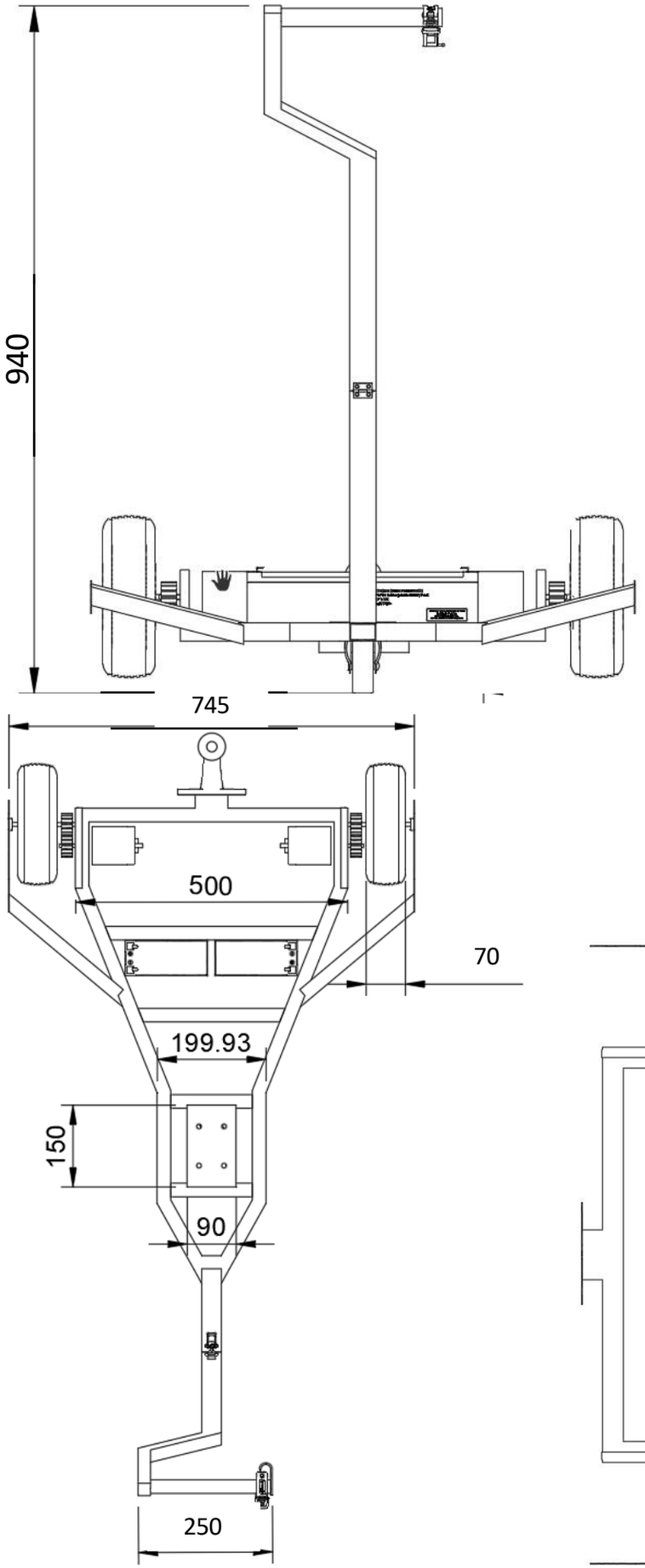
Exploded and detailed

Key	Name	Function
A	Tow Ball	To allow gliders to be attached easily to the product
B	Tow ball mount plate	To provide an accessible easy mount for any tow attachment
C	DC Motor	To provide driving force to wheels
D	Rubber tyre	To give the motor a large surface area to apply it's driving force to, helping tow larger aircraft
E	Motor mount plate	To allow the motors to be mounted securely and easily removed if maintenance is necessary
F	Gearing	4:1 gear ratio necessary for peak motor performance with specific motor/battery combination
H	10Ah 12v battery	2 glider batteries to provide enough power and endurance for the product to operate
I	Castor wheel mount plate	To provide a solid, durable plate on which the front castor wheel will be mounted
J	Castor wheel	This free wheel will provide stability and excellent manoeuvrability for the product
K	Over-centre latch	This latch will allow the neck of the product to be folded/unfolded with great ease
L	Handle	A round, durable handle to allow the user to grip the product
M	Throttle	Electric PWM thumb throttle will allow the user to control the RPM and speed of the motors, to whatever towing speed is best
N	Ball bearings	To allow the wheels and motor to spin with as little friction as possible
O	Bearing mount plate	To provide a secure mount for the end bearing and prevent lateral movement of the wheel axle assembly
P	Hinge	To allow the neck of the handle to fold in half, making it more compact for storage and transportation
Q	Wheel axle	To allow the wheel to mount to the bearings on each end, and give the gear a place to engage with the motors and wheels



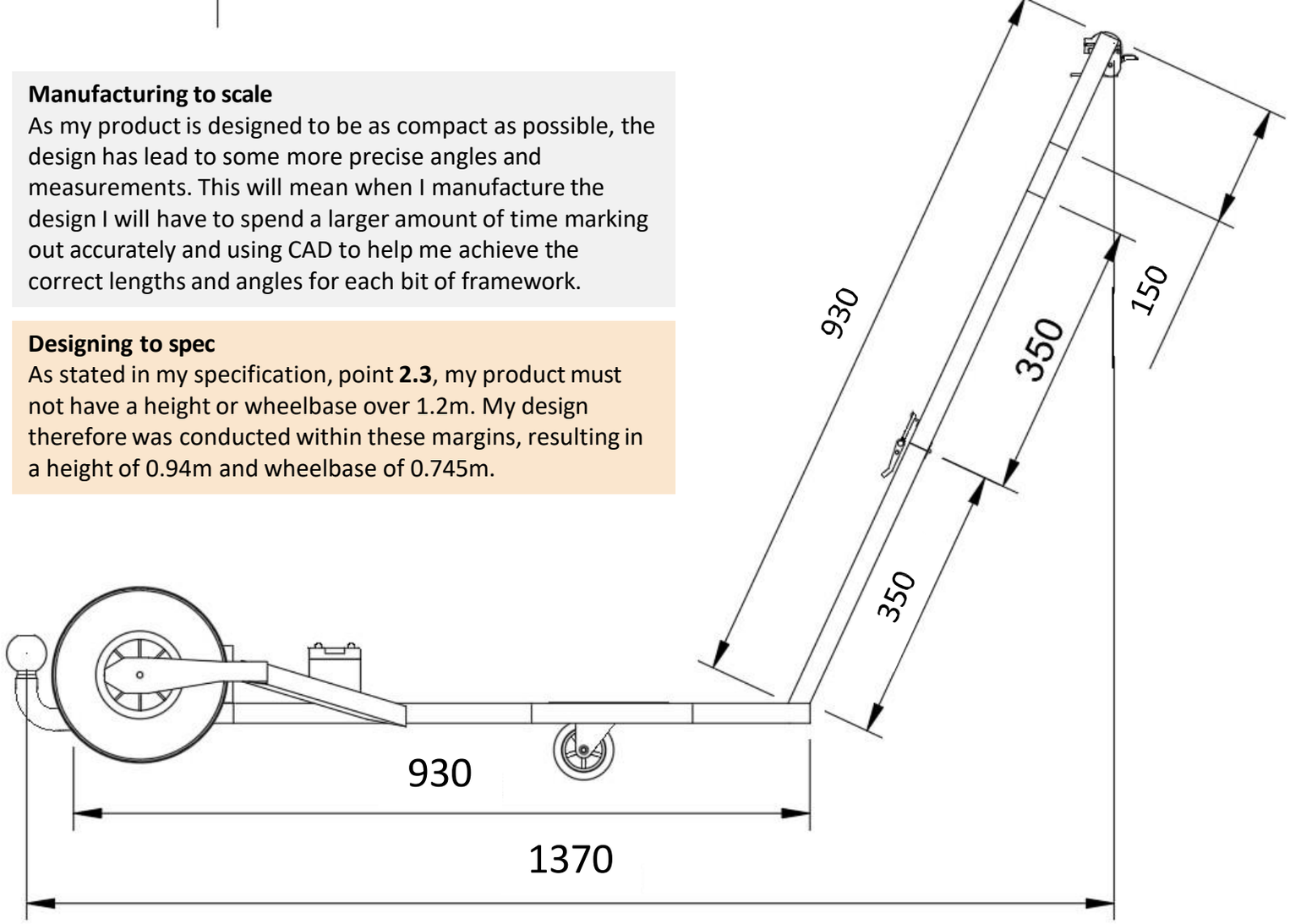


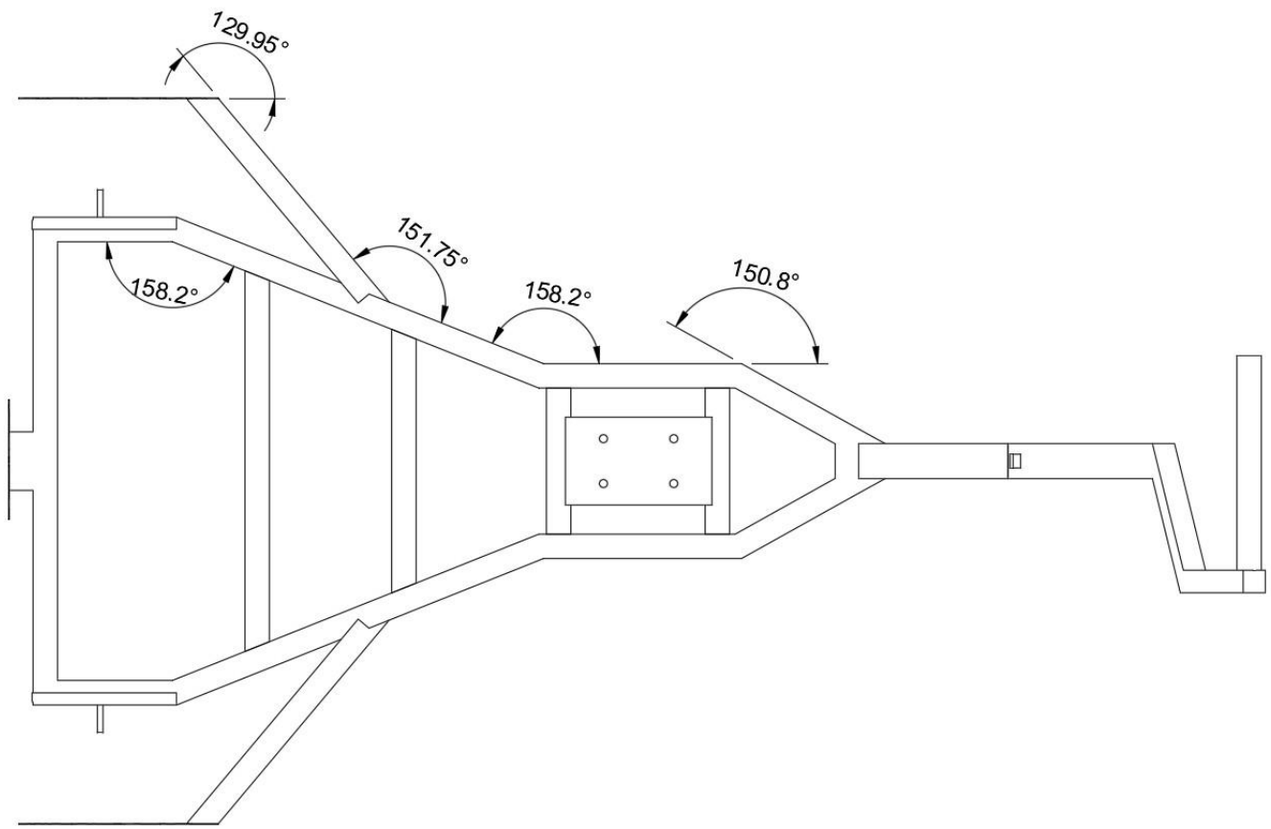
Engineering Orthographic View



Manufacturing to scale
As my product is designed to be as compact as possible, the design has lead to some more precise angles and measurements. This will mean when I manufacture the design I will have to spend a larger amount of time marking out accurately and using CAD to help me achieve the correct lengths and angles for each bit of framework.

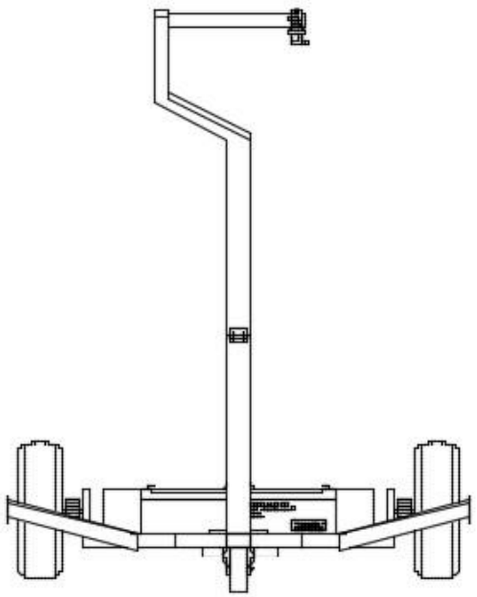
Designing to spec
As stated in my specification, point **2.3**, my product must not have a height or wheelbase over 1.2m. My design therefore was conducted within these margins, resulting in a height of 0.94m and wheelbase of 0.745m.

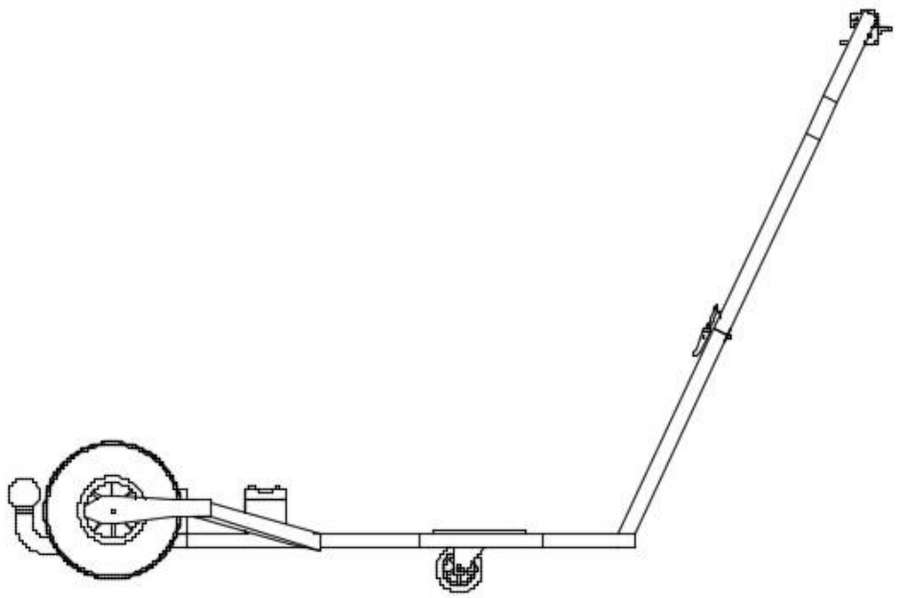


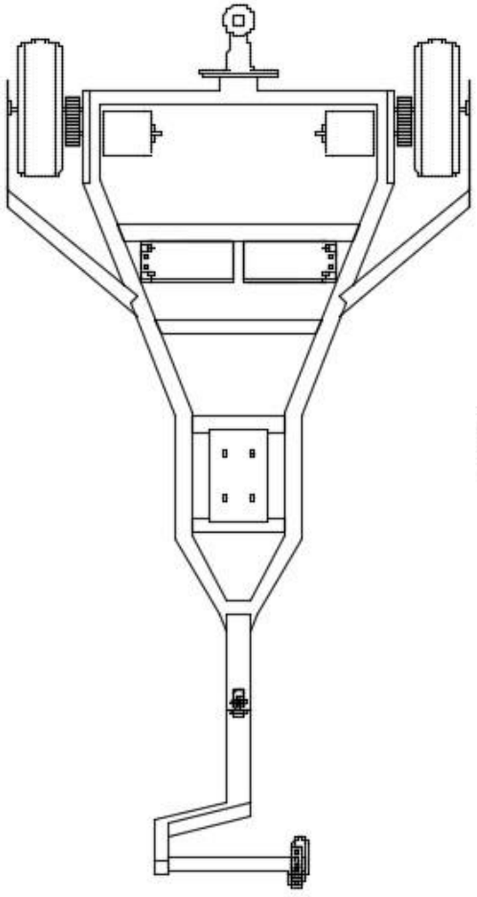


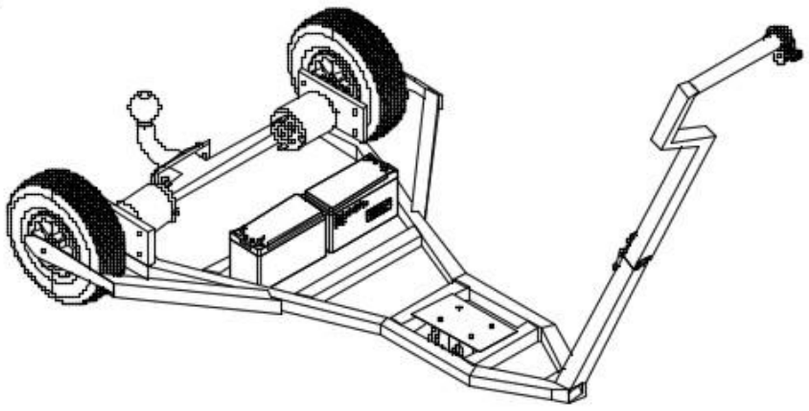
Scaling + sizes
To make my product as compact as possible, I have tried to scale it around the components being used. There is no wasted space, and everything is scaled to allow for tight tolerances between components and enough room for any extra electronics. The design is tapered as the larger components such as the batteries, motors and electronics are sat between the 3 wheels. This means there is less requirement for space towards the front of the design, so I included a taper to ensure no wasted material, or space in my design.

Engineering Orthographic View









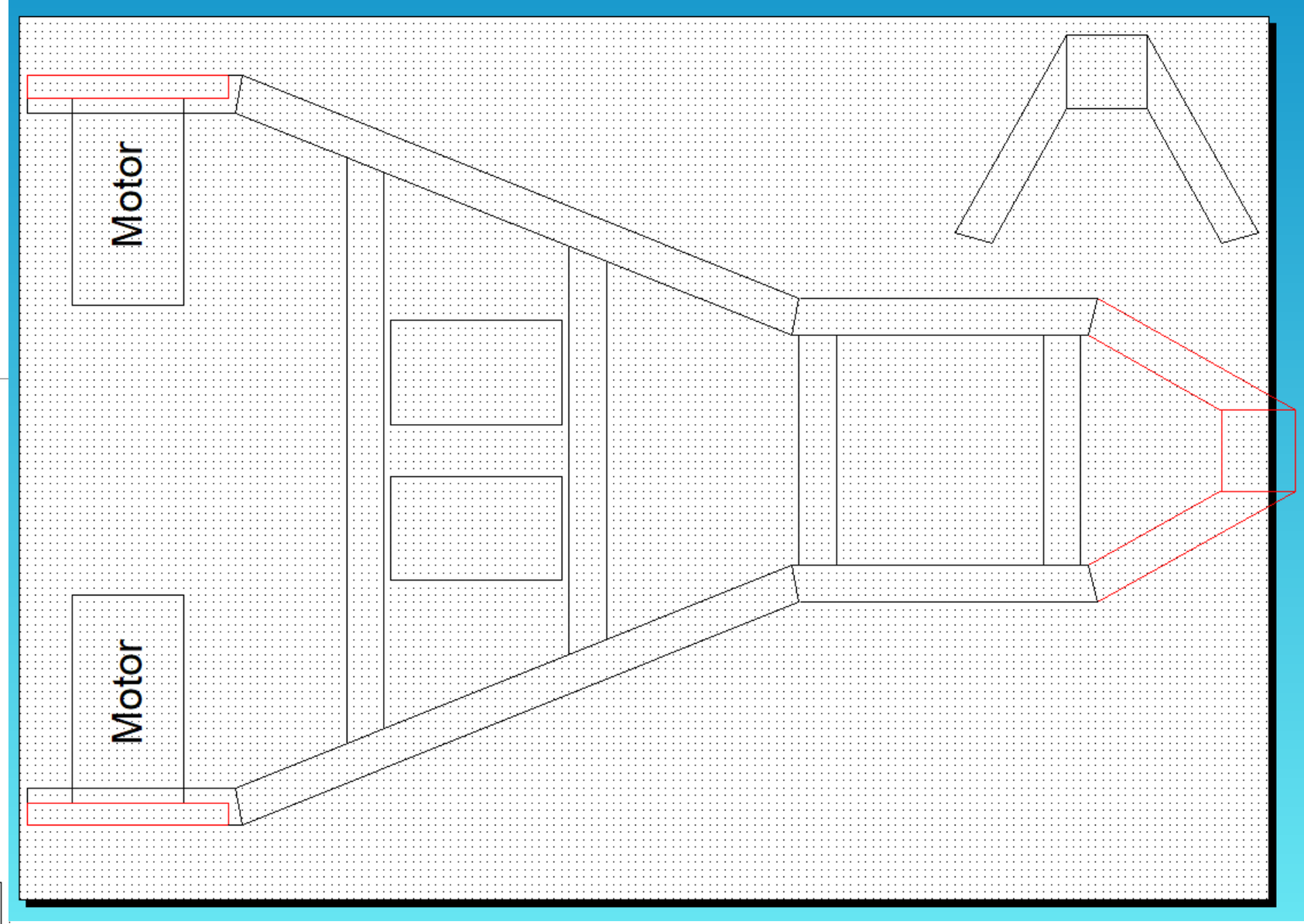
Product Design	V15	Luca Mac Gregor 23/02/2022	
		Orthographic Drawing	
		Final Design Frame - -	V15
			1/1

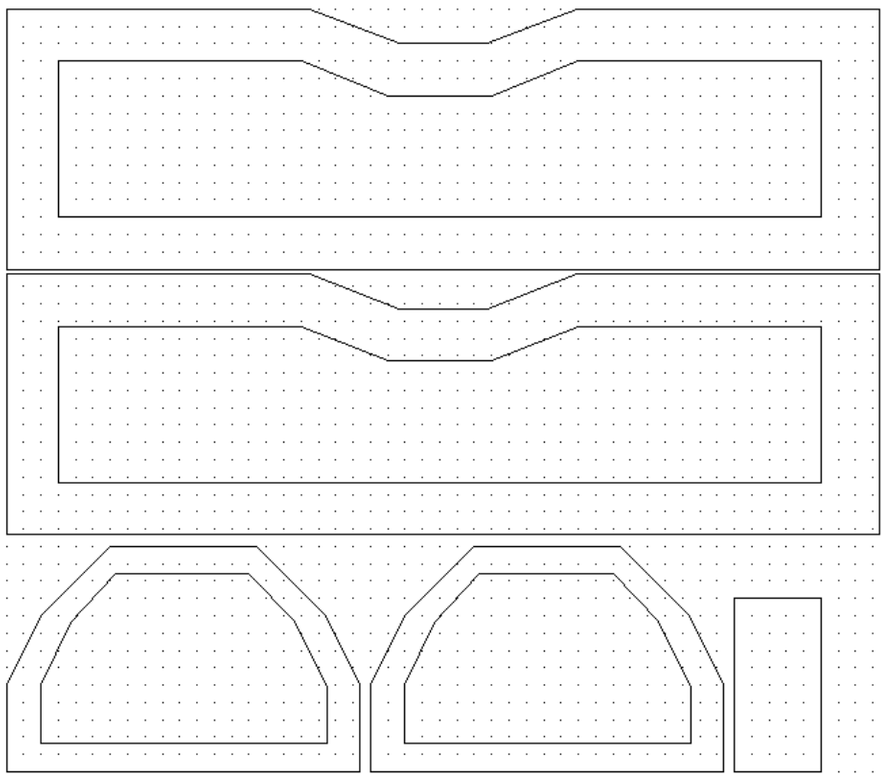
Rendered Orthographic View

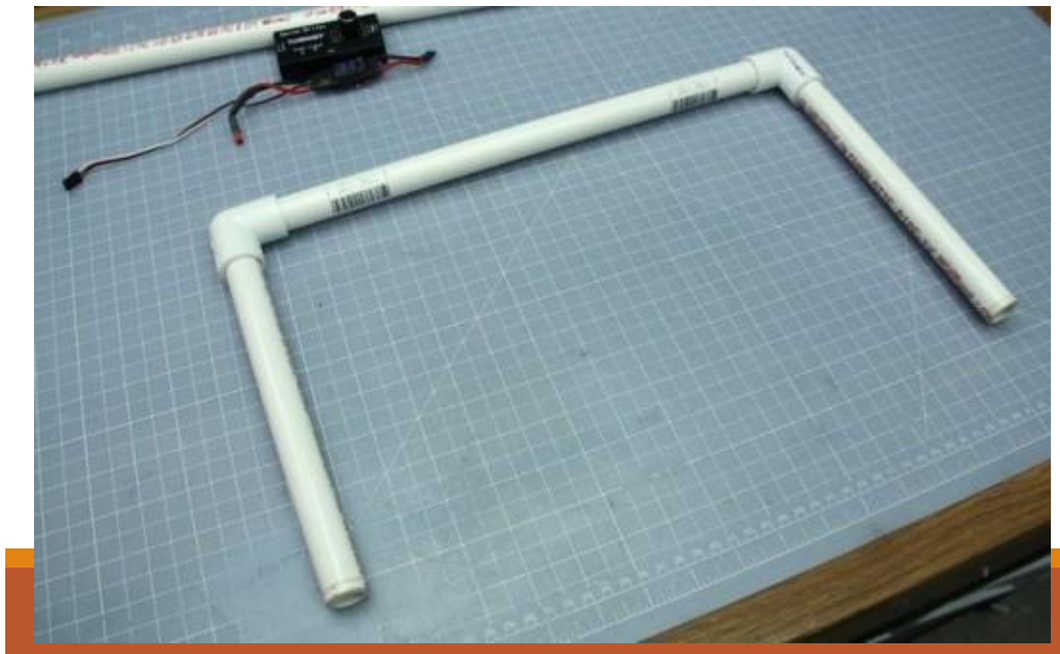
Techsoft 2D design files

2d Design Frame
To allow me to cut my mild steel box section to size, I decided I would laser cut the exact shapes out of card to use as a template when cutting or marking out. Additionally, once cut, there will be a card 'female' template which can serve as a welding jig to ensure the pieces are held at the correct angles.

2d Design Formers
To create my foam mould for the fibreglass, I decided to shape the foam using a hotwire bow. The principle of the hotwire bow is a high resistance wire under tension between 2 points, has a current passed through it and is run through the foam, melting a cut line into the material. To get more complex and detailed shapes, 'formers' are often made out of a material with a high melting point, which the bow can be run over to cut the shape between. To this effect therefore, I have created these formers which will be laser cut out of MDF, to help me get a precise shape on the cowling.







Hotwire bow
The image to the left is an example hotwire bow. It is the original copy that I based my hotwire bow off of. I had already made the bow previously for non-school work, so there was little work necessary to use it in my design. I made it using Nichrome wire (which has very high resistance), strung between a simple PVC pipe frame. The wire was mounted at each end of the 'fork' to a conductive bolt which in turn had a wire soldered to it. These wires then plugged directly into a power source (either from mains or LIPO batteries), heating the wire.

Production plan 1

Task	Tools / Equipment	Safety precautions	Q.C Question	Q.C Check	Material/component cost calculations	Cumulative total cost	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk7	Wk8
Cut frame														
Laser cut card frame	Laser cutter, card	Nil	Are widths/lengths as expected?	Measure to check	A1 sheet of card - £11.51 for 25, 11.51/25 = **£0.46**	**£0.46** for 1 sheet I am using								
Mark out cut lines onto mild steel	Scribe, steel rule, guillotine	Caution with scribe, fingers clear guillotine	Do markings match card template?	Measure to check	25mm box section - £9.44 per metre, 3.955m used, 3.955 x 9.44 = **£37.34**	**£37.80**								
Cut box section to rough size	Hacksaw	Caution with hacksaw + sharp metal	Are the angles and sizes roughly accurate?	Compare to card templates to check	-	-								
File box section to exact size	Large flat file	Caution with sharp metal	Are pieces exactly to size?	Measure to check	-	-								
Test fit frame and adjust	Card template, large flat file	Caution with sharp metal	Does the frame take the exact intended shape?	Check pieces in card template	-	-								
Weld frame														
Clean oxidisation/grease off box section for welding	Hand drill, flap wheel, emery cloth	Caution with flying material, wear goggles	Is the surface clean enough for a good weld?	Visual inspection	-	-								
Clamp frame for welding	G-clamps	Nil	Is the frame secure in place?	Check with light force	-	-								
Tac-weld top side of frame	MIG welder	Welding mask, gloves, heat proof apron	Have the tac-welds secured the frame in shape?	Check with light force **when cool**	-	-								
Tac-weld bottom side of frame	MIG welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								
Weld top side of frame	MIG welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								
Weld bottom side of frame	MIG welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								
Weld handle	Mig welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								
Weld tow ball mount	Mig welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								
Weld castor mount	Mig welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								
Weld wheel mounts	Mig welder	Welding mask, gloves, heat proof apron	Is the frame warped from heat?	Spirit level + visual inspection	-	-								

Production plan 2

Task	Tools / Equipment	Safety precautions	Q.C Question	Q.C Check	Material/component cost calculations	Cumulative total cost	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk7	Wk8
Foam mould						Carried over - **£37.80**								
Laser cut hotwire formers	Laser cutter, MDF	Nil	Has design been cut to exact size?	Measure against CAD	500mmx500mm sheet of 3mm MDF, **£4.33** cut to size	**£42.13**								
Cut foam blocks to size	Band saw, Stanley knife	Qualified teacher for band saw	Is the foam big enough to take the shapes?	Test fit MDF formers	850mm x 500mm x 150mm block of foam, **£40** cut to size	**£82.13**								
Mount MDF formers	Double-sided tape	Nil	Are the formers aligned?	Spirit level + steel rule	-	**-**								
Hotwire cut foam	Hotwire bow, powerpack	Wire hot handle with care	Did the bow run off the formers?	Visual inspection	-	**-**								
Glue cut foam together	Epoxy resin	Wear plastic gloves	Are they glued in alignment?	Steel rule + visual inspection	-	**-**								
Initial sand of mould	Glasspaper	Wear mask as dust is harmful	Has desired shape been achieved?	Visual inspection	-	**-**								
Apply filler to mould	Multipurpose filler	Nil	Are any holes sealed?	Visual inspection	All-purpose powder filler - **£4.98** @ Toolstation	**£87.11**								
Re-sand mould	Glasspaper	Wear mask as dust is harmful	Has filler been sanded back?	Visual inspection	-	**-**								
Cut mould cavity	Stanley knife	Caution with use	Is cavity large enough?	Steel rule	-	**-**								
Fibreglass mould														
Cut fibreglass sheets	Fibreglass sheet, scissors	Nil	Nil	Nil	4000mm x 1000mm sheet of fibreglass, **£8.51** @ Hobbyking.com	**£95.62**								
Mix resin	Container, resin	Wear non-stick gloves	Has right mix of hardener/resin been made?	Check bottle for proportions	Aeropoxy fibreglass resin - **£20.99** at deluxematerials.com	**£116.61**								
Apply resin to mould	Mould, resin	Wear non-stick gloves	Nil	Nil	-	**-**								
Apply sheet of fibreglass	Fibreglass, mould, resin	Wear non-stick gloves	Has resin soaked into all of the glass?	Visual inspection	-	**-**								
Remove excess resin	Squeegee	Wear non-stick gloves	Is any excess resin left?	Visual inspection	-	**-**								
Add next layer + repeat	Fibreglass, mould, resin	Wear non-stick gloves	Nil/as above	Nil/as above	-	**-**								
Finish mould														
Trim excess fibreglass	Scissors, Stanley knife	Wear thick gloves	Are there any loose sections?	Visual inspection	-	**-**								
Initial sand of fibreglass	Glasspaper	**Outdoors + mask**	Is the fibreglass level?	Visual inspection	-	**-**								

Production plan 3

Task	Tools / Equipment	Safety precautions	Q.C Question	Q.C Check	Material/component cost calculations	Cumulative total cost	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk7	Wk8
Finish mould (continued)						Carried over - **£116.61**								
Apply filler to fibreglass	All-purpose filler	Nil	Are all imperfections covered?	Coat whole mould in thin layer	-	-								
Re-sand fibreglass	Glasspaper	**Outdoors + mask**	Is all excess filler removed?	Visual inspection	-	-								
Wet sand fibreglass	Wet and dry paper, soapy water	**Outdoors + mask**	Is the surface completely smooth + level?	Visual + tactile inspection	-	-								
Apply primer in coats	Primer, painting booth/surface	Ventilation + mask	Has the fibreglass been completely covered?	Apply carefully in thin coats	Halfords' 'filler primer' – 1 can **£8.48**	**£125.09**								
Gentle sand	Glasspaper/wet and dry paper	**Outdoors + mask**	Is the surface completely smooth?	Visual + tactile inspection	-	-								
Apply topcoat in coats	Topcoat, painting booth/surface	Ventilation + mask	Is paint evenly distributed without runs?	Apply carefully in thin coats	Halfords' 'BMW Alpine white' – £8.50 per can, 8.5 x 2 = **£17** for 2 cans	**£142.09**								
Gentle sand	Wet and dry paper	**Outdoors + mask**	Has the gloss finish been removed?	Visual inspection	-	-								
Apply clear lacquer	Lacquer, painting booth/surface	Ventilation + mask	Has a glassy/gloss finish been achieved?	Visual inspection	Halfords' 'Clear Lacquer' - **£8.49** per can, 1 can needed	**£150.58**								
Drive system														
Remove wheel hubs	Hammer, vice	Mind fingers	Has wheel been damaged?	Visual inspection	B&Q Rubber pneumatic tyre, £12.24 per wheel, 12.24 x 2 = **£24.48**	**£175.06**								
Cut nylon rods to length	Nylon rod, hacksaw	Caution with saw blade	Are rods correct length	Steel rule	Nylon rod 20mm diameter, £26.86 per metre, 26.86x0.1 = **£2.69**	**£177.75**								
Face off and centre drill holes in nylon rods	Lathe, drill bits	Wear goggles while on lathe	Is hole central?	Vernia callipers	-	-								
Press nylon rods into wheel hubs	Hammer, vice	Caution with hammer	Has nylon rod been damaged?	Visual inspection	-	-								
Mount motors	DC motors, bolts, spanners	Nil	Are motors secure?	Check with moderate force	2x NPC-02446 motors, 2 x 73.04 = **£146.08**	**£323.83**								
Mount axle, gears and wheels	Axles, 4:1 gears, wheels, spanners	Nil	Is there any play in the axles?	Check with force	-	-								
Mount components														
Paint frame	All surface paint	Ventilation + mask	Is all the frame covered?	Visual inspection	Rust-Oleum All surface spray black - **£18**	**£341.83**								

Production plan 4

Task	Tools / Equipment	Safety precautions	Q.C Question	Q.C Check	Material/component cost calculations	Cumulative total cost	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk7	Wk8
Mount components (continued)						Carried over - **£341.83**								
Mount castor wheel	Castor wheel, bolts, spanners	Nil	Is the wheel on securely?	Check with force	1x B&Q Castor wheel - **£3.45**	**£345.28**								
Mount thumb throttle	Throttle, screwdriver, handle	Nil	Is it on securely?	Check with light force	1x E-bike PWM thumb throttle - **£11.87** Amazon	**£357.15**								
Mount hinge + over-centre latch	Hinge, over-centre latch, screwdriver, bolts	Nil	Is there any play in the hinge?	Check with light force	1x B&Q door hinge – £5.42 for 3, 5.42 / 3 = **£1.81**. 1x over centre latch (Amazon), £8.69 for 4, 8.69/4 = **£2.17**	**£361.13**								
Mount cowling	Hand drill, MDF trimmings, bolts	Caution with using drill	Does it fit to the frame?	Steel rule	-	-								
Arrange electronics														
Re-solder servo tester	Soldering iron, solder, throttle	Caution with hot iron	Are any of the joints bridged?	Visual inspection	1x simple servo tester - **£1.57** eBay	**£362.70**								
Mount ESCs	Velcro	Nil	Nil	Nil	2x Victor 883 24V ESCs - **£30** IFI robotics	**£392.70**								
Mount Acrylic sheets	Acrylic sheets, bolts	Nil	Does sheet meet all edges?	Steel rule	Clear Acrylic 3mm sheet - **£6.64** cut to size	**£369.34**								

Cost analysis thoughts

The potential cost of manufacture for this product for me is approximately £370. This means I could realistically sell the initial product to the gliding club at around £500, making a £130 profit. This would be an achievable price, as alternative tow methods are extremely expensive. The downside to my scale of production would be one unit, if not sold would cost me the profit from 3 previous units. This would mean the product would have to be manufactured on a made to order scale, and only be made once an order has been placed.

Time elapsed to manufacture

The product in it's very nature is extremely complex. This in turn results in a busy schedule, taking several weeks to complete. Much of the process will be done by hand, to reduce the environmental impact of the product. For future production, additional skilled workers could decrease the manufacturing time allowing orders to be fulfilled faster. This in turn would lead to more products being produced in a given time, increasing profits. A downside to this would be an increase in price, however as it is so much cheaper than current tow methods, I do not foresee that becoming an issue.

Summary Grid 6

In this section we are looking for a detailed final design proposal that would enable third party manufacture and a manufacturing specification that highlights all of the operations needed to complete the product. We should also see some costings and an analysis of quantity along with aspects of waste management. The candidate does give some detail for third party manufacture but other aspects are limited or omitted battery mounts or stub axle assemblies for example. Most importantly the client/stakeholder input is rather limited. That said, a skilled manufacturer could make and attempt at producing this product albeit with some missing detail.

Possible Further Evidence to access the higher levels

- **The candidate needed to undertake a more extensive cost analysis.**
- **A further analysis of the quantities and waste management should have been submitted.**
- **The ongoing use of the client narrative to potentially trigger further iterations should be evidenced at the top levels of this criterion.**

✓ **This is a level 2/3 and a generous award would be 7 marks out of nine.**

Pearson

GRID 7

Review of Development and final idea

Grid Seven

- Review of the development and final idea
- The most difficult to assess!!
- In this section you are expected to provide evidence of continual review and evaluation of the development and final idea.
- It is imperative that the candidates are analytical and balanced e.g. pro's and con's.
- Evidence in this section is likely to include notes throughout the development and summary pages comparing the final idea to the specification but must include logical and effective communication that uses technical vocabulary and refers to sustainability.
- Some evidence may be found earlier in the folder and so decide where to credit, check teacher annotation.
- Feedback and review should always be focused on the needs that were established in the analysis and the specification.
- Read where the centre has attributed the marks and use this as a starting point

Grid Seven (cont)

- The whole process should have evidence of the analysis of the work of others and the analysis and evaluation of the opinions of others. This could be from a third party
- This evidence is not always logically offered in a single place, with neat presentation in a table for instance.
- In many cases the evidence is found in both development and the end of the design sections. It would also be churlish to ignore the use of the analysis of the work of others in the design ideas, it still could have its role in the development of the final solution, but we must take care to avoid a double award (application of it – rather than research).
- A perceptive evaluation should include a commentary that analyses the client thinking and the overall design possibility taking into account all earlier information, and goes on to suggest further iterations that may be considered as the project progresses

Final Design Specification Check

Specification point	Justification
1.1 Product must function in a way to replicate standard glider towing methods	My design will function in this manner, and reduce the number of people required
1.2 Product must be cheaper to operate than fossil fuel alternatives	As my design runs on glider batteries, there will be no additional running cost to the club to operate it
1.3 Product must have enough power and torque to move all weights of gliders	The 2 motors in the design each make 0.73hp, and 2lb-ft of torque, producing a total of 1.46hp and 4lb-ft of torque, which is equal to the power produced by the club's golf buggy currently used for towing. Therefore, my product will have enough power and torque to tow
1.4 Product must be able to tow on both concrete and grass	The use of air-inflated rubber tires will allow my product to put it's power down on all surfaces. Additionally, letting some air out of the tires will give the product a bigger footprint, and better grip (only if necessary)
2.1 Product must have high quality and professional aesthetics	With the welded black metal frame and white gloss cowling, I believe my design will feature these aesthetic qualities.
2.2 Product must look tough and durable	As the design in based around a mild-steel welded frame, the product will be extremely strong, tough and durable, and will look as such too
2.3 Product must be compact to fit in storage spaces (<1.2m height, <1.2m width)	My design is 1m in height, and 0.8m in width. It is therefore less than the declared maxima
2.4 Product must not look 'home made'	The aesthetics of my design are very professional, and in my opinion, do not look homemade at all. There are also several visible techniques used in manufacture that would be difficult to achieve at home
3.1 Product must be easy and simple to use	With only 1 throttle and 'sway' steering, my product will be extremely easy to use
3.2 Product should be easy and convenient to charge	As it runs on glider batteries, they can be removed easily and charged using the club's already existing infrastructure
3.3 Product should be simple and easy to work on	With a removable cowling, the design is very easy to work on as all parts can be exposed and accessed with the cowling removed
4.1 Product must be able to operate on 5% gradients	As stated, with the power of the electric motors and the grip of the tires, my product should have no issues operating on gradients up to 5%
4.2 Product should be able to function for 2 days operation	With 2 10ah glider batteries, my product will have an average draw of 10 amps in use. This means the product will function continuously for 2 hours. On a typical day at the gliding club, the average time tow equipment is in use is 30 mins per day. This means my product could easily function for 2 days at the gliding club, without charge
4.3 Product should be able to operate between -10C and 35C	Whilst in the cold weather battery life diminishes, electric motors and speed controllers are not effected. Therefore, my product will be able to operate in a wide range of temperatures
4.4 Products maximum tow weight must be >700kg	As my design is lighter and equally powered as existing tow vehicles, it will be able to tow the heavier gliders weighing >700kg
5.1 Product must have a metal based frame	Design is constructed around a fully mild-steel welded frame
5.2 Product must have a shroud/cowling manufactured out of polymers	Design features a fiberglass painted cowl
5.3 Materials chosen for product must have a range of finishes available	Fiberglass and mild-steel each have a very wide range of finishes available, allowing me to pick the finish that best corresponds to the design
5.4 Components must be suited for outdoor operation	The motors I have chosen are fully waterproof, as per most electric motors. The ESCs are however not waterproof, but will be mounted in sealed containers to keep the moisture out
5.5 Components must have good weather resistance, and be unaffected by continuous outdoor use	All components are very durable and will be unaffected by outdoor use
6.1 I will use Job production. Each product will be manufactured one at a time and can be tailored to each gliding clubs needs	Due to the expected demand of my products and the time taken to manufacture, I can conclude this method of production will be suitable
6.2 The manufacturing cost of the entire product I estimate will be around £350-£400.	Total cost = £369.34

Client review of design

Client Review

Do you think the final design is suited to use at gliding clubs?
I think there is a lot of potential for it's use at Buckminster, and other clubs. It looks easy to use, which is very important, and would be able to tow a very wide range of aircraft. Before putting it into circulation we'd have to do careful testing to be sure there is no possibility of damage to our fleet, but if it checks out we could start using it right away.

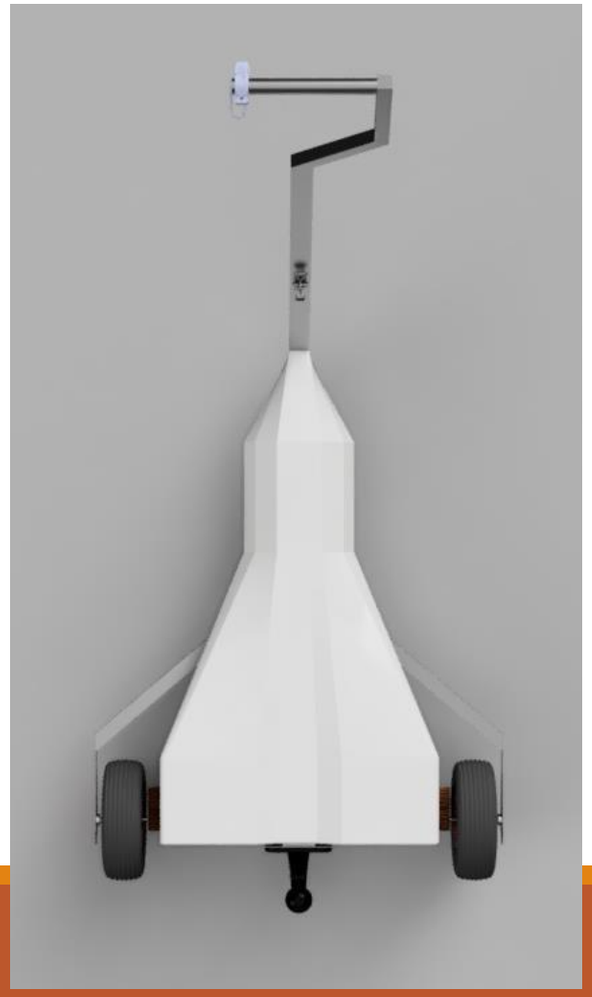
Are there any elements of the design you think could be potentially problematic?
My only concern at this stage is protecting the fiberglass section. We try and keep all of our equipment in the best condition we can but it is still very easy for small chips and light damage to occur in frequent use. Would the fibreglass cowling be strong enough to protect the internal electronics from being damaged, should it be exposed to moderate force?

Can you see any situations where the design would not be an effective tow vehicle?
The only situation I can see this design not working for us would be in icy conditions. When the ground is icy even our buggies don't have enough grip to pull aircraft. However, in these conditions it is very likely we would not be flying.

Do you think this design will make a difference to the operation of the club?
Yes. An additional tow vehicle will speed up our ground operations on a daily basis, and we have a large supply of compatible batteries available to keep it running at low cost. Also, with the use of tow out gear this design would allow 1 person to tow a glider about, instead of the standard 3. This would help us operate by leaving more people at the launch point to help our operation, while fewer are required to move gliders around the field.

My response
I purposely chose fibreglass due to it's strength to weight ratio. It is an extremely strong material, and when bonded with the resin I intend to use, it should be slightly flexible making it very impact resistant. This therefore should allow the product to absorb any damage that may occur and protect the internals.

My thoughts at this stage:
From the Client's review of my design and my check against the specification, I can conclude that it is an appropriate design for it's intended use. It meets all the specification points, and the client deems it appropriate for use at the gliding club she runs, and others. I believe the design properly incorporates everything I initially set out to achieve from it's use, and also will improve upon the operation of gliding clubs. The design is relatively complex in both the manufacture and assembly, however with proper organisation and planning I think it is possible to complete it within the time period allocated. Additionally, the cost of manufacture is relatively low for the quality of product that will be produced.



Time estimates

Order of manufacture
Due to the unique complexity of this product, it is important that I manufacture it in a specific order. Some parts of the design cannot be made until others are, so in this section I will outline the order in which I will manufacture the product, and how long I will allocate for each process.

Frame It is important that the metal frame be manufactured and assembled first. All other parts of the design are built around the frame, so I will need it to be completed first.	**Steps in manufacture** 1. Laser cut templates for metal box section cuts 2. Cut + file box section to laser cut templates 3. Emery cloth each part to degrease it for welding 4. Weld frame in laser cut jig	**Time allocated/expected** This is a lengthy and time consuming process. I estimate completing the first 2 steps will take 5-7 hours. Step 3 will take an additional 2 hours and step 4 can be completed in 3 hours. Total undertaking: **10-12 hours**
Foam mould The next logical step in manufacturing is in creating the foam mould, as any tolerances in the frame will allow me to create a better fitting mould, drawn around the frame.	**Steps in manufacture** 1. Laser cut hotwire formers 2. Join foam blocks together to be cut 3. Put hotwire formers on foam block + hotwire cut 4. Filler + Sand mould until smooth	**Time allocated/expected** This will also be a very time consuming process. Steps 1, 2 and 3 should only take around 1-2 hours. However, step 4 I expect will take between 5 and 7 hours. Total undertaking: **6-9 hours**
Fiberglass Once the mould is finished, naturally the fiberglass cowl can be manufactured. This is a easy and quick process, but the prepping and finishing of the surface can take a long time.	**Steps in manufacture** 1. Cut fibreglass sheets to size and mix resin 2. Apply resin to mould and lay fibreglass 3. Apply next layers of fibreglass 4. Sand + filler fibreglass (prep for paint)	**Time allocated/expected** The initial 3 steps will be very fast. This is because the resin used in fiberglassing is non-workable after 15 mins. These steps therefore should take less than an hour. I'd therefore expect total undertaking: **5-7 hours**
Painting fiberglass This is also a relatively simple process, however the time between coats can increase the total time spent on painting. Additionally, the primer and sanding will increase time.	**Steps in manufacture** 1. Prime surface and sand back between coats 2. Apply paint every 15 mins 3. Wet + Dry surface ready for lacquer 4. Apply lacquer	**Time allocated/expected** I'd estimate step 1 to take around 2 hours. Step 2, with 4 coats, will therefore take 1 hour. Step 3 I'd estimate to take 30 mins. Step 4 would probably take around 30 mins again. Total undertaking: **4 hours**
Mount components Components can be mounted to the frame, and any miscellaneous tasks like painting the frame can be done. This is probably the most ambiguous step in terms of time to complete.	**Steps in manufacture** 1. Paint frame 2. Mount motors + handle 3. Mount wheels + drive system 4. Mount ESCs, batteries + throttle	**Time allocated/expected** Step 1 I'd estimate will take about 1 hour, as a simple all surface paint that doesn't require a primer can be used to protect the frame. The other steps I estimate could take up to 4 hours. Total undertaking: **5 hours**

Summary Grid 7

We see evidence across the portfolio of a review of ideas, this takes the form of more formal reviews of the final idea and of course annotation throughout that has reviewing statements along with the client stakeholder narrative that has taken place. The candidate does evidence some client discussion and we do see some limited modification being made as a result of those interactions. The work does really lack a balanced evaluative commentary and would benefit from some kind of advantage/disadvantage analysis which is an omission in this case.

Level 3

The award is 7 marks out of 12

Possible Further Evidence to access the higher levels

- **The candidate should have completed a positive/negative analysis to gain some balance.**
- **We should see further evidence of client /stakeholder interaction that impacts the proposals throughout the 'iterative process'.**
- **We should see a more detailed analysis of the proposed materials and their suitability.**

Pearson

Grid Eight

- Communication of design ideas
- Demonstrate a perceptive selection and accomplished use of traditional/manual graphical techniques to communicate design proposals.
- Demonstrate a perceptive selection and accomplished use of computer-aided design (CAD) techniques to communicate design proposals.
- Demonstrate a perceptive selection and accomplished use of written techniques to communicate design proposals.

- All of these strands need to be evidenced and be effective but also perceptive, if for instance the best communication method is a sectional view and the candidate recognizes this that is perceptive.
- It is important to firstly communicate in the most appropriate method and not just present a range of communication techniques as a tick list to ensure ‘a range’ is presented.

Summary Grid 8

In the communication section we are looking for the candidates to evidence all three communication elements traditional, CAD and written. We did see this evidence in this submission but the other key to success is that the selected method is effective. To some extent the sketched element did lack some technical detail, but it is difficult to argue that the candidate has not shown enough evidence not to award a ‘top box’ mark

This is a top-level submission

The award is 5 marks out of a possible 6.

Possible Further Evidence to access the higher levels

- **The candidate needed to show further technical detail and knowledge and understanding in some of the subassembly design work and the annotation.**

GRID 9

Tools and Equipment

Grid Nine

- Tools and equipment

- A sophisticated selection of materials, fixtures, components and fittings which are fully appropriate for the final prototype, showing an in- depth understanding of material properties, the requirements of the end user, and the intended purpose of the prototype.
- There should be evidence of the selection of these materials made in the final design proposal that will enable justification. This does not preclude the iterative approach to manufacture that allows changes or modelling take place as a matter of course.

- Accomplished use of tools, equipment and techniques to prepare materials for the manufacture of the prototype, showing an in-depth understanding of the need for dimensional and geometric accuracy.

- A consistently high degree of safe working practice for self and others.

Grid ten

- Quality and Accuracy
- Produce a prototype that demonstrates accomplished making skills at an advanced level in relation to a sophisticated design problem

- Produce a fully functional prototype which matches the end user needs.

- Produce a prototype that fully meets the design specification.

- Demonstrate a sophisticated application of an iterative approach to manufacture to produce a prototype

Manufacturing the Frame

Image 1

Image 2

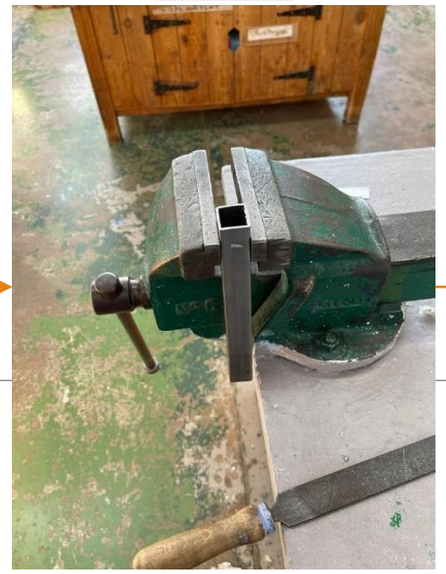
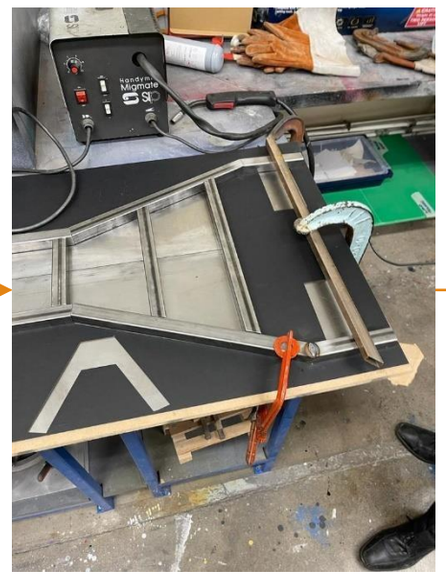


Image 3

Image 4

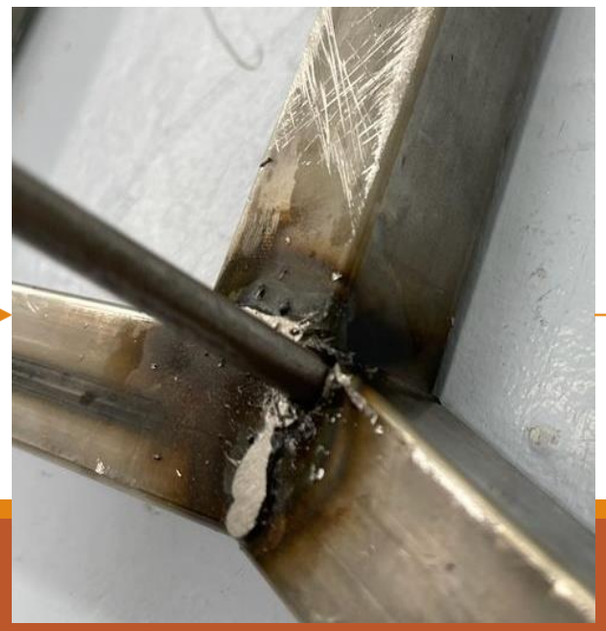
Cutting the pieces
I first laser cut the template of the frame out of card. This would serve as a pattern for me to follow on each piece of the box section frame (image 1). I then roughly cut the metal to size, and then filled it down to shape by hand (image 2). Image 3 shows all pieces completed and Image 4 shows them fitting in the card template I laser cut. I was very happy with the tolerances I had filed to, and did not have to recut any pieces. Whilst it was a very time consuming process, it was the most efficient way to do it available to me in the school workshops.



Welding the frame
Before welding the frame, I had to create a separate surface to weld on. This was necessary as from the welding tests I discovered the school metal workbench was not level. I therefore manufactured a level steel table to weld on, as it would ensure my frame come out straight and true (image 1). Image 2 shows the frame in the card jig I laser cut, and clamped in place ready for welding. Image 3 shows the first weld I made on the frame. It was a good weld which set my standard for later joins. I welded all joints on the top and bottom until I was left with the welded frame (image 4)

Problems + troubleshooting
On 2 welds in the frame, the welding torch melted through the top surface, leaving a hole. This obviously resulted in a less strong weld, and aesthetically lacking too.

To address this, I drilled the hole out to a metric diameter, and found some steel rod to fill the whole. I cut the rod to be flush with the top surface of the frame, and welded it in. Once welded, I filled it down with the rest of the frame.



Manufacturing the Frame

Image 1

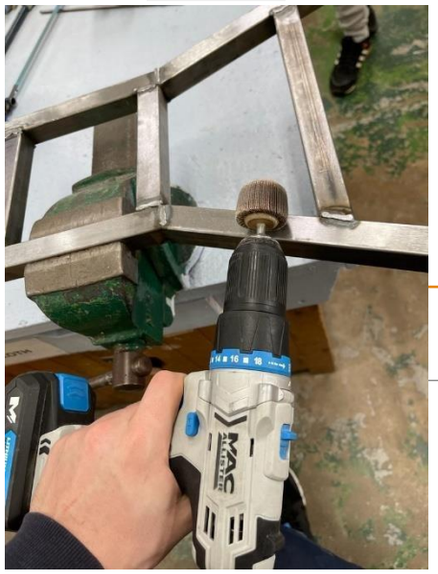


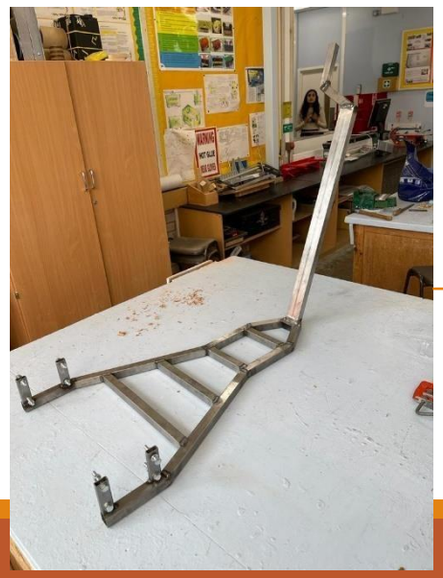
Image 2

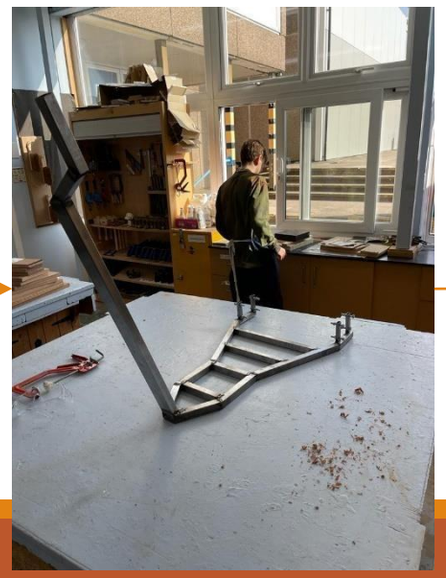
Image 3

Image 4

Further welding and cleaning
Before I welded any piece on, and after the frame had been completed, I used a flap wheel attachment on a hand drill to clean the surface of the metal from oxidation and grease (images 1 and 2). I then welded the front “A frame” on (image 3) and created the handle separately (image 4). Next, I welded the neck of the handle to the frame, and cut it in half where the hinge would be. The essential parts of the frame were now in place and I could begin welding on the mount points for my components, and any other welding jobs before I painted it.

Mountings + fixings
Initially, I cut and welded on 4 pillars at the rear of the frame which would serve as motor mounts (image 1). I had drilled the holes in them ready for the aluminium motor plates before welding. I created a mount for the tow ball at the back of the frame (image 2), by cutting a sheet of thick steel, boring large holes in it and welding it to a box section spacer. The spacer would give the tow ball enough clearance from the back of the frame (image 3). Out of the same steel sheet, I cut a plate to mount the front castor wheel on, drilled holes in it and welded it across the front frame (image 4).





End result
As per the image to the right, you can see the final result of the completed frame with the motors and wheels mounted (details of mounting the wheels and the drive system will come on a later slide). I was extremely happy with how the frame turned out, as it was level and straight, and all the welds were extremely strong. It also was relatively heavy, providing lots of downforce over the rear wheels giving better traction.

Manufacturing the Foam mould

Image 1

Image 2

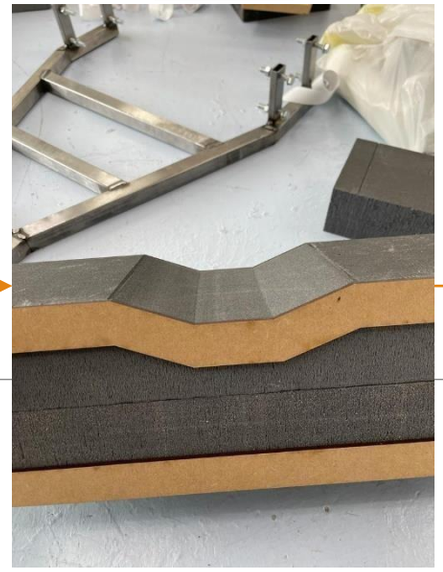
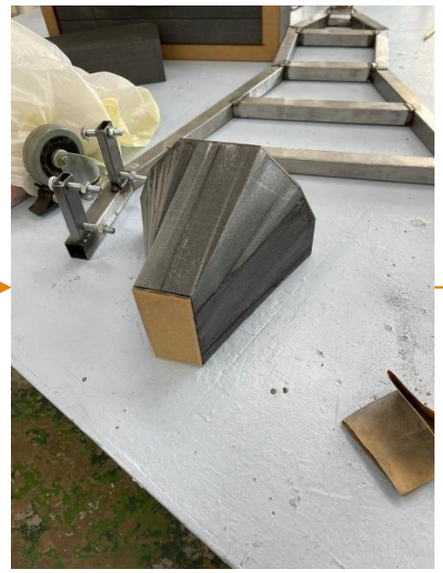


Image 3

Image 4

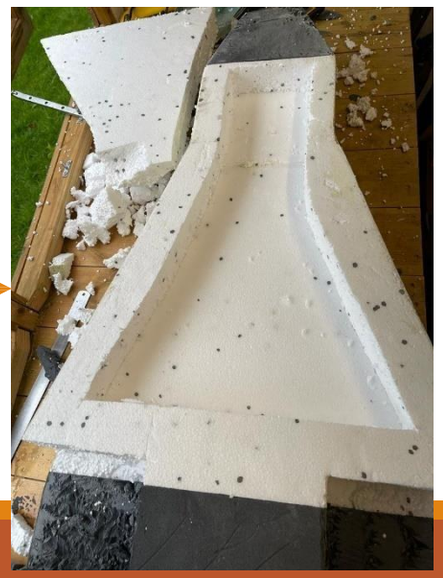
Hotwire cutting parts

Firstly, I laser cut MDF formers for the hotwire bow to run around, creating the desired shape (image 1). Then, I glued sheets of foam together to create a big enough block for me to cut each part, glued the formers onto each side of the block and cut the foam with the hotwire bow (image 2). The cutting went very smoothly and was quick and easy to do. The mould had 4 sections, the nose, the neck, the main body and the tail. I cut the tail first, and then moved on to the main body (image 3/4).



Joining and prepping mould

Next, I continued cutting the neck and nose of the mould (images 1 and 2) and once all was cut, began assembling them. Due to a shortage of foam in school, I had to use 2 different types of foam. This did not impact the final result in any way, as they had similar densities. I aligned all parts of the mould and glued them together (image 3). This was very easy as all parts had been cut from the same formers, so naturally fit very well. The most time consuming stage of the process was in the sanding of the mould (image 4), as it was very easy to chip the foam and create a hole to later be filled.



Creating a cavity

Once joined, I used a long Stanley blade to cut out a cavity in the bottom of the mould. This was necessary as the motors would sit internally, as would all the electronics once complete. It was easy to cut the foam into the desired shape, but tricky to extract it without damaging the rest of the delicate foam. I found a steel rule was a good form of leverage to pry the cut sections from the rest of the mould. Once this was competed, I further sanded and applied filler to the mould until it was ready to have fibreglass applied.

Fiberglassing + finishing

Image 1

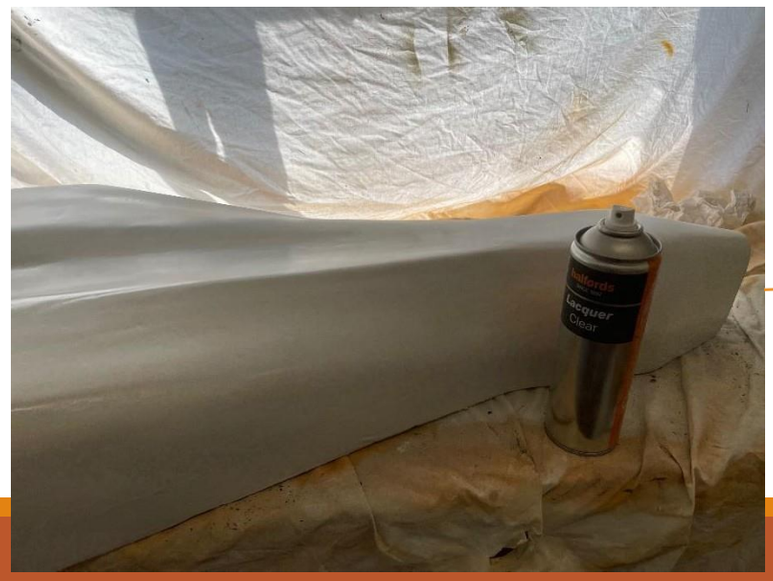
Image 2

Image 3

Image 4

Fiberglassing + filler
The process of Fiberglassing itself is very quick, so it was not possible to take any photos during the process as I had to get the layers on before the resin cured. Additionally the process had to be done near a window due to the toxic elements in the resin. I first cut the 3 fibreglass layers to size (image 1) and mixed the resin. I applied the resin to the mould first, laid the first layer and further applied resin. Then I added the second and third layers in the same order, and used a credit card to remove all excess resin. Once cured, I then sanded the fibreglass and applied filler to level the surface (images 2,3,4).

Painting
I used Halfords' primer, paint and lacquer in all stages of painting. Initially, I used filler primer (image 1) to seal any further imperfections in the mould, and sanded it back between coats. I applied 3 coats of primer and sanded them until the mould was completely level. I then used white car body paint on the primer, applying a further 4 coats every 15 minutes. The result was very good (image 3) and nearly had the gloss finish I was hoping for. I then used wet and dry paper with soapy water to remove the gloss finish, ready for the lacquer.



Lacquer + final finish
I used clear lacquer on the cowling to give it a glossy, gel coat like finish. Additionally, the use of car body paint meant that the paint underneath was weather resistant and quite durable. After 4 coats of lacquer, the cowl came out with a very glossy finish, and was smooth to the touch. I was very pleased with how it turned out, as I followed the same steps to finish the mould as I did in my developments, resulting in a similar quality finish. The image to the right shows the finished cowl.

Drive system

Image 1

Image 2

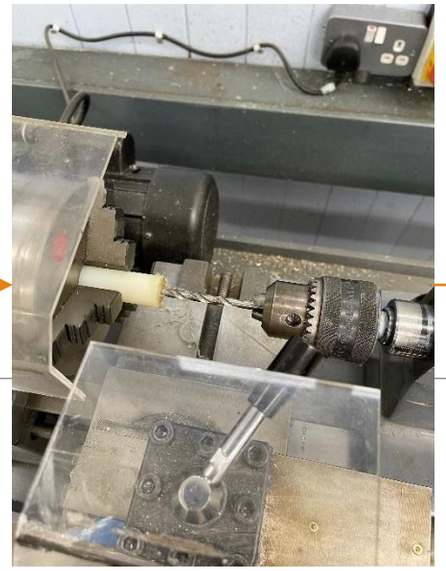
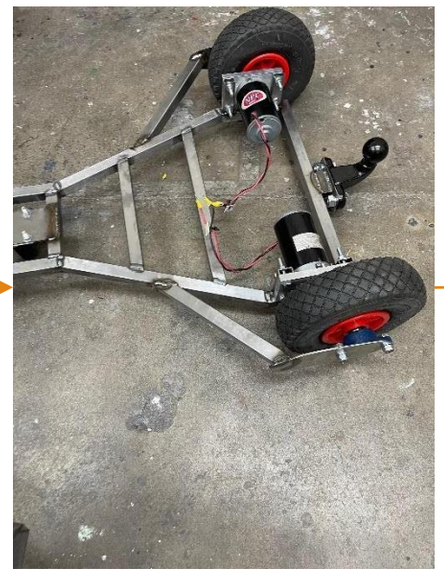


Image 3

Image 4

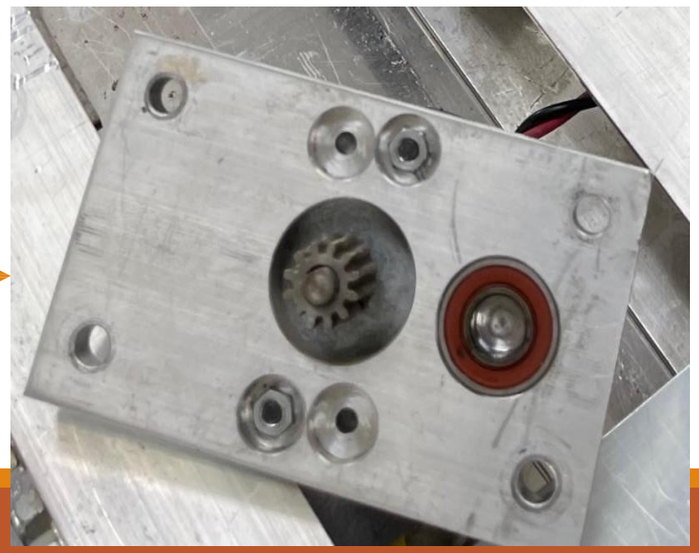
Wheels + axle
I bought the wheels in B&Q as they were a perfect size for my product and where air inflated. To mount them to the product, I had to machine an adapter to sit in the hub which would take the axle. I first removed the existing wheel hub (image 1) and selected a nylon rod to turn into my adapter. Using the Lathe, I first faced off the piece and then drilled holes of increasing sizes in the rod until I had the correct diameter (image 2). I then hammered the adapter into each wheel, and as it was such a tight fit there was no need for glue (image 3). The axle was then hammered in and the gear attached (image 4).



Mounting wheels
At each end of the axle, the design featured a bearing. The inboard bearing was mounted in the motor plate itself, however the outboard one would need support to be mounted and keep the wheel stable (images 1 + 2). To mount the bearing therefore, I cut box section to the appropriate dimensions, and welded it to the frame. I also then cut 2 thick steel plates and welded them to the end of the frame (images 3 + 4). This then allowed me to mount the wheels to the frame for good.

Gearing
The manufacturer of the motors suggests a 4:1 gear ratio with these motors, as they turn such a high RPM. In school we had the appropriate gears so I therefore decided to use them in my design.

As the image shows, the motor plates have a central hole where the shaft from the motor comes through. This shaft already has a gear on it. To the right of that hole, is a ball bearing. In that hole, the axle for the wheel mounts. Between that hole and the wheel, the larger gear engages with the motor.



Mounting components

Image 1

Image 2

Image 3

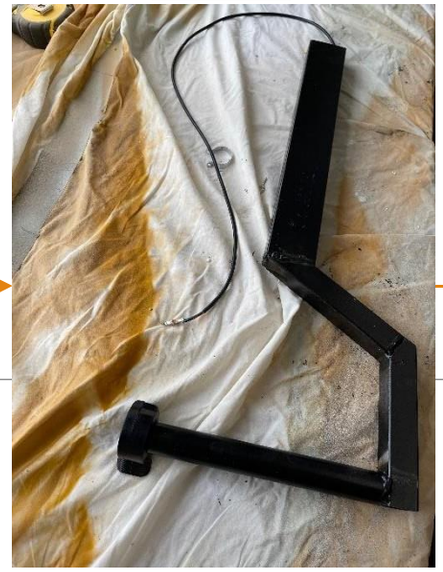
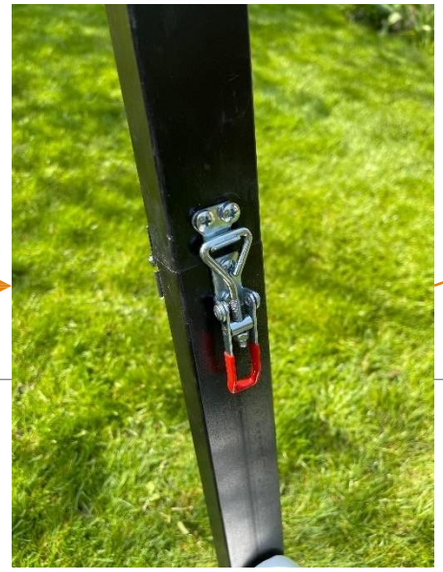


Image 4



Painting + Handle
I decided to paint the frame black. I used all-surface black spray paint to cover the frame and protect it from rust. I used this paint because I knew previously it was durable and left a good finish (images 1 + 2). Once painted, I did the handle and mounted the thumb throttle. I put the throttle on the end of the bar, and threaded the lead through the handle itself (image 3). I then mounted the handle to the neck of the frame via a hinge and over centre lock. I was initially worried there would be too much play in the hinge, however there was absolutely none when the fastener was tight (image 4).

Cowl
previously made a mount plate for
or wheel, putting it on the frame for
time was simply a matter of
g a few bolts (image 1/4). To mount
ling, I cut some thick MDF mounts,
epoxy resin to glue them to the
nage 2). I then drilled holes through
e and the plates and thread a bolt
them (image 3 + 4). I later glued the
e MDF plate, so removing the frame
ply a matter of loosening some
is made the cowl easily removable,
k to do.

Throttle cable
I threaded the throttle cable all the way through the frame, past the front castor wheel to the electronics bay. This allows the cable to be fully concealed by the frame, improving aesthetics.

Arranging electronics

Image 1

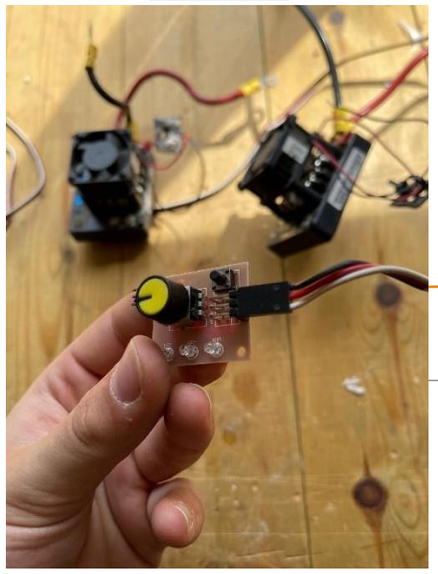
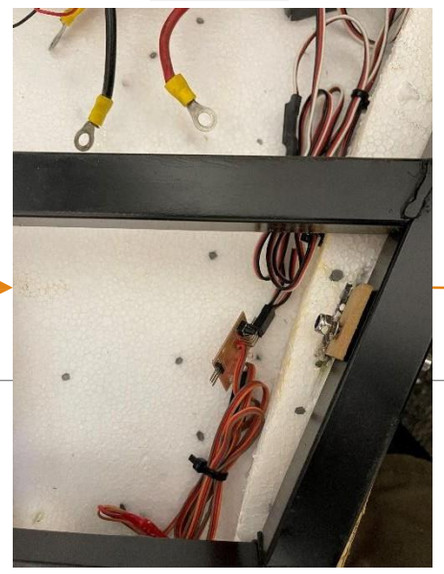


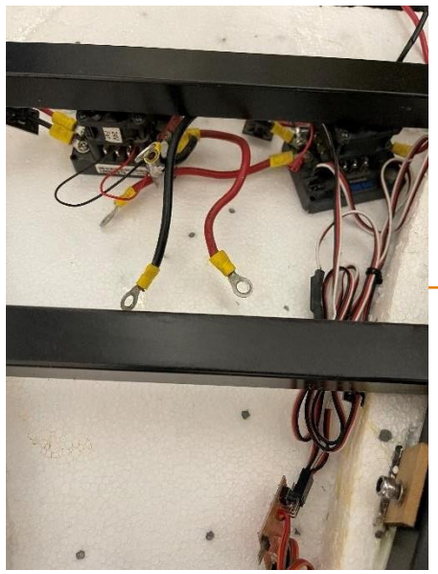
Image 2

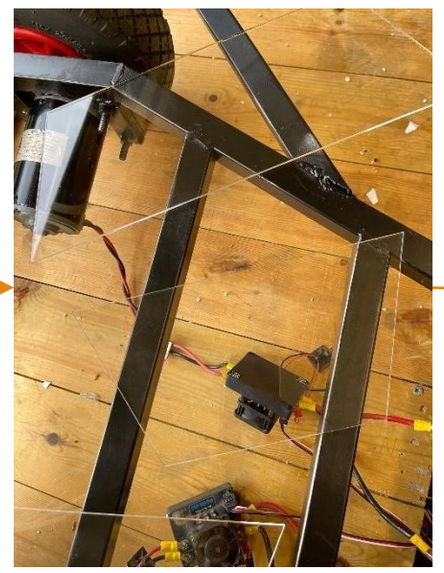
Image 3

Image 4

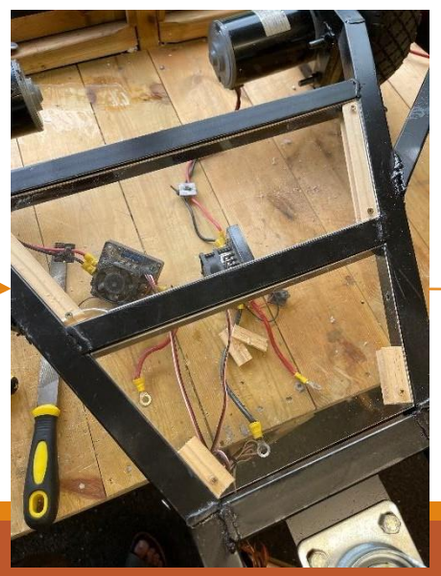


Throttle wires
To interface the throttle PWM signals to the ESC's signal wire, I decided to use a simple servo tester circuit (image 1). The circuit originally used a potentiometer to give PWM inputs to the servo/ESC. I removed this potentiometer and re-soldered the 3 wires from the throttle (image 2). I had soldered an extension lead to the throttle lead to allow it to reach the electronics bay (image 3). I then cable tied the extra length wires and stored them down the side of the frame (image 4).

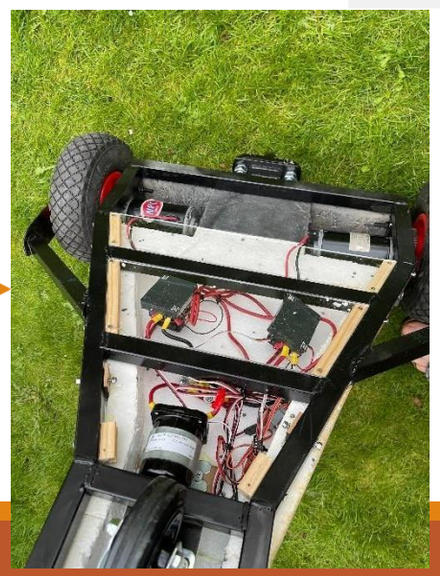




ESCs + Power
I first connected each ESC to it's respective motor and test fit them in the rear compartment of the frame (image 1 + 2). I concluded this was a suitable place for them so would later go on to mount them with double sided tape. I then used epoxy resin to glue an MDF plate to the foam cowl, and mounted the transformer coil to it (image 3) with self-tapping wood screws. I later connected the coil to the live wire from the battery, and the output to the live of the ESCs. I then laser cut clear acrylic sheets to serve as a 'splash guard' for the electronics, ensuring they are not damaged when the product is used outdoors in the rain.

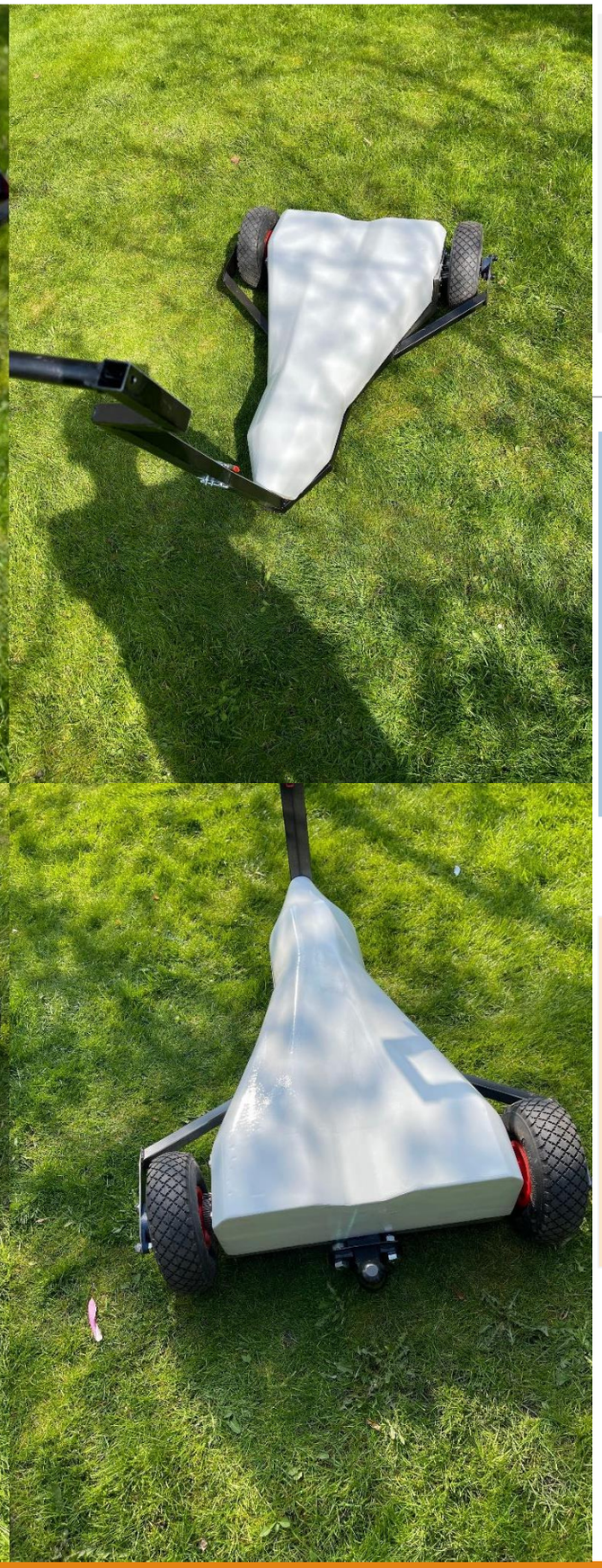


Acrylic splash guard
To mount the acrylic, I simply screwed plywood mounts to the side of the frame, which the acrylic would sit on and be screwed in to. The tolerance on the guard was so tight, there was no need to seal round the edge of each piece, as they were already as watertight as they would need to be. In gliding, we can't fly when it's raining so the only circumstances where the product will be exposed to rain will be when it is pulled over puddles or light drizzle. This guard therefore will prevent water from getting into the foam and electronics.



Finished product





Final assembly
The final assembly of the product went very smoothly, as I knew where everything needed to go from my final design. This meant that nothing was left for me to work out or improvise in the construction. This also resulted in the product turning out exactly like intended, fitting it's purpose well.

My thoughts
I was extremely pleased with the final result of manufacture. In my opinion, it conveys a very professional aesthetic, and does not look homemade at all. It is easy to move around when not under power, and folds down to be a relatively compact shape as expected. The fiberglass cowl has exactly the finish I intended it to have, and looks as if it has a Gel coat applied – much like a glider.

Client thoughts
"I think it looks very professional, almost like something I'd expect to pay for. It's much smaller than any existing tow vehicles we use, so we would have no problem storing it in our hangar. It also looks very simple and easy to use, which is fantastic as we would not have to train our membership before it's use. I think it has great potential at a club like ours".

GRID 11

Testing & Evaluation

Grid Eleven

- Testing and evaluation
- An analysis of the prototype is performed that includes testing against the specification.

- Evaluation of the prototype in meeting the needs, wants and values of the client/end user and specification.

- An analysis and evaluation of the impact on the environment, including life-cycle analysis of the final prototype.
- Any real testing of the product designed realistically needs to be taken back to the client/stake holder to ensure fitness for purpose and to assess in some way whether the brief has been met.
- A key aspect of any design needs to be checked against the specification, whilst it may not be feasible to assess all specification points the key ones need to be tested and assessed.
- After completing the testing it is important to pull together the results into an evaluation summary, that uses the results to inform the designer about future changes that may improve the product performance.

- The summary should include information about the needs of the user/stake holders being met or not, the appropriateness of materials and method of construction as well as sustainability has been considered.

Testing my design

Initial test
My first test of the design was on a lighter single seat glider (approx. 350-400kg). I fitted the aircraft with it's 'tow out gear', and hooked it onto the tow ball. The tow ball itself was a good height, taking the weight of the glider's tail well. I then slowly applied throttle until the tow combination began to move. It functioned very well, with a wide speed range and excellent manoeuvrability.

Handling
Due to the front castor wheel, the design was very easy to steer, by applying a light force on the control column. Additionally, unlike a car, the design is so compact it can exceed 90 degrees in angle between towbar and vehicle, which a car cannot achieve due to the bodywork. This therefore meant the product was more manoeuvrable than golf buggies/cars.

Heavier aircraft
The next logical step in the testing of my design was to tow a heavier glider. I elected to use a high performance 2 seat glider, which was much heavier than the single seater. This glider (pictured right) is one of the heaviest gliders at Buckminster gliding club, at around 700kg fully loaded. My product had no issue towing it, as the extra weight of the tail applied more downforce to the rear tyres.

Battery life
I used the product to tow the single seat glider from the hangar round to the launch point, with a total duration of 5 minutes. I then towed the aircraft back again, making a total working time of 10 minutes. Before I put the batteries in, I measured their charge with a club battery checker. It read 96% charge before the test, and 88% after. At 8% per 10 minutes of use therefore, a realistic expected battery lifetime would be 2.08 hours, which as stated in a previous slide is sufficient for a day's operation at a club.

Ease of use
To accurately assess the ease of use of the product, I allowed several club members test it out. I observed no issues with the operation of the product, and saw no confusion as to it's purpose. This was a big success to me, as it meant my product was clearly fir for purpose, and was meeting several specification points. It also showed it was club-friendly, and suited for use at gliding clubs.

Thoughts at this stage
In my opinion, the testing went very well. There were no major drawbacks in it's design or operation, and every requirement for a tow vehicle had been catered for in it's design. I believe it could actually make a difference to a gliding club's operation, making it potentially useful product that saves clubs time and money.

3rd party feedback

Client's thoughts

Did the product meet your expectations?

- "Very much so, yes. Having seen it in use at the club I was impressed at it's wide towing capacity, as it could even tow our heavy 2 seaters."

Would you make any modifications to the prototype?

-"I only have 1 concern about the operation of the prototype at our club. When we store vehicles in the main hangar with the aircraft, we have a rule that prohibits the use of motors/engines in the hangar. This is to prevent any potential damage to aircraft, from uncontrolled vehicles. The design is quite heavy, and when not under power may not be easy to pick up and move. Some sort of lifting handles on the side of the frame might help us move it around the hangar/club for storage when it's not in use."

Having seen it in operation, is there anything that you believe could be a potential issue?

-"The product would make a difference to our operation as a club, and would potentially save us a good amount of time each day. However, as we are constantly training new people at the club, we would have to define a minimum criteria for members who are allowed to use this product. In conventional towing, we have a team of 3, meaning there is always 1 experienced person responsible for the combination. As this vehicle only needs 1 person, we would have to be sure they know what they are doing to prevent inexperienced people damaging gliders with no supervision."

Club chairman's thoughts

Do you think this is something the club would be interested in using?

- "I do. This vehicle would help the club by saving time moving the gliders around the field. This would allow us to do more launches per day, increasing the club's profits."

Club treasurer's thoughts

Do you think the club would be receptive to purchasing one or more of the product?

- "Yes, at the price you have suggested (£260), this would represent a massive saving on for us. For example, last month to maintain one of our vehicles, we had to get it serviced which included installing a second hand gearbox. That totalled £1500 in running costs for that vehicle. For £1500, we could have bought 5 of your tow devices, and scrapped out fossil fuel powered vehicle fleet. This would also save money on fuel, as the club obviously has to buy the fuel for it's current vehicles."

Club member 1's thoughts

"I found the vehicle simple and easy to use. As it's already designed around existing tow methods, all the equipment it uses is all familiar to us, so simply attaching the glider to this vehicle instead of a golf buggy etc. is no different really."

Club member 3's thoughts

"It looks quite professional, as if we had bought it from a big company. There are a few companies who make tugs for powered aircraft which are similar to this one. Some feature more advanced technology like autobraking or parking brakes etc. Maybe features like that could be incorporated into later versions."

Club member 2's thoughts

"I think the vehicle looks a little small for some of the heavier gliders. It looks as if it would struggle pulling something like a Duo Discus (a heavy 2 seater) on a more hilly site like the Mynd (midland gliding club). Here however, I think it would work very well for us."

My response

Whilst the Mynd (pictured above) is an extreme site, I do think the product would lack the traction to move a heavy glider on the steepest parts of the Mynd. Perhaps wider/bigger wheels could be fitted as an option for more extreme gliding clubs?

Test against specification

Specification point	Does the product meet point?
1.1 Product must function in a way to replicate standard glider towing methods	The product can successfully tow gliders using conventional equipment as well as standard towing methods
1.2 Product must be cheaper to operate than fossil fuel alternatives	The product runs on glider batteries which are extremely cheap to charge. Additionally, it's simplicity in comparison to cars/buggies means maintenance costs/time is vastly reduced
1.3 Product must have enough power and torque to move all weights of gliders	The product is powerful enough to move all aircraft it was tested on (350kg-700kg range)
1.4 Product must be able to tow on both concrete and grass	It functioned well on both surfaces in testing; the grass runway and concrete taxi ways
2.1 Product must have high quality and professional aesthetics	Club members remarked it looked as if it had been manufactured professionally
2.2 Product must look tough and durable	Due to it's size vs manned tow vehicles, members did wonder if it was more fragile than current vehicles in use
2.3 Product must be compact to fit in storage spaces (<1.2m height, <1.2m width)	The product was built to the design, which was within these dimensions
2.4 Product must not look 'home made'	User testing revealed it did not come across as home made
3.1 Product must be easy and simple to use	No members reported any issues with it's use
3.2 Product should be easy and convenient to charge	Glider batteries are readily available, and club kit can be used to charge them
3.3 Product should be simple and easy to work on	With a removeable cowling, all components can be easily exposed and worked on
4.1 Product must be able to operate on 5% gradients	Whilst I was unable to test this at Saltby, the product would certainly tow single seaters on steep gradients. One member did question if it would be able to tow a 2 seater up slope. This would need to be investigated
4.2 Product should be able to function for 2 days operation	In testing product showed battery consumption as expected
4.3 Product should be able to operate between -10C and 35C	I was unable to test down to -10C, but the product did function in direct sunlight at 20C, and in the evening at 10C. Further testing would be required for the extreme temperatures, however it is unlikely they will occur in the UK
4.4 Products maximum tow weight must be >700kg	The heaviest glider I tested the product on had a gross weight of 700kg, and it was towed with no issues
5.1 Product must have a metal based frame	Product does feature a fully mild-steel frame
5.2 Product must have a shroud/cowling manufactured out of polymers	Product does feature a fiberglass painted cowl
5.3 Materials chosen for product must have a range of finishes available	Product features intended finishes on all materials used
5.4 Components must be suited for outdoor operation	The cowl and clear acrylic splash guards protect the components from the weather
5.5 Components must have good weather resistance, and be unaffected by continuous outdoor use	Protected and concealed electronics will not be effected by the weather
6.1 I will use Job production. Each product will be manufactured one at a time and can be tailored to each gliding clubs needs	Due to the expected demand of my products and the time taken to manufacture, I can conclude this method of production will be suitable
6.2 The manufacturing cost of the entire product I estimate will be around £350-£400.	Total cost of manufacture was within those boundaries, at approximately £370

Life-cycle analysis

Raw materials

Mild steel
My design is largely constructed out of mild steel. I believe I used the material as efficiently as possible, as I only used it where it was required to make the frame structurally sound.

Mild steel itself however requires a lot of energy to be extracted from the ground, processed and then shipped in the form I have used.

This being said however, mild steel is extremely easy to recycle, and it is said that more than 85% of steel is recycled. This means it's possible the steel I have used has already been recycled multiple times, and if not, will be after my product has been discarded.

Fiberglass
Another large component of my design is made from fiberglass. Fiberglass is notably not a natural material, and is actually a blend of glass fibre cloth and polymer resin. I used 3 sheets of fiberglass in my product, which was necessary to ensure it was strong enough to withstand everyday use.

The production of the resin and glass fibre cloth is also slightly energy intensive, however that is not the biggest issue with fiberglass.

It is impossible to recycle fiberglass. Grinding and shredding fiberglass will destroy most of the glass fibres, thereby impacting it's properties making it useless. For my product, this means the shell itself will have to be disposed of by other means.

Fiberglass itself though is one of the least energy-intensive production materials of today. As the glass is made from silica (sand), it is readily available and easily made.

MDF
Certain elements of the manufacturing process and the final design itself feature MDF parts. MDF is a sustainable and environmentally friendly material.

As it's produced from wood fibre, many wood shavings or other parts of a tree that are discarded can be used in MDF. This puts less strain on the environment in terms of sourcing the raw materials. It is however, quite tricky to recycle, but it stores enough carbon to offset it's carbon footprint.

Polystyrene
The mould for my product was made out of polystyrene board. Polystyrene is not an environmentally friendly material for several reasons. I used it as sparingly as possible however my manufacturing process did produce polystyrene waste.

Producing polystyrene is an enormous creator of dangerous waste, and a large contributor to global warming.

It is very slow to degrade and cannot be recycled. If it is disposed of improperly, the decomposing foam can leach harmful chemicals into the environment and water sources. It is so lightweight it can easily be blown around or washed away, so must be disposed of very carefully.

Acrylic
Acrylic's massive use across the globe makes it one of the most unsustainable materials out there. I used a very small amount in my product, as a substitute for glass.

In theory, acrylic can be recycled however a specialist waste centre has to be used. This means acrylic is often disposed of in the normal waste, leading to environmental pollution and ecosystem disruption. Acrylic therefore is unsustainable.

Manufacturing the product

Hand tools used:
- Hacksaw
- Flat file
- Glasspaper
- Hand drill
- Guillotine
- Stanley knife
- Spanners/screwdrivers
- Hammer/mallets

Machines used:
- Laser cutter
- MIG welder
- Electric drill
- Band saw
- Scroll saw
- Belt sander
- Pillar drill

I relied on electricity quite heavily during manufacturing. While I carried out all processes I could by hand, I still found it was necessary to use electricity to complete certain processes. I tried to make my usage of electric machines as brief as possible, and I believe I did not use a significant amount of power during manufacturing my product

Sourcing goods
To get some premade components, I had to both order online and drive to get them. I made sure everything I ordered online was from the UK, so not significant amount of fuel was factored into my product. Additionally, when sourcing components myself, I made sure to plan my trips so the fuel I used in the car would cover multiple shops e.g. the Halfords I travelled to was next to B&Q, so I made sure to minimise trips by planning what I needed to buy.

Assembly
To assembly my product, no energy was expended, other than by me. Everything simply bolted together which I did with a spanner by hand.

Use
Being battery powered, my product is designed to reduce environmental impact from burning fossil fuels. The strong, durable metal frame will last for an extremely long time before failure, especially with the coats of paint I applied to protect it from rust. Fibreglass is a very slow degrading material, and extremely strong so will also last a very long time. The batteries will eventually need replacing, however it is expected different batteries will be used frequently reducing the need to purchase new ones. The electronics will likely have the shortest life, however they can easily be replaced allowed the base frame and cowl to be reused and modified as technology improves and user needs change.

End of life
Once my product becomes obsolete or is discarded, it can easily be separated into it's component parts. The fibreglass cowl can be removed, all electronics unbolted and the wheels removed. This will leave the mild steel frame, which can easily be recycled, the electronic components which if undamaged can be reused, and the fibreglass cowl which will have to be thrown away. When disposing of the cowl, it must be done properly to a trusted waste handler otherwise it might cause environmental damage. On the whole however I consider the product to be relatively environmentally friendly, and believe it's scope for modification and lifetime extension will make it more sustainable, as non-recyclable materials used in it's construction will have a much longer lifetime than if they had been used somewhere else.

Summary Grid 11

The candidate did evidence both aspects of the assessment criterion but the conclusions simply lacked detail, the use of the specification was not really the diagnostic tool to measure the success indeed much of the concluding remarks were largely descriptive offering only limited balance. The candidate did not really offer modifications and therefore evidence an iterative approach.

It is a level two submission and would gain an award towards the top of this criterion.

The award would be 8 marks out of a possible twelve.

Possible Further Evidence to access the higher levels

- **The candidate needed to show further engagement of the client/potential target market.**
- **A more perceptive approach to the product evaluation, perhaps an online stakeholder discussion or a questionnaire analysis.**

Overall Summary

The candidate has produced a good quality portfolio, the work illustrates something of an iterative approach and the candidate does engage with a client group or target market. Overall the candidate uses this group reasonably well and the design phase has some potential. The work lacks real technical content at times and the use of the client is limited at times.

To access the highest levels of the assessment criteria we should see a much more iterative approach to the design possibilities with an ongoing stakeholder narrative that informs the design decisions.

This was apparent in part but we did see missed opportunities that could have been undertaken.

Overall the candidate would gain 93/95 marks and therefore an A grade at the 2019 standard.

Your Subject Advisor

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Q and A session

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