Hovercraft VDP 2

GROUP 13
PAUL LONGE
BRADLEY BLOCKSIDGE
KEQI SHU
DIVINE ABRAHAM
XIANG ZHANG
ALEXANDROS IAKOVOS AGRAFIOTIS

Body and Skirt – Final Design

Body

Shape

The shaped body will be roughly 418 x 295mm in size, allowing for the thickness of the skirt.
It will be a rounded rectangle shape.

Reinforcement layer

This layer will attached to the bottom of the hovercraft providing support to the structure.

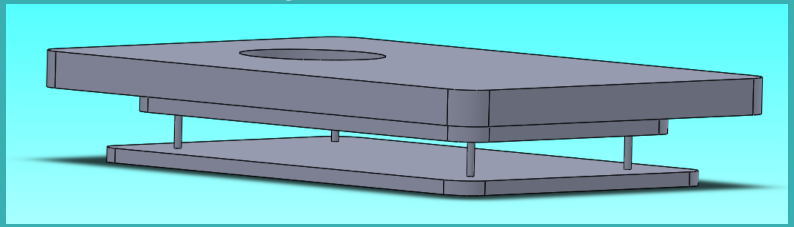
Momentum Curtain

This final layer increases the velocity of the air under the hovercraft therefore increasing the pressure giving it more lift.

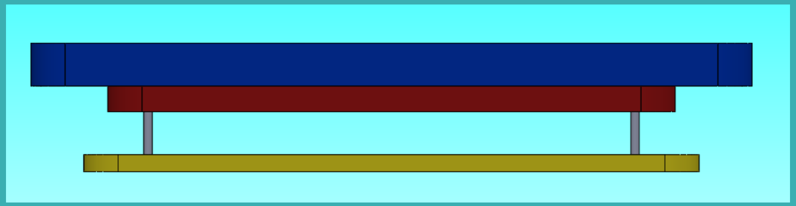
Skirt

A bag skirt design will be used.
+Less material- Lighter, cheaper.
+Simple design-Less time consuming.

Completed Chassis



Chassis Layers

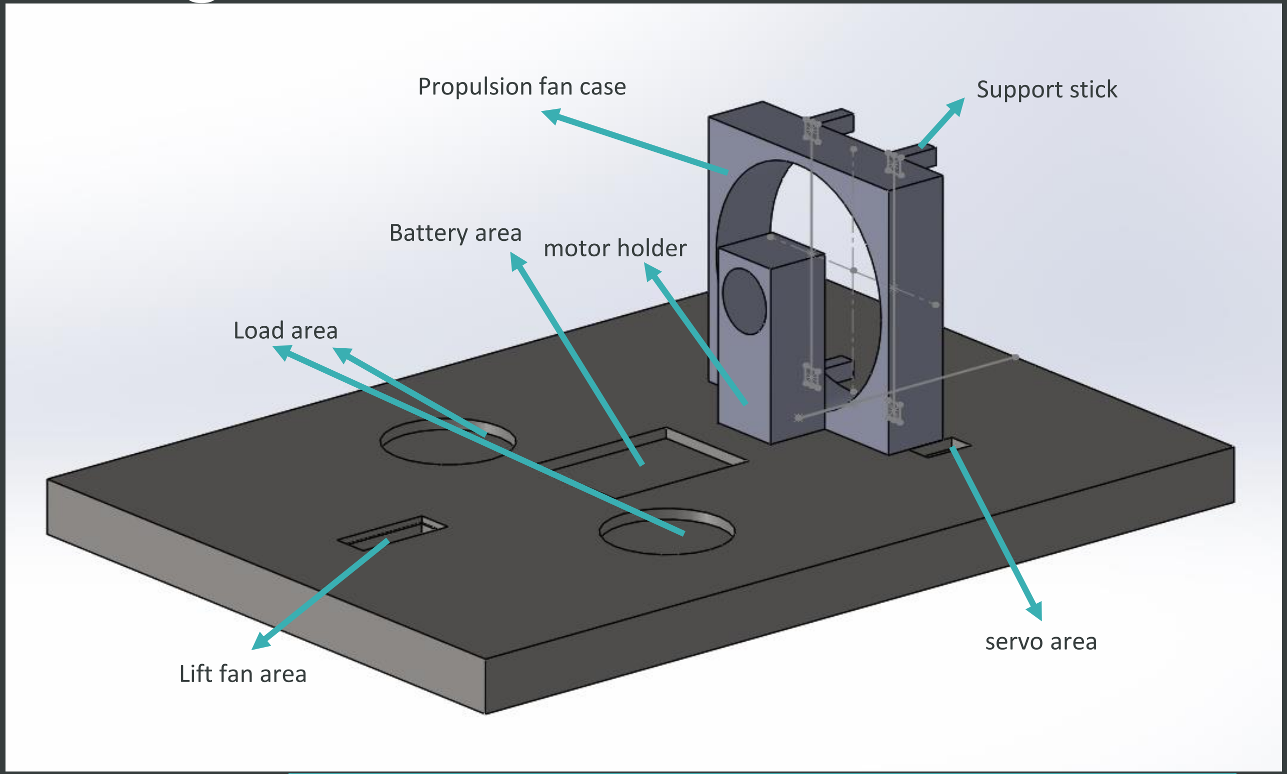


- Shaped Top Layer
- Reinforcement Layer
- Momentum Curtain

XIANG ZHANG- Payload Engineer

Payload – Final Design

- The load areas are placed symmetrically about the center line of the hovercraft.
- Grooves are provided for the lift fan, load, servo, motor holder and battery to be fixed to them.
- All of the extruded cut should be larger than the actual components to fix them.
- Servo is on one side of the propulsion fan.
- Four support sticks will be placed behind the propulsion fan to fix the rudders.



CALLCULATIONS

- All of the apparatus are vertically symmetrical about the centre line except for the servo.
- Horizontally symmetric---left hand side moment=right hand side moment
  (150+11+51)*(87.5+15)=33*102.5+200*x+200*x(x=position of the load)
  X=46mm
- The load area should be placed 46mm away from the centre point to balance the hovercraft.

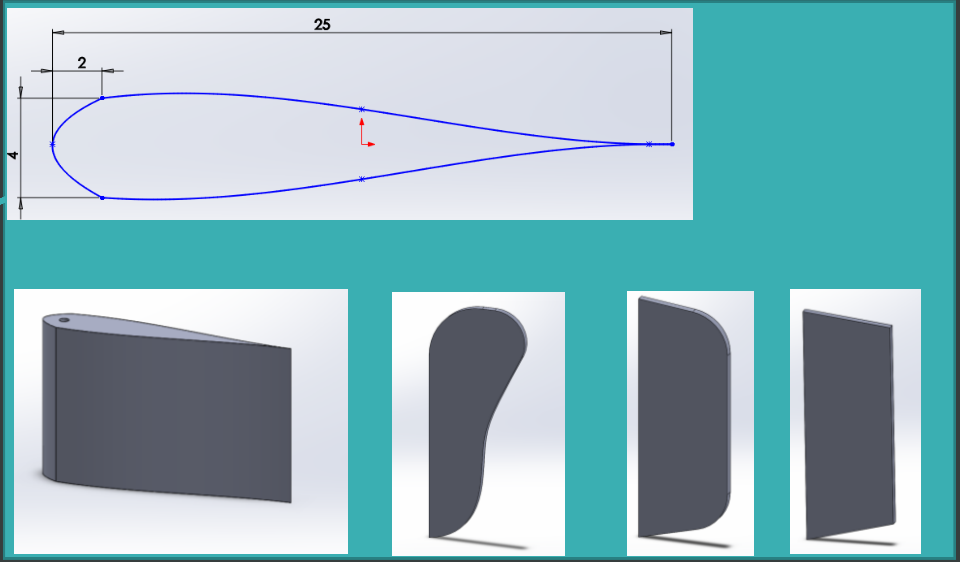
Name	Length x width x thickness/mm	Weight/g
Payload area	415 x 292 x 25	340(without load)
Battery	74 x 55 x 20	145
Lift	75 x 75 x 15.4	33
Propulsion	100 x 100 x 25	150
servo	23 x 12 x 27	11
Load	57 x 57 x 11.5	200
motor	27.7 x 27.7 x 47	51

Paul Longe – Integration Engineer

Turning – Final Design

In order to turn the hovercraft, the use of rudders was selected as it was the option that best fulfilled selection criteria.

- Rudders can be made with a cheap material, and are easy to manufacture.
- Having more than one rudder increases the amount of air that can be redirected, the rudders needs to have a synchronized movement system. A simple linkage was chosen over a more complex 4 bar system.
- Radius of turn needs to be minimized, this is done by redirecting more air flow through a symmetrical airfoil design to minimize air drag. And through having two rudders rather than just one.
- The rudder is secured through the use of pins attached to the cowling. The location of the pin is in the thickest part of the rudder as it will bear high amounts of load.
- There is a 4mm tolerance between the height of the rudder and the parts to secure it



Although it is difficult to calculate how much airflow the rudders are able to redirected, I have done calculations to show how much rotation can be achieved over a time period with the rudders set to different angles.
The table displays total angle turned over a time period at different angles of the rudder. It shows a 10° increase in rudder angle results in a 8.5% increase in turn for all times

	A	B	C	D	E	F	G
1							
2							
3		Volumetric flowrate of air (m^3/s)	0.2		Moment of inertia (kgm^2)	0.0441	=C9*C5^2
4		velocity of craft (m/s)	20		Air volume (m^3)	0.0734	=C3*C8
5		distance from centre of mass to rudders (i	0.21		Air mass (kg)	0.089915	=F4*C6
6		air density (kg/m^3)	1.225		Momentum when moving straight (kgm/s)	1.7983	=F5*C4
7		angle of rudders (°)	90		Perpendicular momentum (kgm/s)	1.7983	=F6*SIN(RADIANS(C7))
8		time (s)	0.367		Angular momentum (kgm^2/s)	0.377643	=F7*C5
9		mass (kg)	1		Angular Velocity (°/s)	8.563333	=F8/F3
10					total rotation angle (°)	180.0659	=DEGREES(F9*C8)
11							

Rudder angle 60°	
Time (s)	Angle turned(°)
0.1	11.58
0.2	46.31
0.3	104.20
0.4	185.25

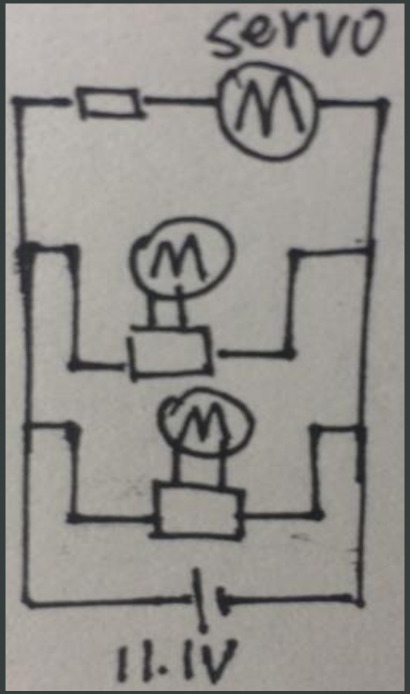
Rudder angle 70°	
Time (s)	Angle turned(°)
0.1	12.56
0.2	50.25
0.3	113.06
0.4	201.00

Keqi Shu- Powertrain Engineer

Powertrain – Final Design （as simple as possible）

Motor & Circuit

- Study the battery & motor controller
- Evaluate the torque and the turning speed under load condition.
- Parallel circuit.
- Power the servo by series connect a resistor.(balance the voltage)
- Set up the safety ratio to 1.2.



	Servo	resistor	Lift	thrust	Needed (*1.2)	provid
Voltage(V)	6- 7.4	3.7-5.1	12	6-15		11.1
Energy (Wh)	0.84	0.9	5.52	8.54	18.96	28.8
Weight (g)	11	1	55	58.8	125.8	
torque	20Ncm			58.8gcm		
Price(£)	5.45	1		4.39		

Transmission Structure

- Decided to use Linkage mechanism.
- Use the most severe conditions to decided the length of links.
- Use excel to have the turning angle relationship.
- Change the links length and find the best solution.
- Errors of servo in turning angle(strict to 100)
- Turning angle difference in two sides

Calculations & Proves

P=IV, current and voltage of servo and resistor are nearly the same .

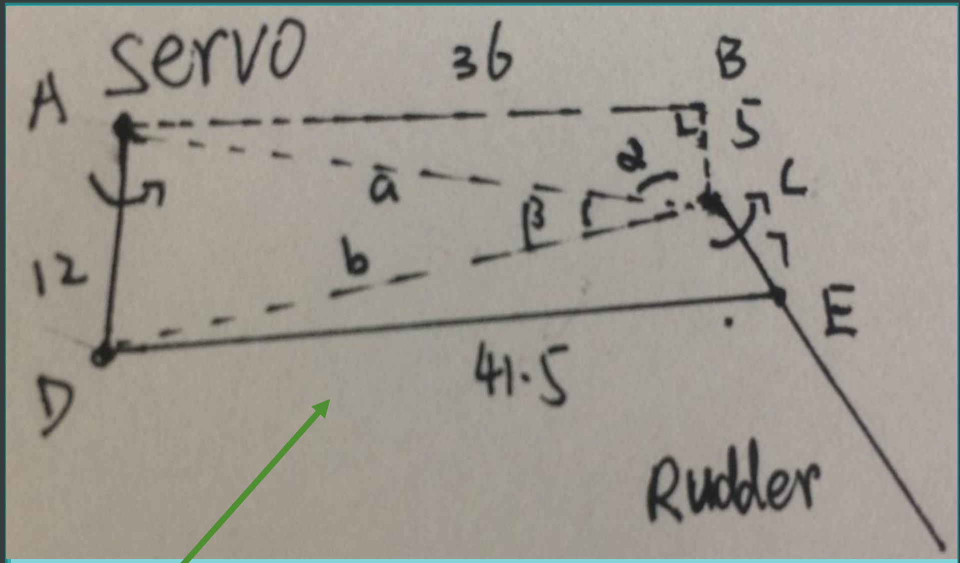
DF =3(n -1)-2n' =1

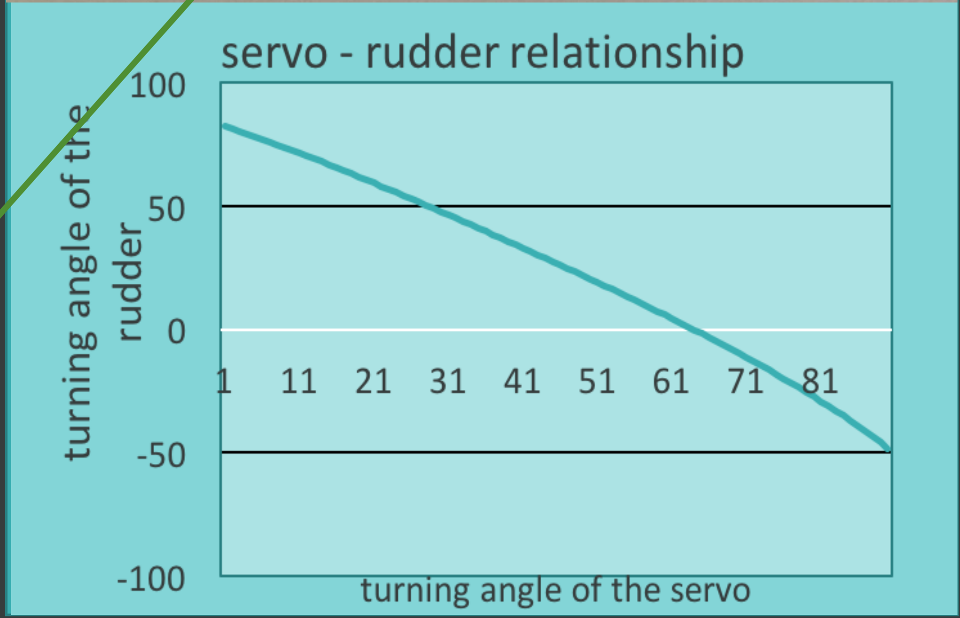
The Law of Cosines

$a^2=b^2+c^2-2bc\cos A$ etc

The Law of Sines

$\sin A / a = \sin B / b = \sin C/c$





Alexandros Iakovos Agrafiotis – Design Engineer

Fans-Materials & Total Cost

- **Axial Fan, Centrifugal Fan & Material Selection**

- Basic material is going to be the Craft foam Blue because it is thick (25mm) strong enough for not breaking with the load and it is very light. Also, easy to change the shape. Cost is £12/ m^2 .

- A centrifugal fan is going to be used for the lift as it needs low power to produce high pressure.

- An axial fan is going to be used for the thrust of the hovercraft as it produces high air flow and it needs low power in order to work efficiently.

- The total cost of the hovercraft is going to be around £130

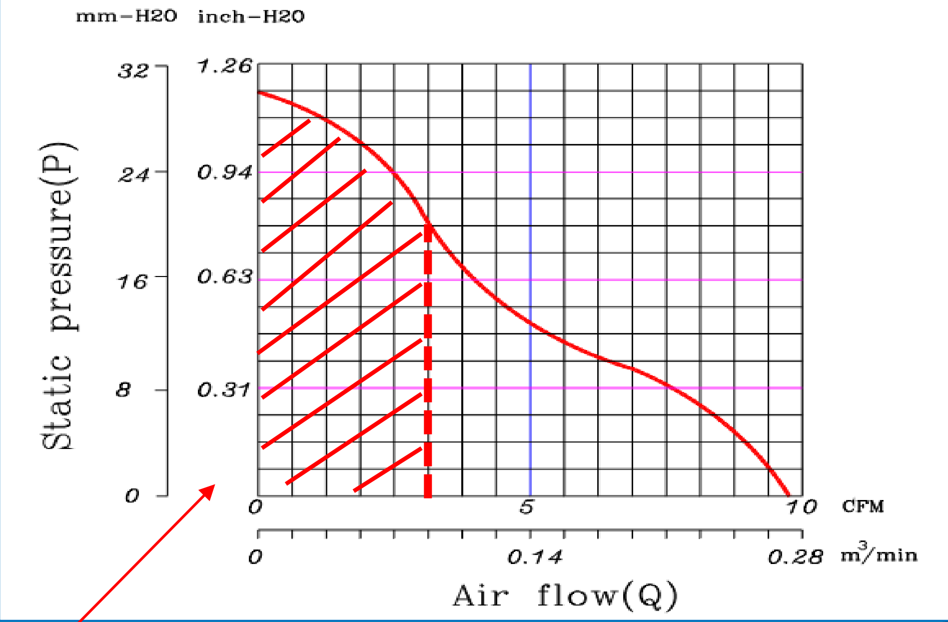


Diagram 1- Static Pressure versus Air flow

Calculations

Pressure needed to lift a hovercraft for A3 size around 2kg is : **P= F/A = 162.81 *Pa***

Where F= m x g =**19.62** & A= size A3 – hole of fan **= 0.120505 m²**

In order to produce the pressure needed we will need low air flow under 2.29 m/s. That means the total pressure is the Static Pressure and the Dynamic Pressure: $P_t = P_s + P_d = 173.73 + 3.21 =$ **176.97 Pa**

Where $P_d = ½ \times \rho \times v^2 =$ **3.21 Pa**

We are not able to calculate the air flow and thrust from the Axial Fan as it is going to be with custom blades and a motor that produces 7800 rpm.

Centrifugal Fan (Lift) Specifications		
Rated Voltage	12V	7V Min.
Rated Current	0.46 Amp	0.55 Amp Max.
Rated Power	5.52 W	At 12V
Speed	4500RPM	±10%
Dimensions	L × W × H (mm)	75 × 75 × 15.4
Weight	55 grams	-

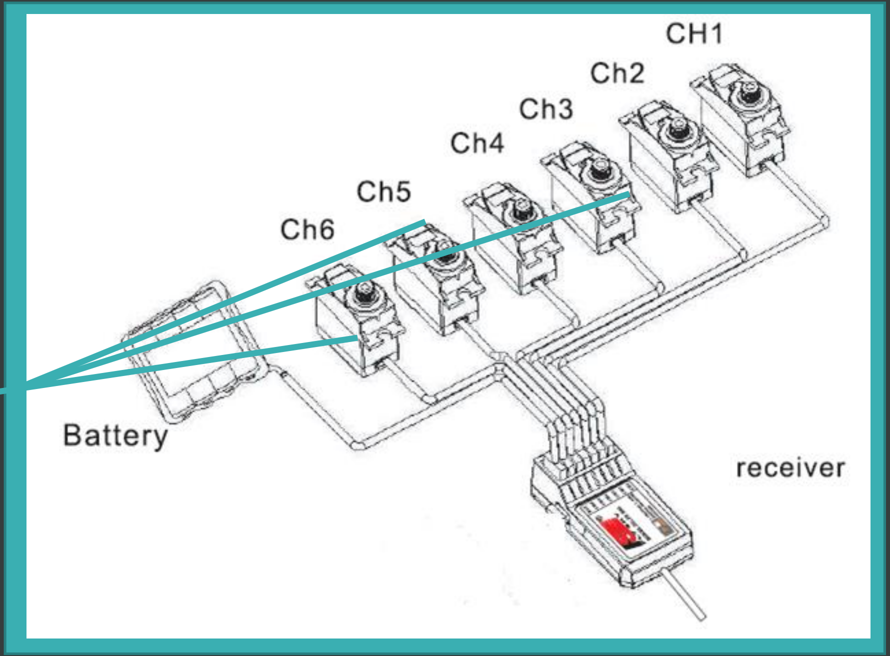
Circuits & ESC's – Final Design

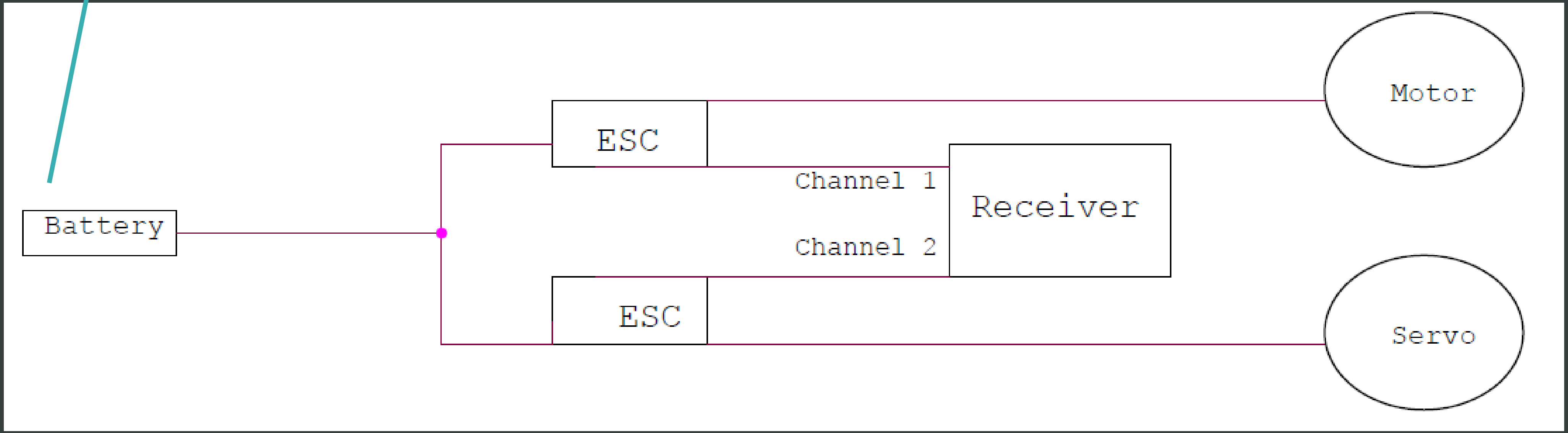
- **What am I supposed to Control?**

1. Lift
2. Speed
3. Direction

- **How Will I do it?**

1. Battery connected to the ESC and ESC to Receiver.
2. Each channel of the receiver will be connected to an ESC.
3. ESC will be connected to the motors (fan) or a servo (rudder) that needs to change with user requirement.





The following pages show the process through which we developed the VDP2

Included in the following pages are VDP1, calculations, sketches and designs done. And some of the reasoning for why we have developed the hovercraft in this way

Design group 13

PORTFOLIO

PAUL LONGE
BRADLEY BLOCKSIDGE
KEQI SHU
DIVINE ABRAHAM
XIANG ZHANG
ALEXANDROS IAKOVOS AGRAFIOTIS

Roles

EG2005 Hovercraft Design Group 13

Tom Gibbs	tg131	Fourth Year Manager
Sameera Fernando	asf13	Fourth Year Manager
Divine Abraham	da201	Electrical & Control Systems Engineer
Alex Agrafiotis	aia16	Design Engineer
Bradley Blocksidge	bb196	Chassis Engineer
Paul Longe	pl151	Integration Engineer
Keqi Shu	ks485	Power Train Engineer
Xiang Zhang	xz184	Payload Specialist

Group 13

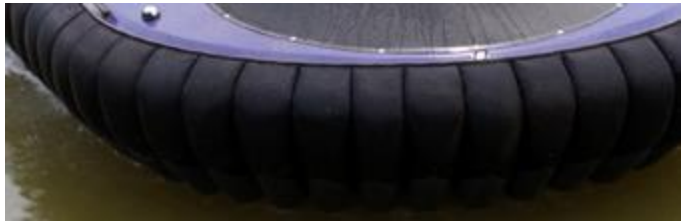
VDP1 Concept Designs

Chassis and Skirt

Skirt

The are two main types of skirt.
Wall skirt- Easy to build, lighter, cheaper
Finger Skirt-Good at going over obstacles, good for high speeds, smoother ride.

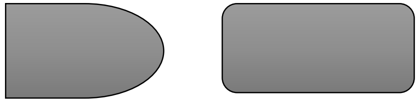
Finger



Wall

Body

Hovercraft Shape- There are two main hovercraft shapes that are predominantly used. Tear drop and rounded square shapes will most likely be the one we choose.

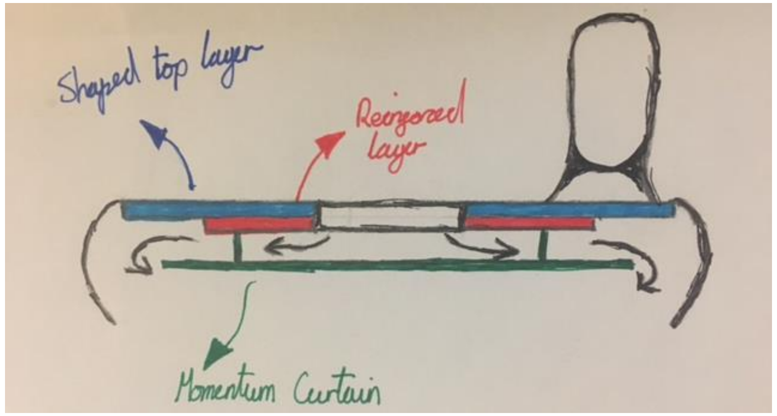


Size- Can only be *420 × 297mm* in size. From one of side of the inflated craft to the other.

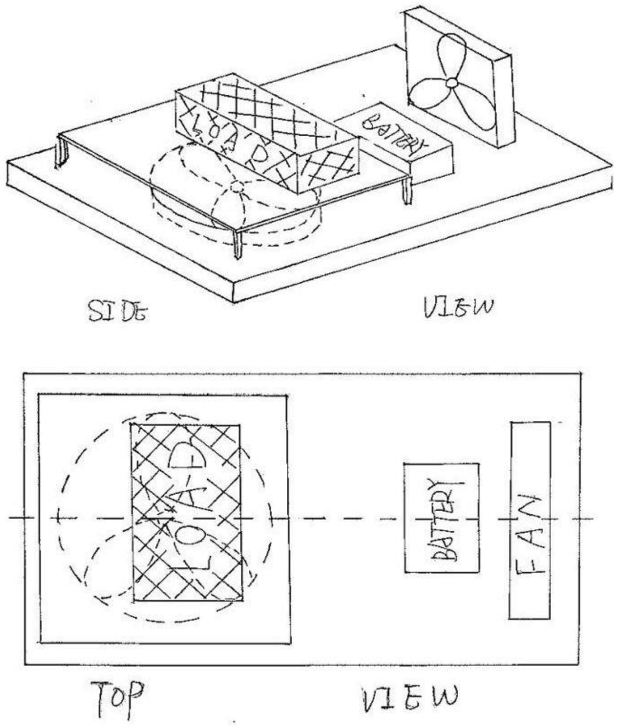
Reinforcement-The hovercraft needs to be light. If we make the body of the craft out of a single piece of light weight material it will likely bend and possibly break. To counter this a reinforcement layer could be added.

Hovercraft lift

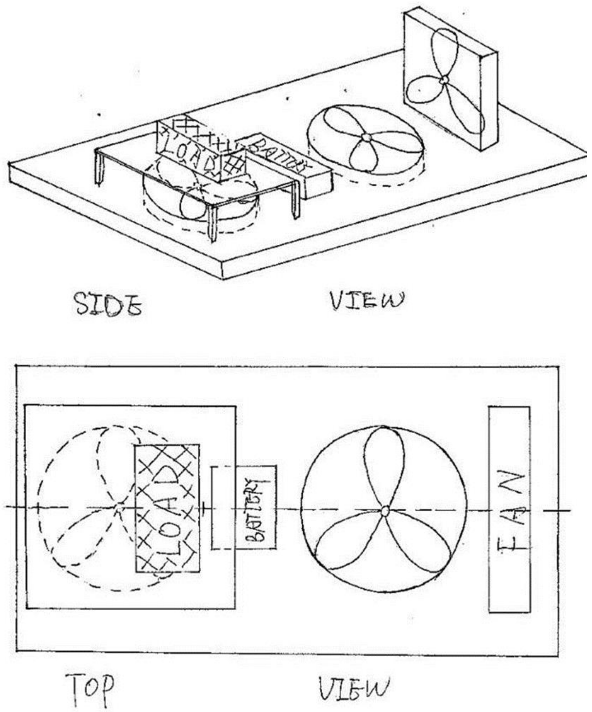
Momentum curtain- Higher pressure air under the hovercraft as less air leaked out the sides. Meaning the craft lifts higher.
Open plenum- No added material so the craft will be lighter and the hovercraft will be easier to build.



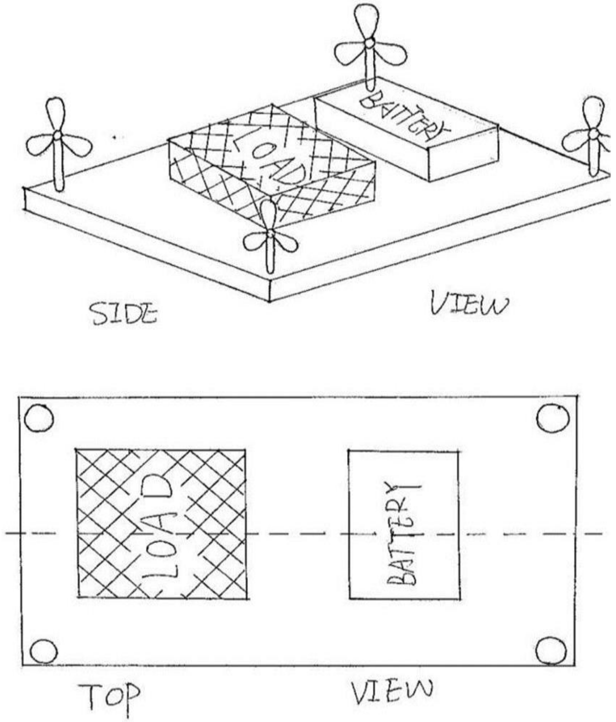
Payload



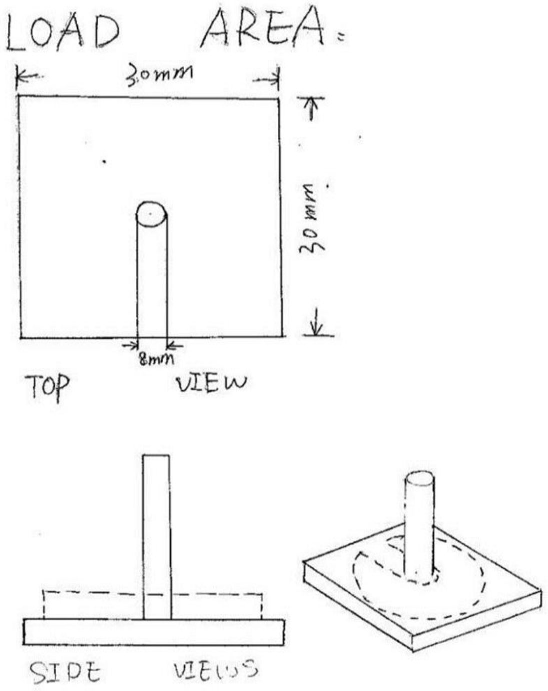
1



2



3



- There are two fans in 1 Both of the lift and propulsion are in the same size

- Two lifts and one propulsion are in 2
- Two lift should be in the same size

- Four small propulsion fans are in the corner of the hovercraft in 3

- Easy to put the mass on
- Help to control the balance when put the mass on

All of the apparatus in this area should be symmetrical as much as possible to control the balance.
All of the dimensions should be measured for the balance test.

Integration Engineer - Paul Longe

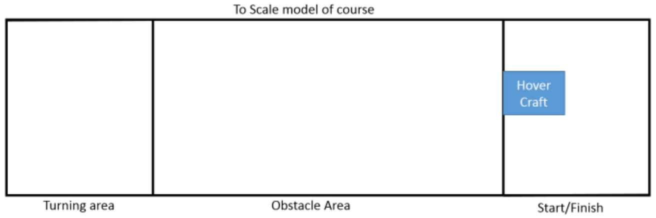
Turning of a Hovercraft

Requirements

- A hovercraft of max size 297x420mm must be capable of completing a 180° turn within a minimum area of 1x1.2m.
- The hovercraft needs to manoeuvre within a 2.4x1.2 meter area.
- The hovercraft needs to be able to overcome obstacles of maximum height 5mm, if they can not be overcome by lift, the hovercraft needs to be able to avoid them through manoeuvers.

Integration Engineer - Paul Longe

Turning of a Hovercraft



Integration Engineer - Paul Longe

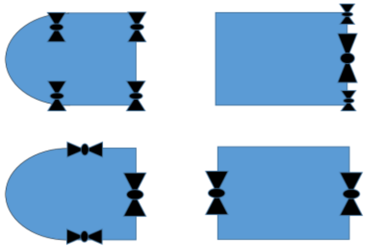
Bow Thruster

- Thrust fans can be turned off
- Reduces affects from moment of inertia

- Needs powerful lift fans
- Additional Tubing
- Harder to manufacture

Integration Engineer - Paul Longe

Additional thrust fans

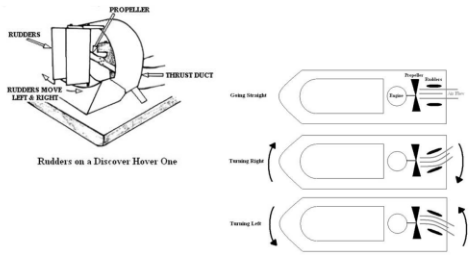


- More flexibility in design
- Greater thrust

- Expensive
- More wires required
- Uses up more power

Integration Engineer - Paul Longe

Rudders

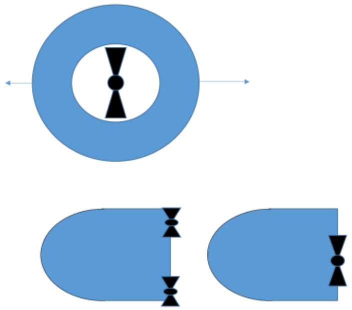


- Liable to effects from moment of inertia
- High radius of turn

- More air redirected, smaller radius
- Smaller radius requires more and better designed rudders
- Works when coasting

Integration Engineer - Paul Longe

Servomechanism rotating fan



- More precise in angle of control
- Control speed of rotation

- Always needs thrust applied
- More complex
- Liable to effects from moment of inertia
- Imprecise control

Rotors, Fans & Materials

- ✓ Low in cost
- ✓ Extra Energy
- ✓ More Power
- ✓ Less efficient
- ✓ Less space requires
- ✓ Low weight (plastic)

- ✓ Low in cost
- ✓ More thrust because of the length of blades
- ✓ More efficient
- ✓ More space requires
- ✓ Low weight (Carbon)

- ✓ Low in cost
- ✓ More thrust because of the length of bla[illegible]s
- ✓ M[illegible]er-full
- ✓ Mo[illegible] space requires
- ✓ Low weight (plastic)

- Materials & Cost

Materials	Thickness	Cost
Aluminium sheet	0.9mm	£11/m^2
MDF	3.6mm	£3/m^2
Carbon Fiber	0.75mm	£61.15/300mm x 300mm x 0.75mm
Craftfoam Blue	25mm	£12/m^2

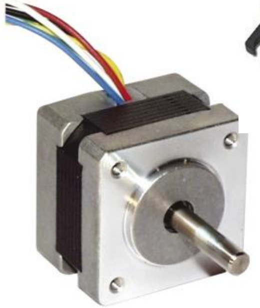
For the main body of the hovercraft I would recommend Craftfoam Blue as it is very light material with Aluminium sheet in order not to brake from the load.

Motors & Batteries

BATTERY
- 2600mAh
- 28.8Wh
- 11.1V
- I_{max}: 5.2A
- Re-chargeable

- Budget
- Power
- Weight
- Stability

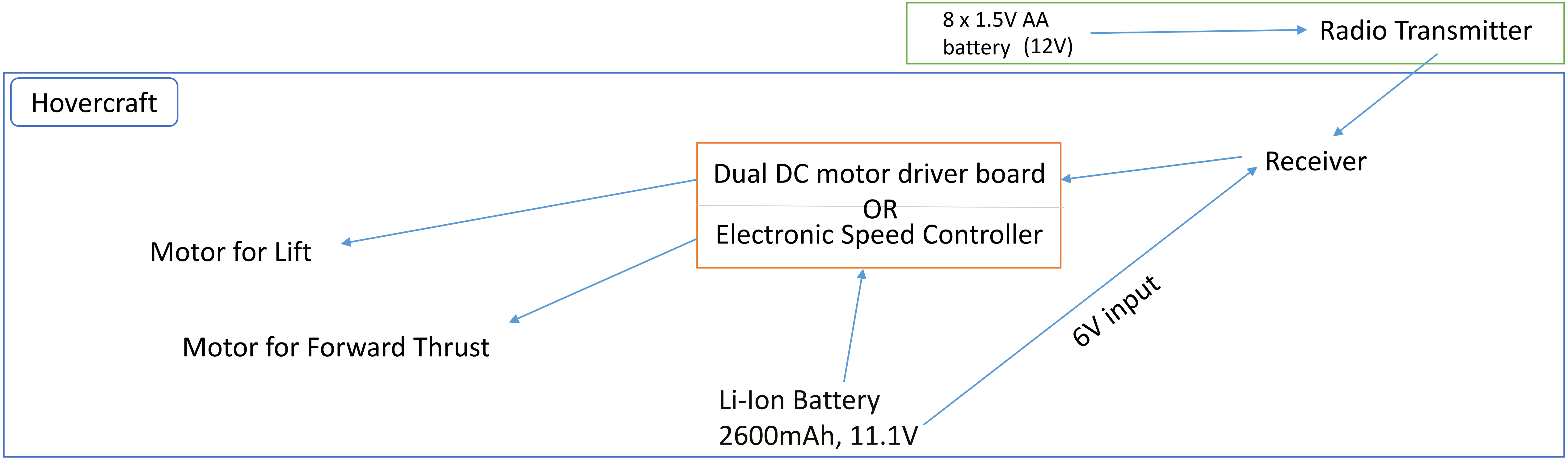
- Motion Motor
  - servo motor £8.90
    - Close-loop control, stability, high speed change, steady torque
    - Comparatively expensive
  - Stepper Motor £2.00
    - Cheap, Open-loop control
    - Small torque
  - DC Linear Actuator Motor £21.71
    - Easy to control, direct force on the liner direction
    - Expensive, hard to apply on motion control
- Load Motor
  - Brushless motor £24.33
    - Low energy cost, low electrical interference, Stable, accurate and controllable rotate speed
    - Expensive
  - Brushed motor Very low
    - Cheap, stable rotate speed,
    - Produce heat, low efficiency, low output power
  - DC Geared Motor £19.99
    - Great torque, save space
    - High cost, low rotating speed
- Other



The Hovercraft will need either 2 Electronics Speed Controllers, one for the Lift & one for Thrust (Total of £8) or a Dual DC motor driver board (£3.74+)

Specification:	Electronics Speed Controllers	Dual DC motor driver board
Control Speed	Pulse Width Modulation	Pulse Width Modulation
Brake	Yes	No
Low Voltage Protection Threshold	Yes	No
Over-heat protection:	Yes	No
Throttle signal loss protection	Yes	No



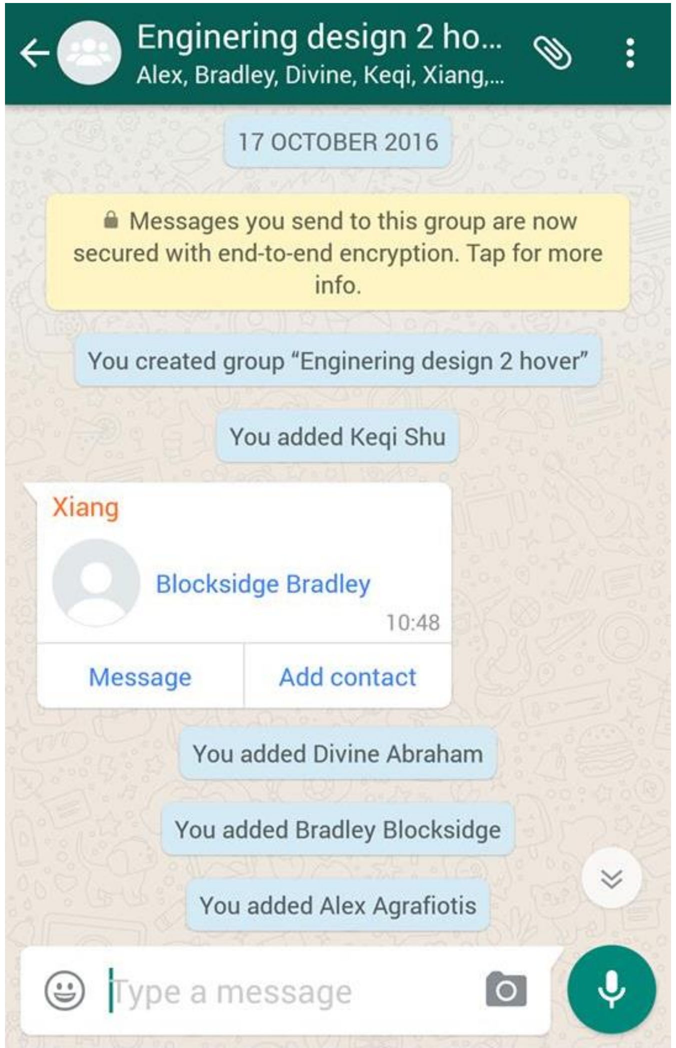
Individual calculations, sketches, presentation slides

The following pages, are each group members individual parts

Start of project

My job is the Integration Engineer, I am responsible for liaising between members of the team, and ensuring all components fit together well, for this I need a holistic understanding of the hovercraft, and good communication skills.

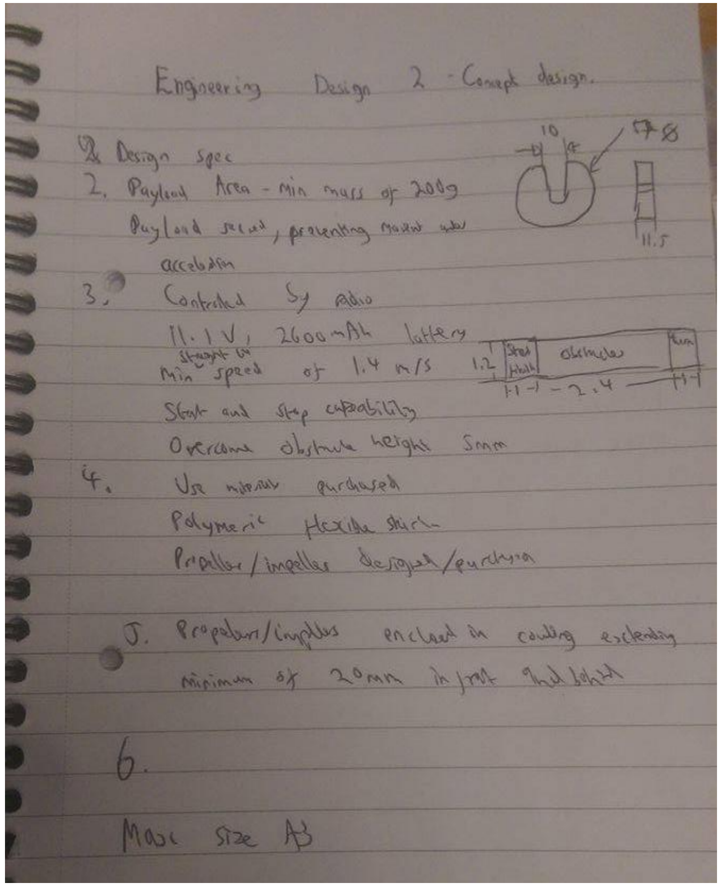
To improve communication, the first thing I did was to create a group 'whatsapp' chat. This was to allow members to communicate through instant messaging software



Design specification

The first thing that I did was to begin to review the design specification, and make basic notes of the important criteria the hovercraft had to fulfil.

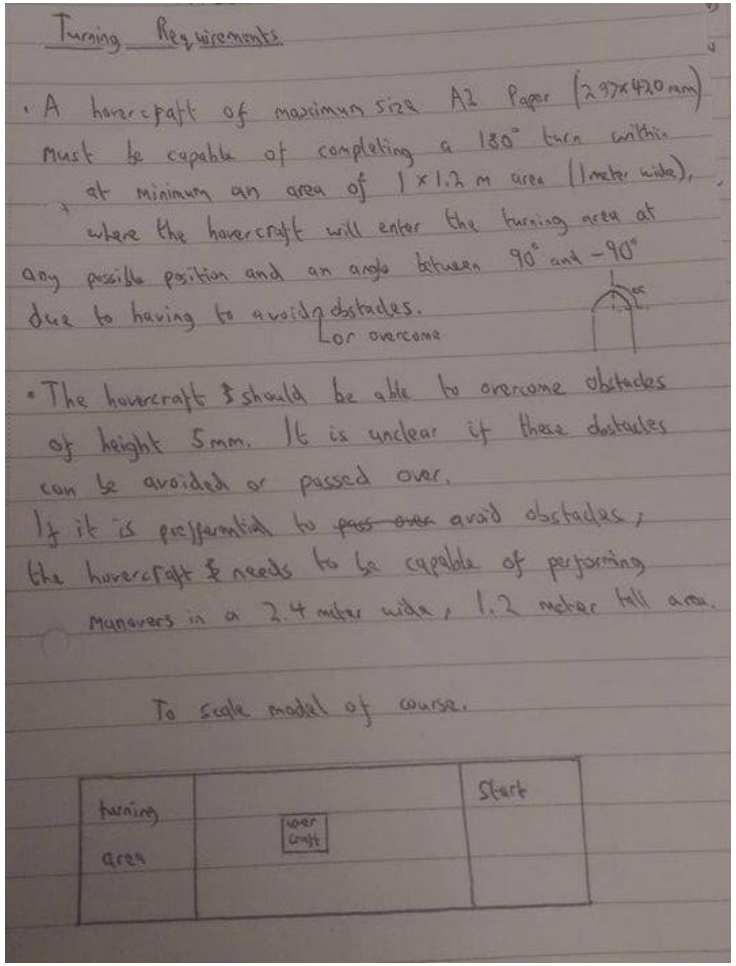
2. Payload area – min mass of 200g, payload secure, preventing movement under acceleration
3. Controlled by radio, 11.1V, 2600mAh battery, minimum straight line speed of 1.4m/s, start and stop capability, overcome obstacles of maximum height 5mm.
4. Use materials available for purchased from university website, polymeric flexible skirt, propeller/impeller can be designed or purchased
5. Propeller/impeller enclosed in a cowling extending a minimum of 20mm in front and behind.
6. Max size of hovercraft A3



Design specification for turning

Again in a written format I created a design specification for the turning of the hovercraft, as well as creating a to scale model of the course.

- A hovercraft of maximum size A3 paper (297x420)mm must be capable of completing a 180° turn within at minimum an area of 1x1.2m where the hovercraft will enter the turning area at any possible position and an angle between 90 ° and -90° due to having avoided or overcome obstacles.
- The hovercraft should be able to overcome obstacles of height 5mm.


Turning Requirements.

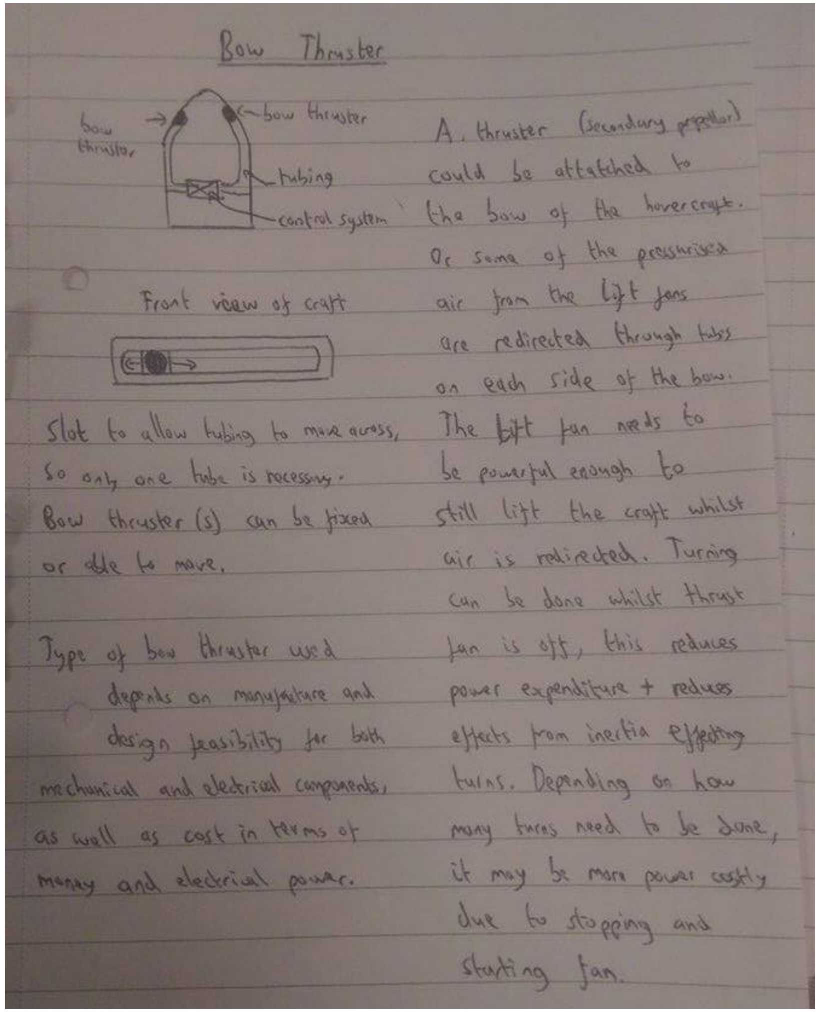
- A hovercraft of maximum size A3 Paper (297x420 mm) must be capable of completing a 180° turn within at minimum an area of 1x1.2 m area (1meter wide), where the hovercraft will enter the turning area at any possible position and an angle between 90° and -90° due to having to avoid obstacles. or overcome
- The hovercraft should be able to overcome obstacles of height 5mm. It is unclear if these obstacles can be avoided or passed over.

If it is preferential to ~~pass over~~ avoid obstacles; the hovercraft needs to be capable of performing manovers in a 2.4 meter wide, 1.2 meter tall area.

To scale model of course.

VDP1 Preparation

In preparation for the VDP1 I did research on different methods available for a hovercraft to manoeuvre.

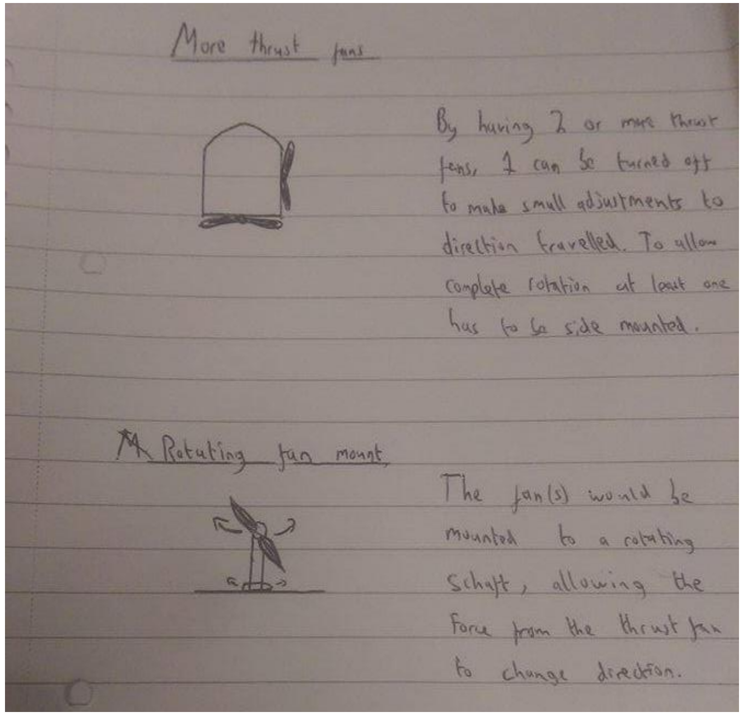


Bow Thruster

A thruster (secondary propellor) could be attatched to the bow of the hovercraft. Or some of the pressurised air from the lift fans are redirected through tubes on each side of the bow. The lift fan needs to be powerful enough to still lift the craft whilst air is redirected. Turning can be done whilst thrust fan is off, this reduces power expenditure + reduces effects from inertia effecting turns. Depending on how many turns need to be done, it may be more power costly due to stopping and starting fan.

Slot to allow tubing to move across, so only one tube is necessary. Bow thruster (s) can be fixed or able to move.

Type of bow thruster used depends on manufacture and design feasibility for both mechanical and electrical components, as well as cost in terms of money and electrical power.

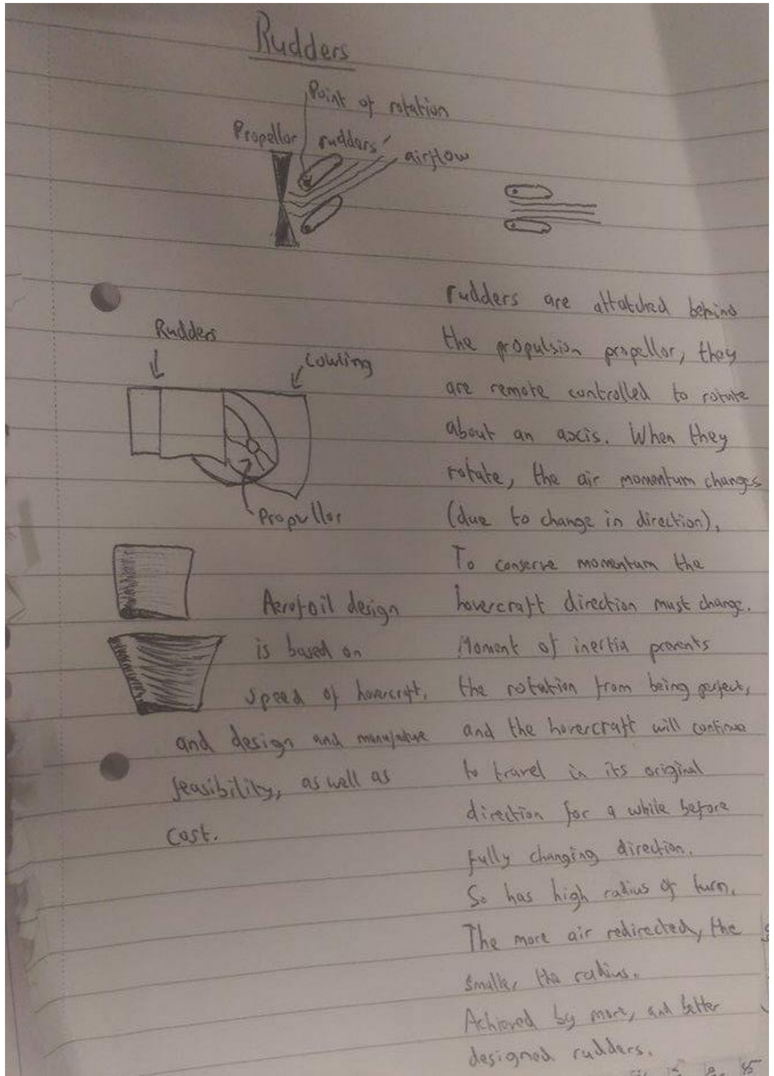


More thrust fans

By having 2 or more thrust fans, 1 can be turned off to make small adjustments to direction travelled. To allow complete rotation at least one has to be side mounted.

Rotating fan mount

The fan(s) would be mounted to a rotating schaft, allowing the force from the thrust fan to change direction.



Rudders

rudders are attatched behind the propulsion propellor, they are remote controlled to rotate about an axis. When they rotate, the air momentum changes (due to change in direction). To conserve momentum the hovercraft direction must change. Moment of inertia prevents the rotation from being perfect, and the hovercraft will continue to travel in its original direction for a while before fully changing direction. So has high radius of turn. The more air redirected, the smaller the radius. Achieved by more, and better designed rudders.

Aerofoil design is based on speed of hovercraft, and design and manufacture feasibility, as well as cost.

VDP presentation

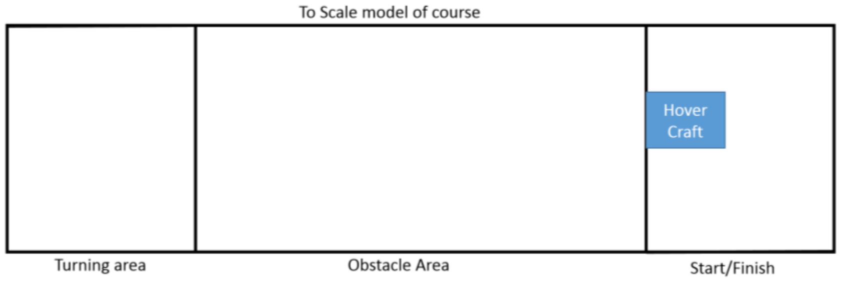
Using the information from the research I was able to create my presentation, using short bullet points that I would elaborate in detail during the presentation

Integration Engineer - Paul Longe

Turning of a Hovercraft

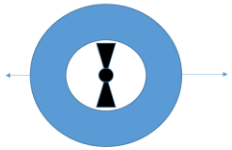
Requirements

- A hovercraft of max size 297x420mm must be capable of completing a 180° turn within a minimum area of 1x1.2m.
- The hovercraft needs to manoeuvre within a 2.4x1.2 meter area.
- The hovercraft needs to be able to overcome obstacles of maximum height 5mm, if they can not be overcome by lift, the hovercraft needs to be able to avoid them through manoeuvers.



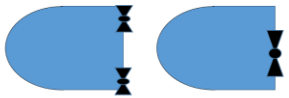
Integration Engineer - Paul Longe

Servomechanism rotating fan



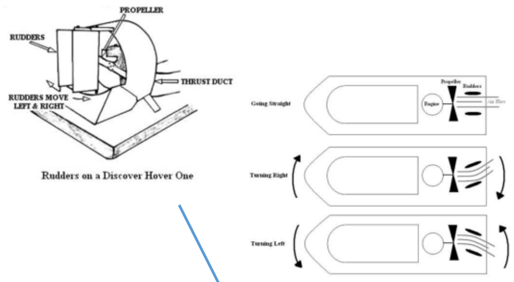
- More precise in angle of control
- Control speed of rotation

- Always needs thrust applied
- More complex
- Liable to effects from moment of inertia
- Imprecise control



Integration Engineer - Paul Longe

Rudders

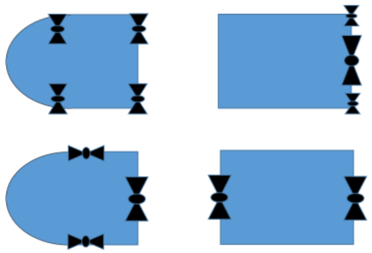


- Liable to effects from moment of inertia
- High radius of turn

- More air redirected, smaller radius
- Smaller radius requires more and better designed rudders
- Works when coasting

Integration Engineer - Paul Longe

Additional thrust fans



- More flexibility in design
- Greater thrust

- Expensive
- More wires required
- Uses up more power

Bow Thruster

- Thrust fans can be turned off
- Reduces affects from moment of inertia

- Needs powerful lift fans
- Additional Tubing
- Harder to manufacture

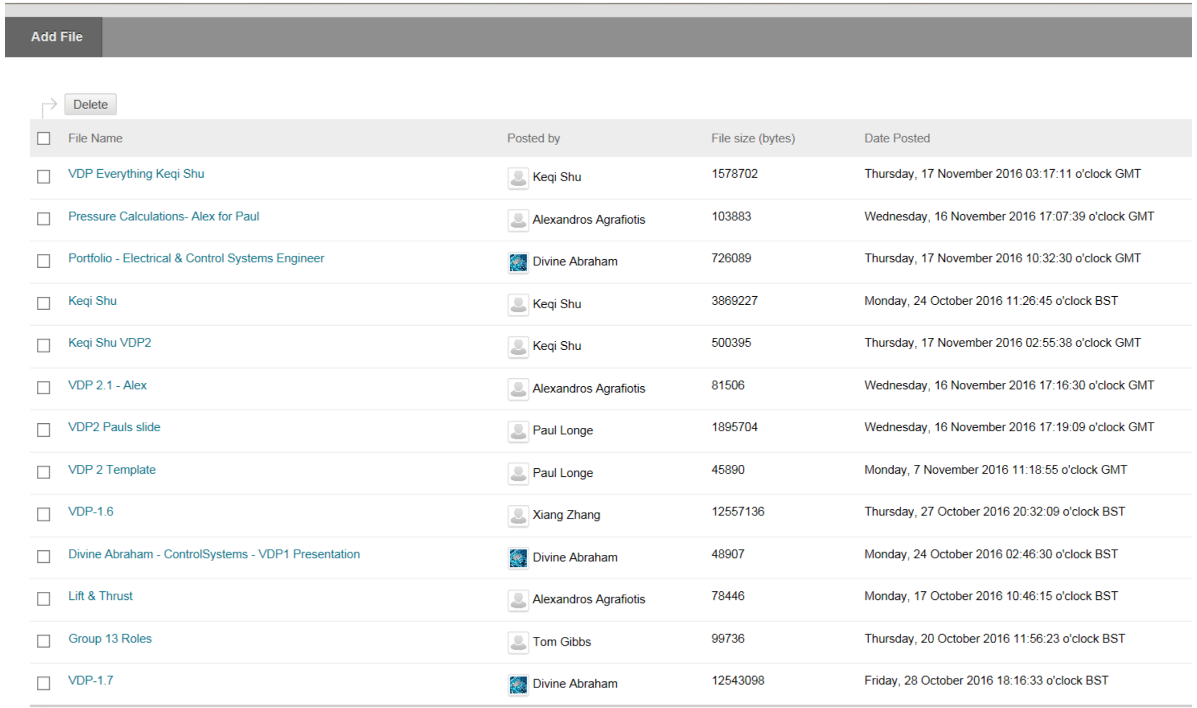
These images came from online sources, I created the others in Microsoft PowerPoint, I used slide animations to fit all the information to one slide.

Improving VDP

As the Integration Engineer, I was tasked with putting together each persons slides for the VDP. Each person would add an update of their slide to the file share labelling them VDP1.1, VDP1.2 and following this pattern with each update.

I quickly found that the presentation had an unprofessional appearance, due to each person having a different style of presentation.

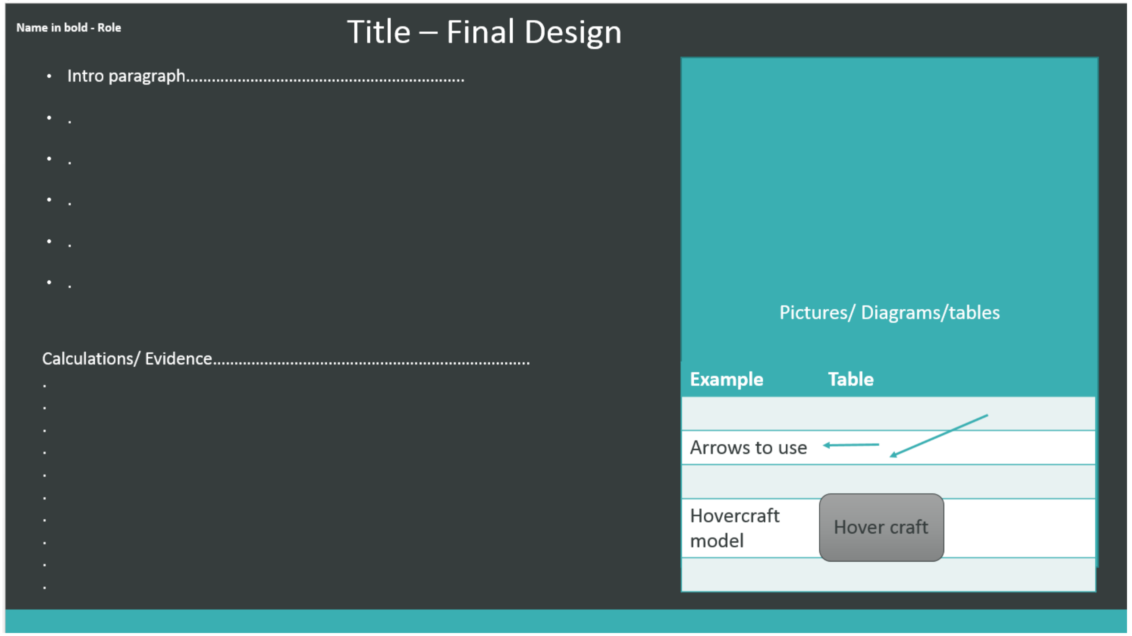
To correct this, I created a template for the next presentation that each member of the group would follow.



Add File

Delete

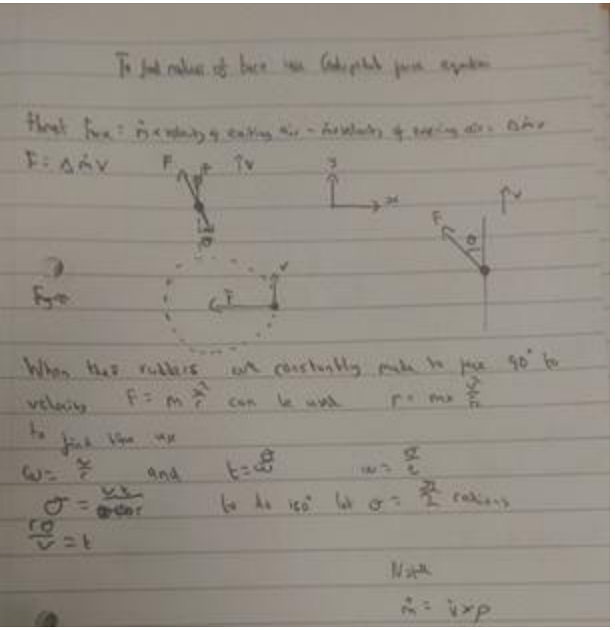
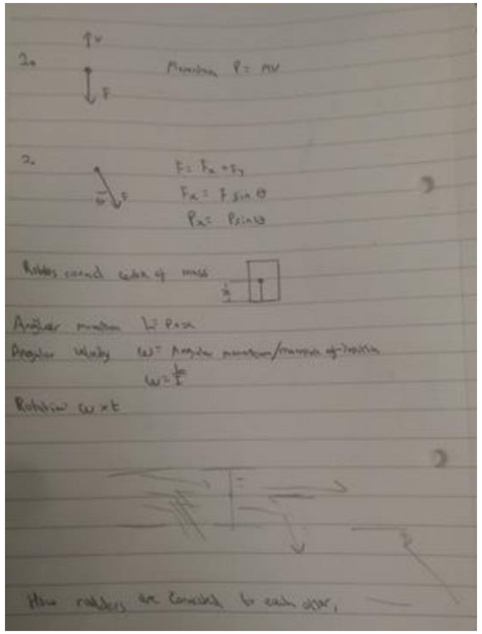
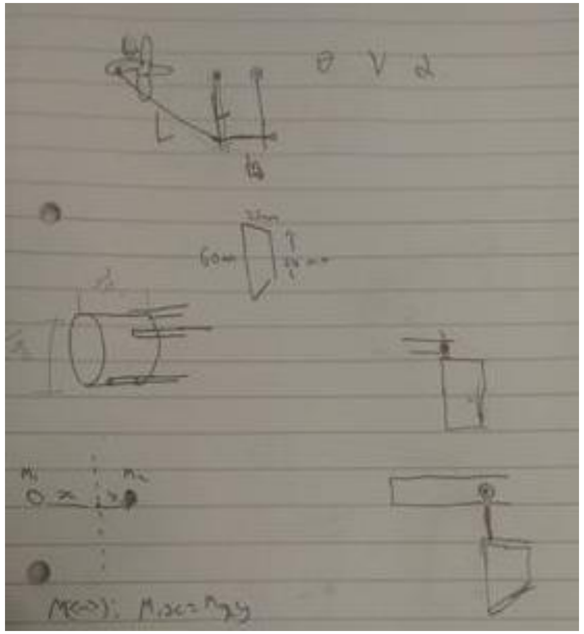
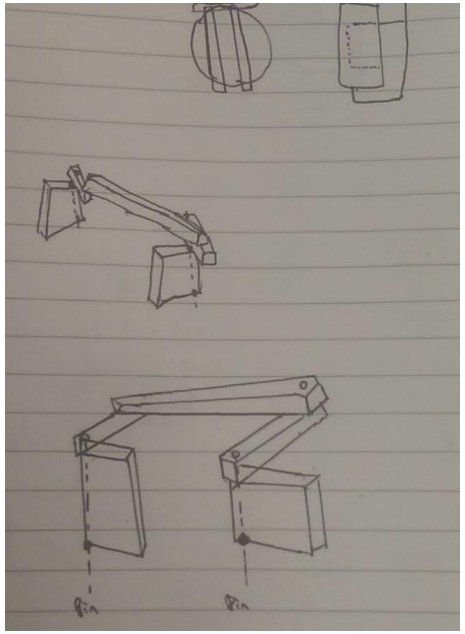
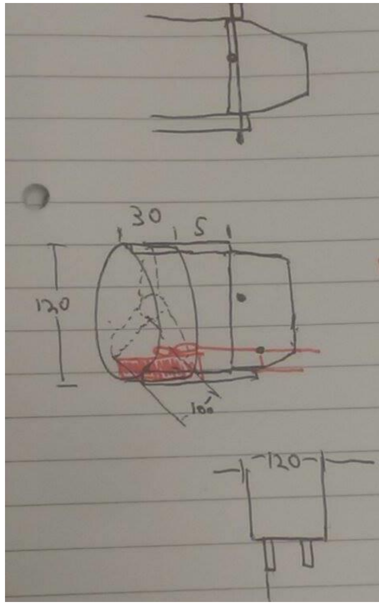
File Name	Posted by	File size (bytes)	Date Posted
VDP Everything Keqi Shu	Keqi Shu	1578702	Thursday, 17 November 2016 03:17:11 o'clock GMT
Pressure Calculations- Alex for Paul	Alexandros Agrafiotis	103883	Wednesday, 16 November 2016 17:07:39 o'clock GMT
Portfolio - Electrical & Control Systems Engineer	Divine Abraham	726089	Thursday, 17 November 2016 10:32:30 o'clock GMT
Keqi Shu	Keqi Shu	3869227	Monday, 24 October 2016 11:26:45 o'clock BST
Keqi Shu VDP2	Keqi Shu	500395	Thursday, 17 November 2016 02:55:38 o'clock GMT
VDP 2.1 - Alex	Alexandros Agrafiotis	81506	Wednesday, 16 November 2016 17:16:30 o'clock GMT
VDP2 Pauls slide	Paul Longe	1895704	Wednesday, 16 November 2016 17:19:09 o'clock GMT
VDP 2 Template	Paul Longe	45890	Monday, 7 November 2016 11:18:55 o'clock GMT
VDP-1.6	Xiang Zhang	12557136	Thursday, 27 October 2016 20:32:09 o'clock BST
Divine Abraham - ControlSystems - VDP1 Presentation	Divine Abraham	48907	Monday, 24 October 2016 02:46:30 o'clock BST
Lift & Thrust	Alexandros Agrafiotis	78446	Monday, 17 October 2016 10:46:15 o'clock BST
Group 13 Roles	Tom Gibbs	99736	Thursday, 20 October 2016 11:56:23 o'clock BST
VDP-1.7	Divine Abraham	12543098	Friday, 28 October 2016 18:16:33 o'clock BST



Paul Longe – Editor – Integration Engineer

VDP 2

For my final concept design, I chose to use rudders after discussing with members of the team, on which design was the most feasible. I had to work closely with the payload and powertrain engineers. A lot of sketches were used to explain complex ideas.

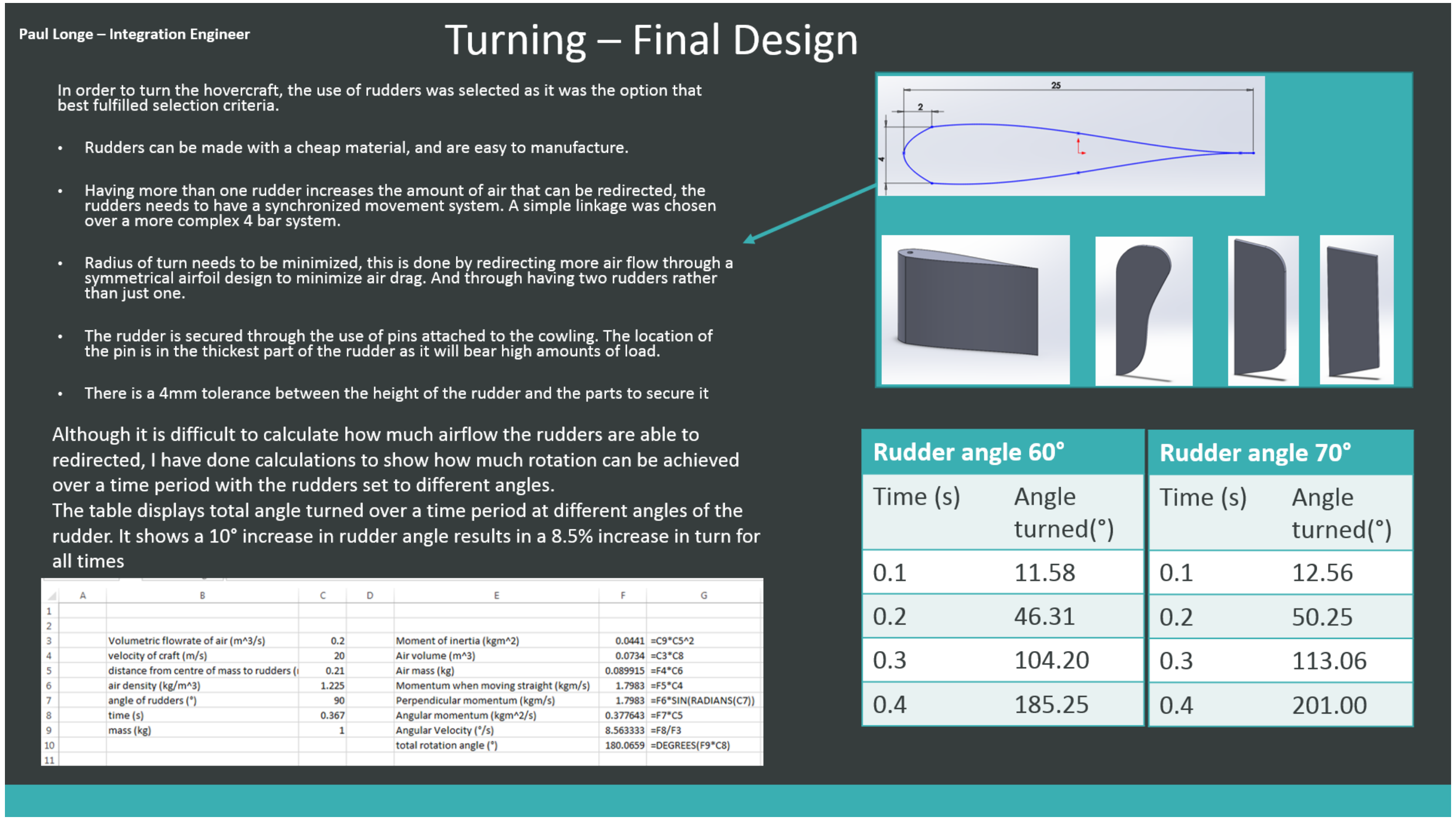






For my calculations I wanted to find how much air needed to be redirected by the rudders in order to perform a turn within an area. I attempted to find which equations would be relevant, and how they could be combined. I used: linear and perpendicular momentum, flow rate, angular rotation, centripetal acceleration and thrust force equations to find relevant information.

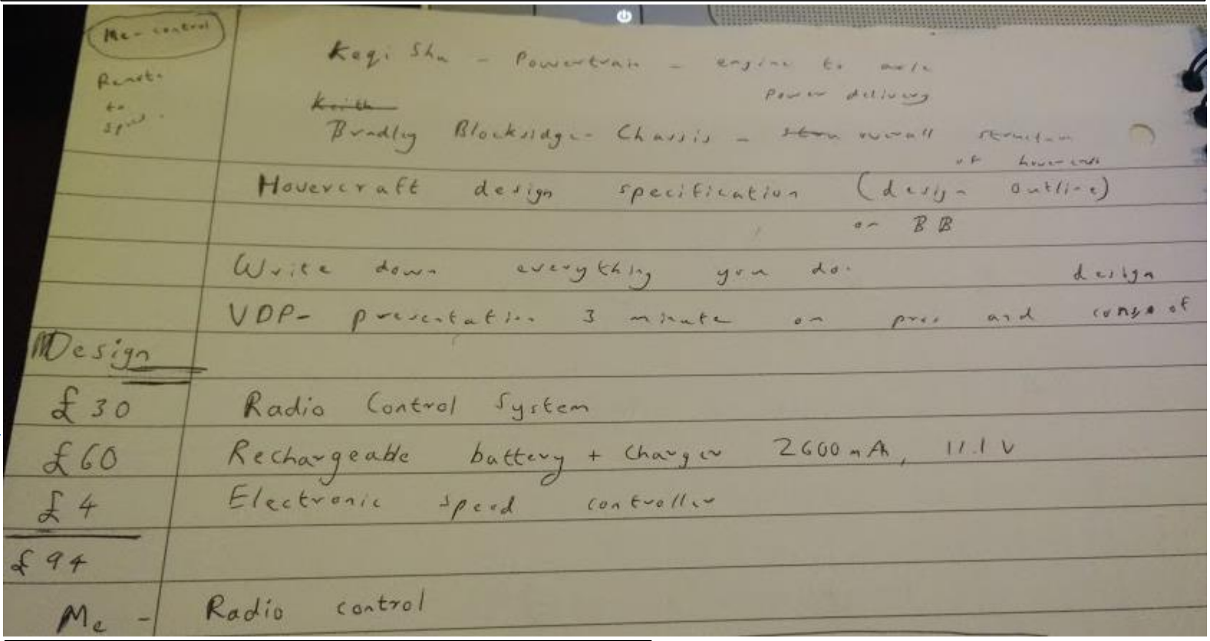
These sketches were used in the discussion of different ideas I presented to my group members, in terms of how the servo would connect to the rudders, dimensions of the cowling, and what system would be used to ensure the rudders turn in synch.

VDP 2 continued

I created some models of the rudders in SolidWorks of the rudder, using different aerofoil designs, and formed calculations inside of Microsoft excel, some of the inputs are assumptions, but can be changed freely and will automatically update the output



This is the initial notes on the roles of other team members who I'll have to work closely with. There are also some information about the initial cost estimation for my role



The price of each electronic equipment that I'll need to purchase for the minimum performance of the hovercraft is taken into account. The prices were taken directly from the blackboard site for the module. This was an initial estimate and has since changed.

The more up to date estimate is to the right:

Price	Equipment Name
£30	Radio Control System
£60	Rechargeable battery and charger
£4 **x 2** = £8	Electronic Speed Controller (ESC) **x2**
£94	

Electronic Speed Controller Eagle-20A	FOR USE WITH BRUSHED MOTORS ONLY. WILL NOT WORK WITH BRUSHLESS MOTORS	Cont Current: 20A	
		Burst Current: 25A	
		BEC Mode: 5v/1A	Battery eliminator circuit (BEC)
		Size: 45x21x8mm	
		Weight: 17g	
Ideal Motor Voltage	12V	Supply: 12V	
Battery to ESC supply	5V	Supply: 5V	

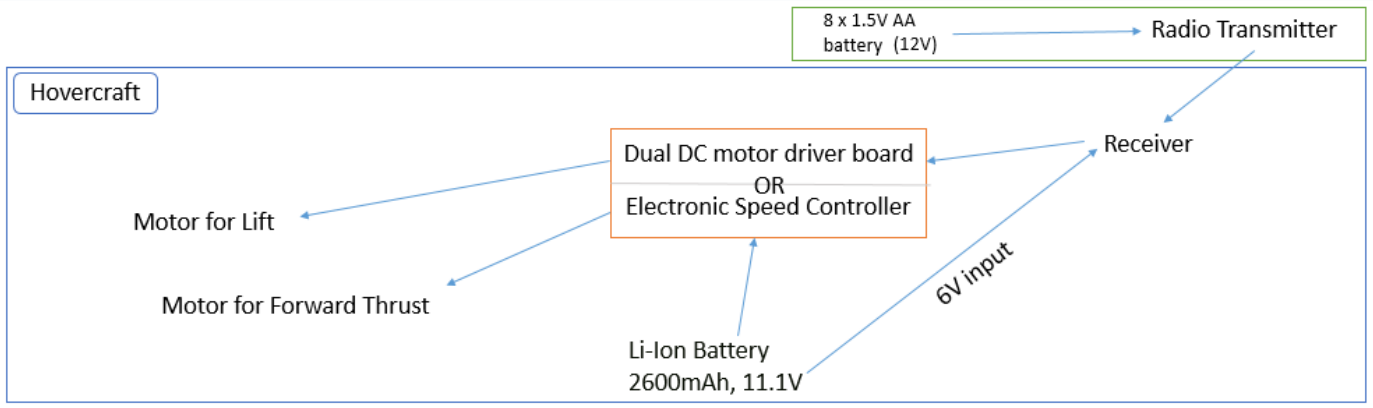
An online document to track the electrical & technical specifications of equipment's that could be used in the hovercraft design.

https://docs.google.com/spreadsheets/d/1ixjO9tZKks7eivinseuBxZE

Electrical & Control Systems Engineer – Divine Abraham

The Hovercraft will need either 2 Electronics Speed Controllers, one for the Lift & one for Thrust (Total of £8) or a Dual DC motor driver board (£3.74+)

Specification:	Electronics Speed Controllers	Dual DC motor driver board
Control Speed	Pulse Width Modulation	Pulse Width Modulation
Brake	Yes	No
Low Voltage Protection Threshold	Yes	No
Over-heat protection:	Yes	No
Throttle signal loss protection	Yes	No

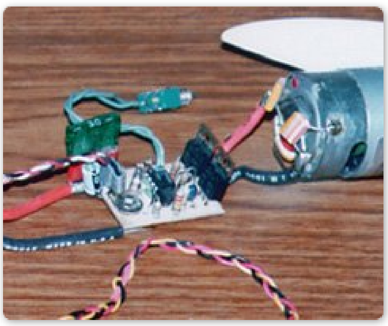


This was my VDP1 Meeting Presentation Slide. It goes through the various options that I've as the electrical engineer, this was a very basic initial design concept.

http://www.stefanv.com/electronics/escprimer.htm

Speed Control Fundamentals

Early electric R/C car speed controls consisted of nothing more than a hefty variable resistor, the wiper of which was moved by a servo. This had the advantage of being simple, but was very inefficient at partial throttle settings. Such a control works by reducing the voltage to the motor, but this means that any voltage that does not appear across the motor terminals must appear across the speed control. For example, at half throttle, a resistor speed control that is controlling a motor drawing 10A from a 6-cell pack will have 3.6V across it, and 10A flowing through it. From our second law, that's 36W, which all becomes useless heat. This would be like running a 40W light bulb in the radio compartment of your plane. Furthermore, half the power being produced by the battery is being wasted. A resistor speed control is only efficient at zero throttle (when no current is flowing), and at full throttle (when there is no voltage drop across the speed control).



A typical (in 1997) high-rate analog speed control connected to a Graupner Speed 600 motor. Notice the fuse in the positive lead from the battery connectors.

An *electronic* speed control (the photo shows a typical high-rate speed control) works by applying full voltage to the motor, but turning it on and off rapidly. By varying the ratio of on time to off time, the speed control varies the *average* voltage that the motor sees. Since at any given instant, the control is either fully off (no current flowing, so $P = 0 \times V = 0$W) or fully on (no voltage drop across the speed control, so $P = I \times 0 = 0$W), this kind of control is *theoretically* 100% efficient.

This website was used to get some basic understanding and applications of the Speed Controller. It had lots of useful and self-explanatory math formulas to improve the initial understandings.

Other References Used:

http://www.rcmodelswiz.co.uk/rc-guides/electric-rc-models-guide/electronic-speed-controllers-esc/

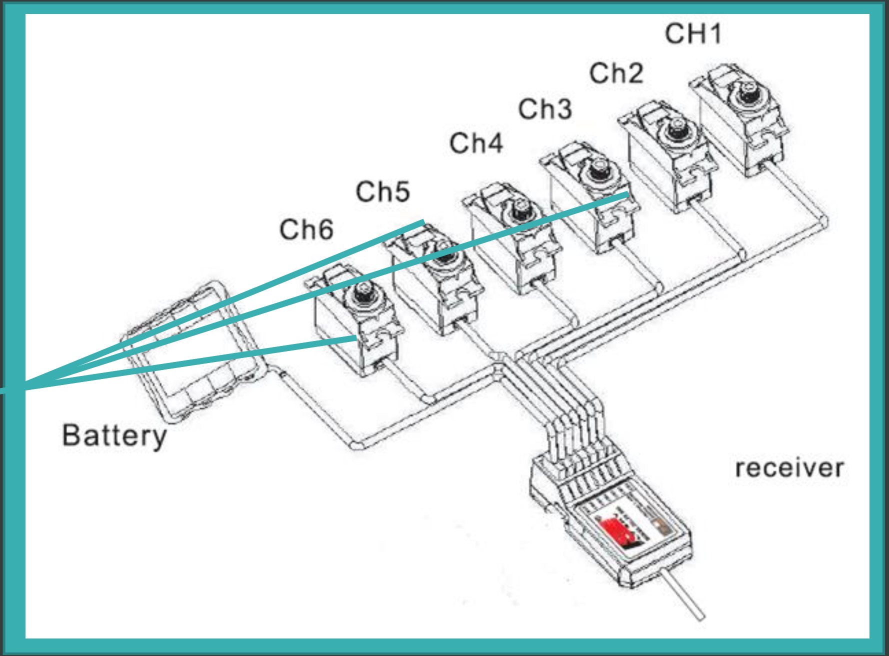
https://dronesandrovs.wordpress.com/2012/11/24/how-to-control-a-brushless-motor-esc-with-arduino/

http://bestpriceonline.co.uk/5v-12v-adjustable-voltage-dual-bec-output-board-esc-distribution-connection-board/

Circuits & ESC's – Final Design

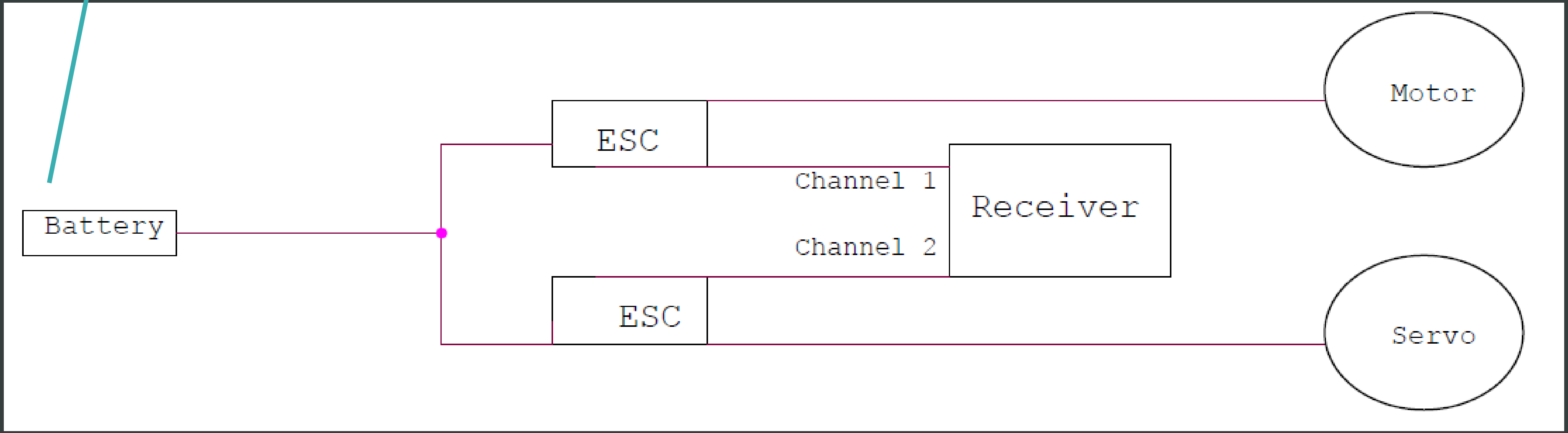
- **What am I supposed to Control?**

1. Lift
2. Speed
3. Direction

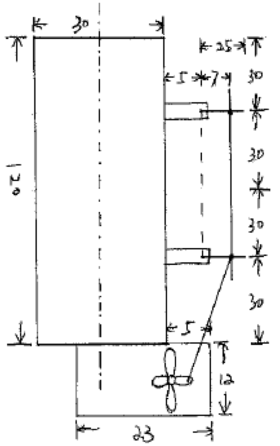


- **How Will I do it?**

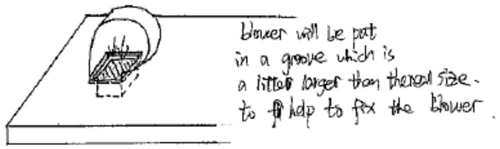
1. Battery connected to the ESC and ESC to Receiver.
2. Each channel of the receiver will be connected to an ESC.
3. ESC will be connected to the motors (fan) or a servo (rudder) that needs to change with user requirement.

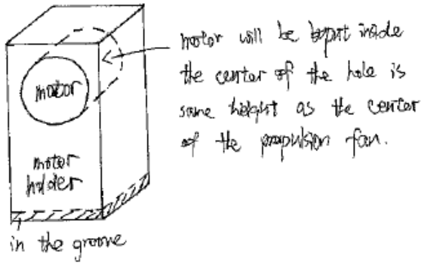


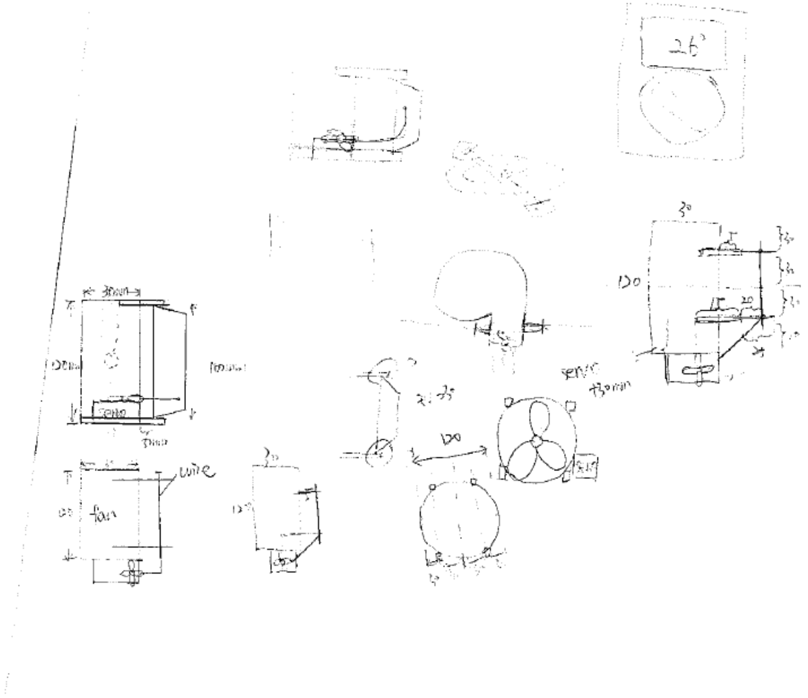
Xiang Zhang – Payload Engineer, sketches

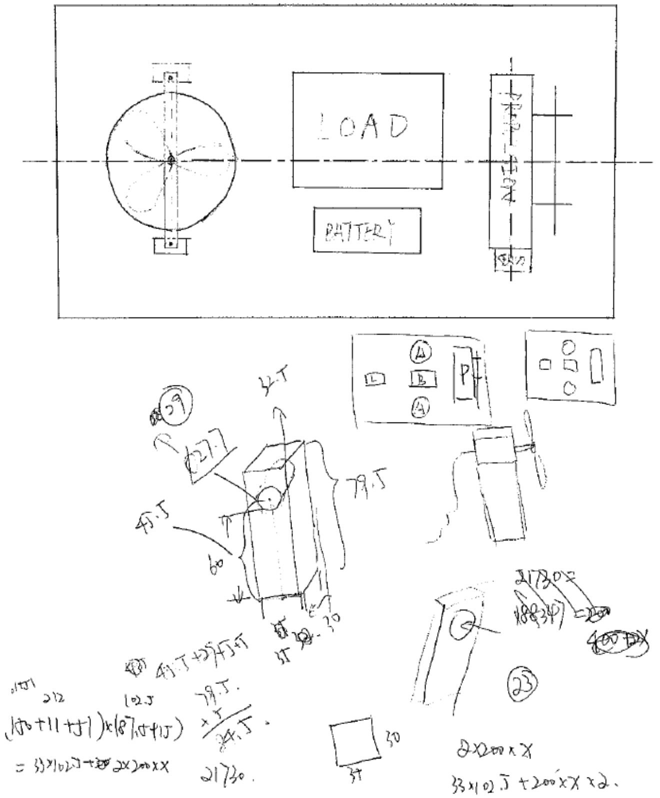


~~Distance~~ Dimensions for the propulsion fan, servo and rudders.





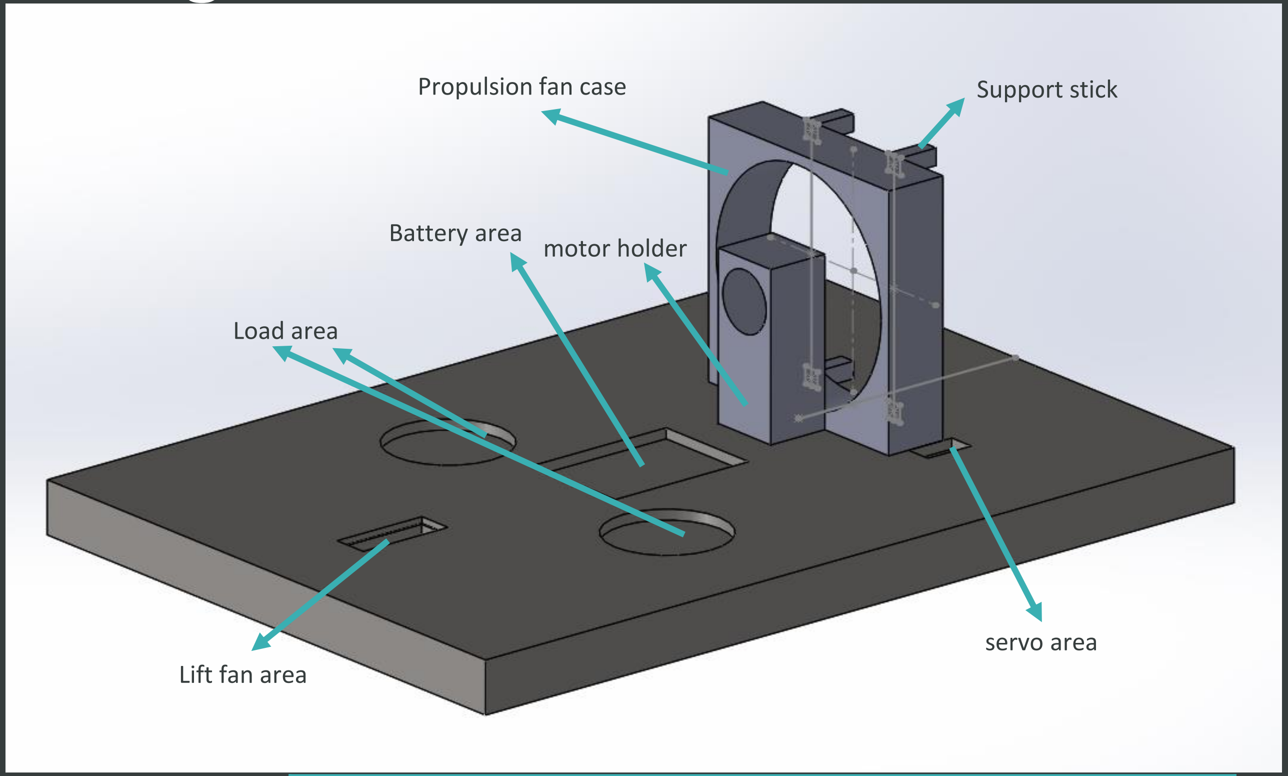




XIANG ZHANG- Payload Engineer

Payload – Final Design

- The load areas are placed symmetrically about the center line of the hovercraft.
- Grooves are provided for the lift fan, load, servo, motor holder and battery to be fixed to them.
- All of the extruded cut should be larger than the actual components to fix them.
- Servo is on one side of the propulsion fan.
- Four support sticks will be placed behind the propulsion fan to fix the rudders.



CALCULATIONS

- All of the apparatus are vertically symmetrical about the centre line except for the servo.
- Horizontally symmetric---left hand side moment=right hand side moment
  (150+11+51)*(87.5+15)=33*102.5+200*x+200*x(x=position of the load)
  X=46mm
- The load area should be placed 46mm away from the centre point to balance the hovercraft.

Name	Length x width x thickness/mm	Weight/g
Payload area	415 x 292 x 25	340(without load)
Battery	74 x 55 x 20	145
Lift	75 x 75 x 15.4	33
Propulsion	100 x 100 x 25	150
servo	23 x 12 x 27	11
Load	57 x 57 x 11.5	200
motor	27.7 x 27.7 x 47	51

Alexandros Iakovos Agrafiotis

CALCULATIONS FOR LIFT PRESSURE

STEP 1

Weight Force in Newtons: $F = m \times g = 2kg \times 9.81\ m/s^2$

$$\mathbf{F \approx 19{,}62\ N}$$

- <u>Force acting under the surface</u>:
  Hole: 45mm x 15mm, Surface: 292mm x 415mm
  So,

$$A \approx (0.292 \times 0.415) - (0.045 \times 0.015)$$

$$\mathbf{A \approx 0.120505 m^2}$$

- <u>Pressure needed in order to lift the hovercraft is</u>:

$$P \approx \frac{F}{A} \approx \frac{19.62}{0.120505} \approx \mathbf{162.81\ Pa} \text{ or } (N/m^2)$$

STEP 2

A centrifugal fan will be used for the lift.

- <u>Dynamic Pressure</u>:
  $Q = \frac{1}{2} \times \rho \times v^2$ where: ρ= Air density (Kg/m^3)
  v= Fluid velocity (m/s)

We know: $\rho = 1.225\ kg/m^3$ & $v \approx 2.29\ m/s$. We know the velocity from the graph provided from the company's data sheet. In order to produce high pressure, the velocity has to be under 2.3 m/s.

$$\text{Therefore, } Q = \tfrac{1}{2} \times 1.225 \times (2.29)^2$$

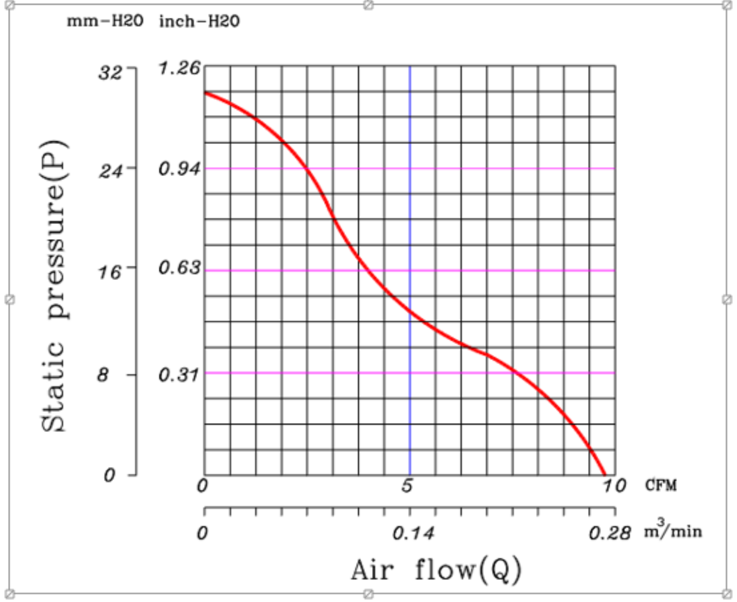
$$\mathbf{Q = 3.21\ Pa}$$

- <u>Total Pressure produced from the centrifugal fan</u>:

$$P_t = P_D + P_S$$

$$\mathbf{P_t = 176.94\ Pa \text{ at } 2.29\ m/s \text{ air flow.}}$$

P_S= Static Pressure (at 2.29m/s) = 173.73 Pa



End of document

Fans-Materials & Total Cost

- **Axial Fan, Centrifugal Fan & Material Selection**

- Basic material is going to be the Craft foam Blue because it is thick (25mm) strong enough for not breaking with the load and it is very light. Also, easy to change the shape. Cost is £12/ m^2 .

- A centrifugal fan is going to be used for the lift as it needs low power to produce high pressure.

- An axial fan is going to be used for the thrust of the hovercraft as it produces high air flow and it needs low power in order to work efficiently.

- The total cost of the hovercraft is going to be around £130

Calculations

Pressure needed to lift a hovercraft for A3 size around 2kg is **: P= F/A = 162.81 *Pa***

Where F= m x g =**19.62** & A= size A3 – hole of fan **= 0.120505 m^2**

In order to produce the pressure needed we will need low air flow under 2.29 m/s. That means the total pressure is the Static Pressure and the Dynamic Pressure: $P_t = P_s + P_d$ = 173.73 + 3.21= **176.97 Pa**

Where $P_d = ½ \times \rho \times v^2$ = **3.21 Pa**

We are not able to calculate the air flow and thrust from the Axial Fan as it is going to be with custom blades and a motor that produces 7800 rpm.

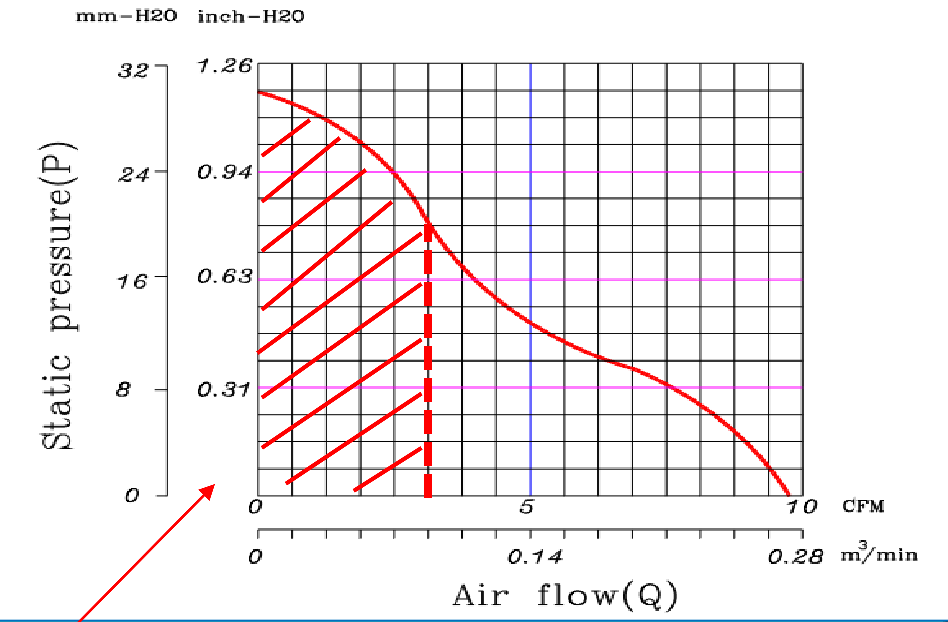
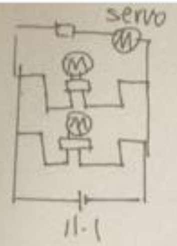
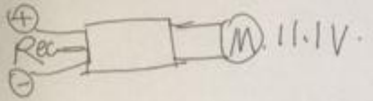


Diagram 1- Static Pressure versus Air flow

Centrifugal Fan (Lift) Specifications		
Rated Voltage	12V	7V Min.
Rated Current	0.46 Amp	0.55 Amp Max.
Rated Power	5.52 W	At 12V
Speed	4500RPM	±10%
Dimensions	L × W × H (mm)	75 × 75 × 15.4
Weight	55 grams	-

Notes





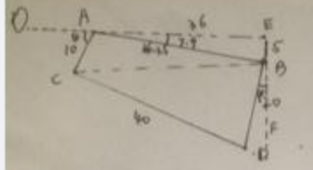
choose the motor close to 11.1V so make it 12V.

6-7.4 servo may be ~~turn~~ burnt by 12V battery so we put a resistor.

$I_r = I_s \quad V_r \approx V_s \quad \therefore P_r \approx P_s$.

Choose the servo that only turns 180° so that it ~~cam~~ can save some money.

KEQI SHU



$AB = \sqrt{AE^2 + EB^2}$

$= 36.35$

~~∠AEB=~~

$\angle AEB = \tan^{-1}\left(\frac{EB}{AE}\right)$

$= 7.9°$

set $\angle OAC = \theta$

$\angle CAB = 180 - \angle AEB - \angle\theta$

$= 172.1° - \theta$

$\cos\angle CAB = \frac{CA^2 + AB^2 - CB^2}{2 \times AC \times AB}$

$CB = \sqrt{1421.32 - \cos\angle CAB}$

$\cos\angle CBD = \frac{BD^2 + CB^2 - CD^2}{2 \times BD \times CB}$

$= \frac{20^2 + CB^2 - 40^2}{2 \times 20 \times CB}$

$\angle OBD = \cos^{-1}\angle CBD$

$\frac{AC}{\sin\angle ABC} = \frac{CB}{\sin\angle CAB}$

$\angle ABC = \sin^{-1}\left(\frac{AC}{CB}\sin\angle CAB\right)$

$\because \angle AEB = 90°$

$\angle ABE = 90 - 7.9$

$= 82.1°$

$\therefore \angle\varphi = \angle DBE - 180°$

$= \angle CBD + \angle CBA + \angle ABE - 180°$

$=$

put the numbers to excel and change the numbers of the length of the links and I found out that BD decided the ~~distance~~ turning divitions, if the ∠BD goes too high, There will be too much turns to the left and too ~~m~~ less turns on the right.

As the turning rudder will ~~only~~ make the craft turn to different direction, so make the rudder to turn on one side greatly will be more effecient.

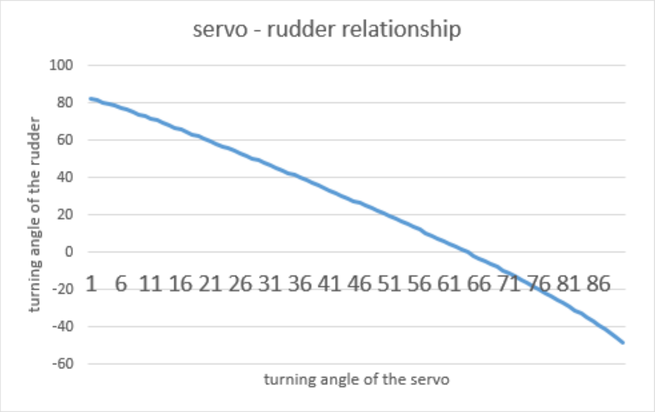
Set up the limited situation.

to firstly make sure the rudder will turn to at least 80° on one side.

DF = 3 (4 - 1) - 2·4 = 1.

Calculations

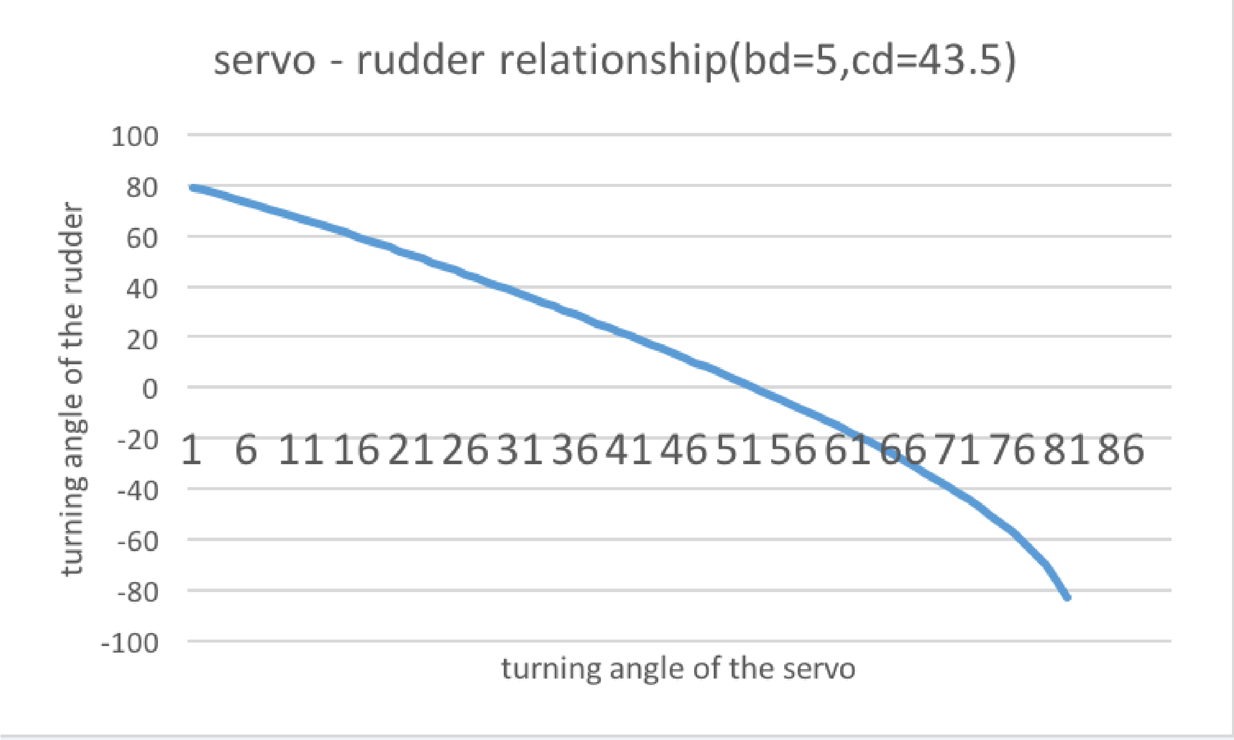
	D	E	F	G	H	I	J	K
1	sinA	A	cosB	B	f degre	ac	bd	cd
2	0.03421611	0.03422278	0.97110364	0.24098387	82.1318204	12	7	41.5
3	0.03852726	0.03853679	0.96827087	0.2525801	81.2202309	12	7	41.5
4	0.04283322	0.04284633	0.9651012	0.2649668	80.2636068	12	7	41.5
5	0.04713341	0.04715088	0.96159458	0.27804242	79.267796	12	7	41.5
6	0.05142725	0.05144994	0.95775101	0.29171866	78.2378874	12	7	41.5
7	0.05571414	0.055743	0.95357043	0.30591949	77.1782654	12	7	41.5
8	0.05999349	0.06002954	0.94905283	0.32057995	76.0926826	12	7	41.5
9	0.06426473	0.06430905	0.94419815	0.33564471	74.9843376	12	7	41.5
10	0.06852725	0.068581	0.93900637	0.35106682	73.8559511	12	7	41.5
11	0.07278046	0.07284487	0.93347743	0.36680644	72.7098357	12	7	41.5
12	0.07702378	0.07710014	0.9276113	0.38282978	71.5479568	12	7	41.5
13	0.0812566	0.08134628	0.92140791	0.39910819	70.3719864	12	7	41.5
14	0.08547833	0.08558276	0.91486723	0.41561736	69.1833484	12	7	41.5
15	0.08968836	0.08980904	0.9079892	0.43233662	67.983257	12	7	41.5
16	0.09388611	0.09402459	0.90077375	0.44924843	66.7727488	12	7	41.5
17	0.09807096	0.09822885	0.89322084	0.46633787	65.5527099	12	7	41.5
18	0.1022423	0.10242128	0.88533038	0.48359224	64.3238987	12	7	41.5
19	0.10639954	0.10660133	0.87710233	0.50100077	63.0869641	12	7	41.5
20	0.11054206	0.11076843	0.8685366	0.51855432	61.842462	12	7	41.5
21	0.11466924	0.11492204	0.85963313	0.53624515	60.590868	12	7	41.5
22	0.11878048	0.11906158	0.85039185	0.55406674	59.3325885	12	7	41.5
23	0.12287515	0.12318647	0.84081266	0.5720136	58.06797	12	7	41.5
24	0.12695263	0.12729614	0.83089551	0.59008119	56.7973068	12	7	41.5
25	0.13101229	0.13139	0.82064029	0.60826573	55.520848	12	7	41.5
26	0.13505351	0.13546747	0.81004693	0.62656418	54.2388024	12	7	41.5
27	0.13907566	0.13952794	0.79911533	0.64497411	52.9513436	12	7	41.5
28	0.1430781	0.14357082	0.78784542	0.66349362	51.6586137	12	7	41.5
29	0.14706019	0.14759549	0.77623708	0.68212135	50.3607272	12	7	41.5
30	0.15102128	0.15160133	0.76429023	0.70085635	49.057773	12	7	41.5
31	0.15496074	0.15558772	0.75200477	0.71969809	47.7498177	12	7	41.5
32	0.15887791	0.15955402	0.7393806	0.73864639	46.4369071	12	7	41.5
33	0.16277213	0.1634996	0.72641762	0.75770144	45.119068	12	7	41.5
34	0.16664274	0.16742381	0.71311572	0.77686372	43.79631	12	7	41.5
35	0.17048908	0.17132599	0.6994748	0.79613399	42.4686263	12	7	41.5
36	0.17431047	0.17520547	0.68549476	0.81551331	41.1359952	12	7	41.5
37	0.17810624	0.17906159	0.67117548	0.83500298	39.7983803	12	7	41.5

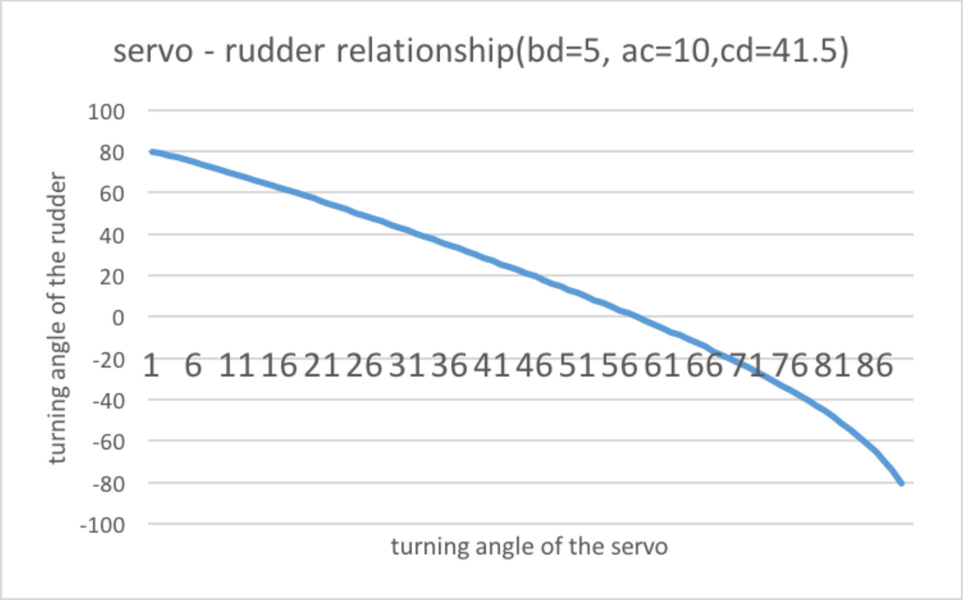


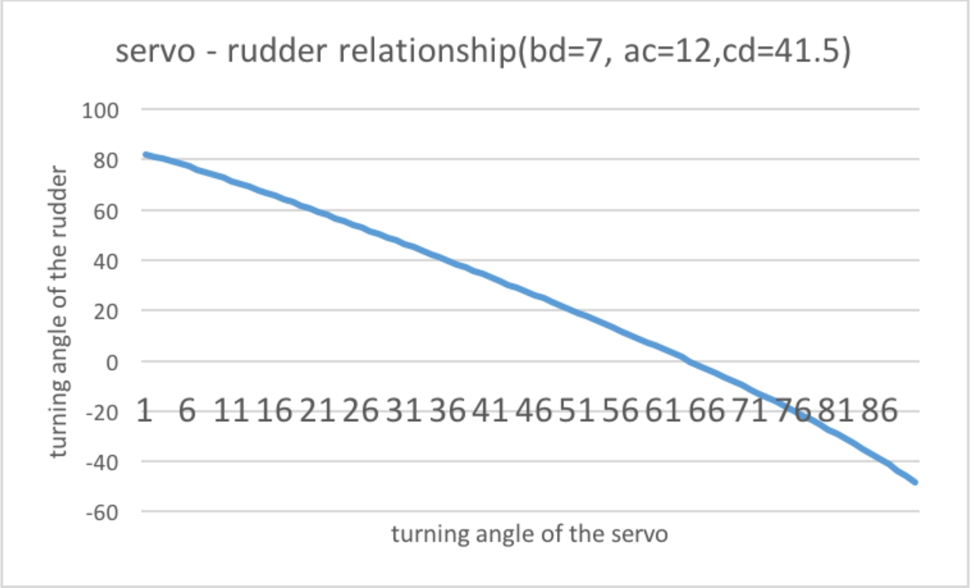
工作表1

Keqi Shu- Powertrain Engineer

Graphs





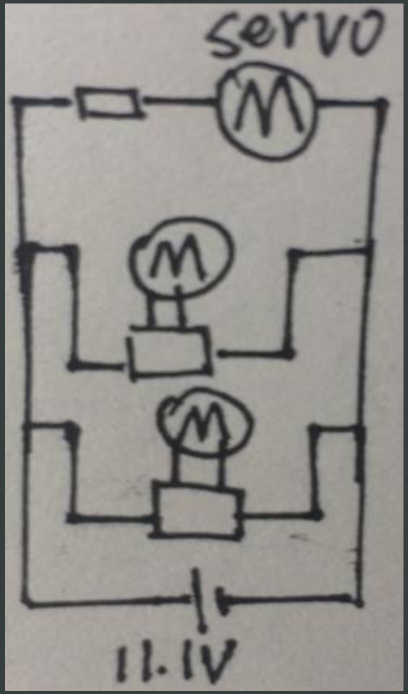


Keqi Shu- Powertrain Engineer

Powertrain – Final Design （as simple as possible）

Motor & Circuit

- Study the battery & motor controller
- Evaluate the torque and the turning speed under load condition.
- Parallel circuit.
- Power the servo by series connect a resistor.(balance the voltage)
- Set up the safety ratio to 1.2.



	Servo	resistor	Lift	thrust	Needed (*1.2)	provid
Voltage(V)	6- 7.4	3.7-5.1	12	6-15		11.1
Energy (Wh)	0.84	0.9	5.52	8.54	18.96	28.8
Weight (g)	11	1	55	58.8	125.8	
torque	20Ncm			58.8gcm		
Price(£)	5.45	1	10.6	4.39	21.44	

Transmission Structure

- Decided to use Linkage mechanism.
- Use the most severe conditions to decided the length of links.
- Use excel to have the turning angle relationship.
- Change the links length and find the best solution.
- Errors of servo in turning angle(strict to 100)
- Turning angle difference in two sides

Calculations & Proves

P=IV, current and voltage of servo and resistor are nearly the same .

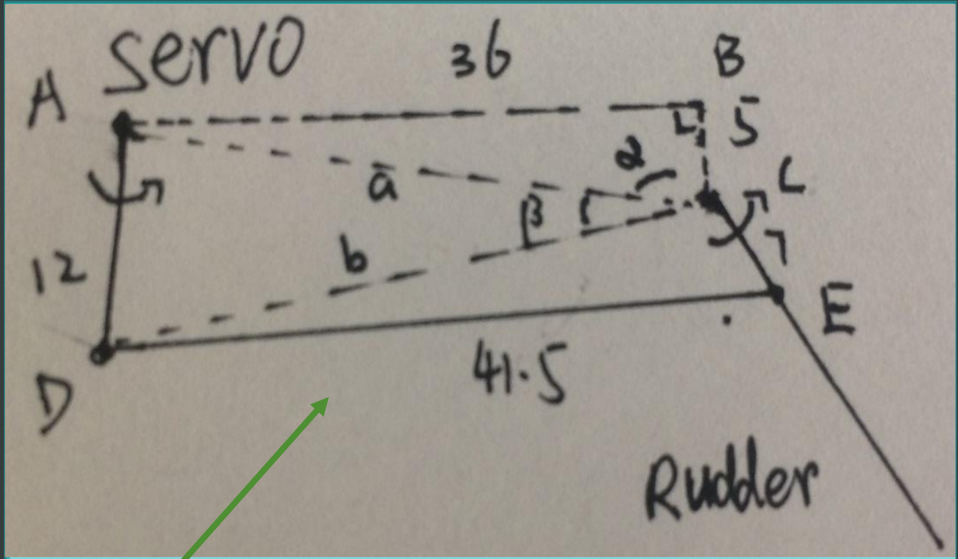
DF =3(n -1)-2n' =1

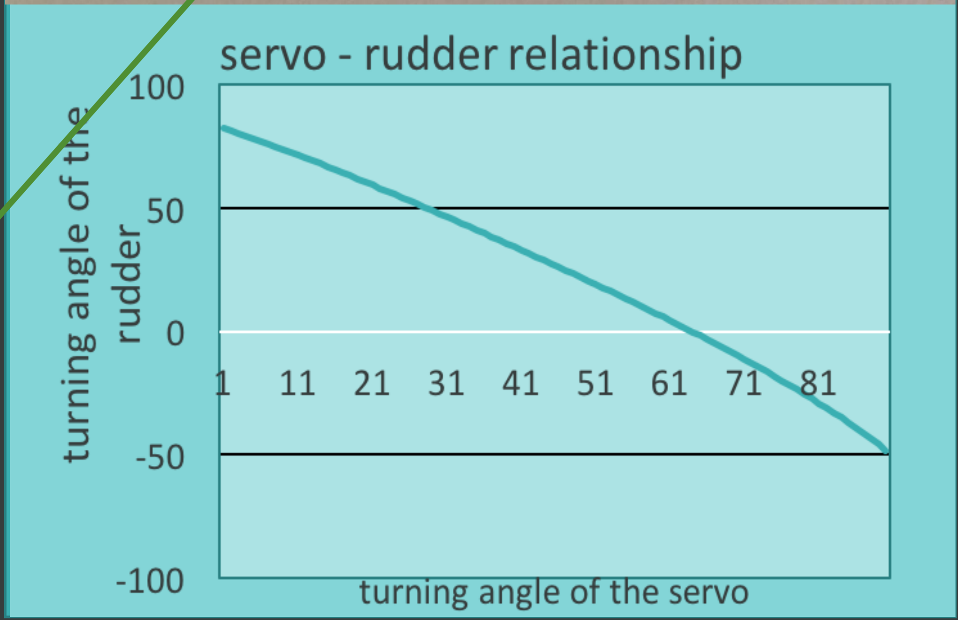
The Law of Cosines

$a^2=b^2+c^2-2bc\cos A$ etc

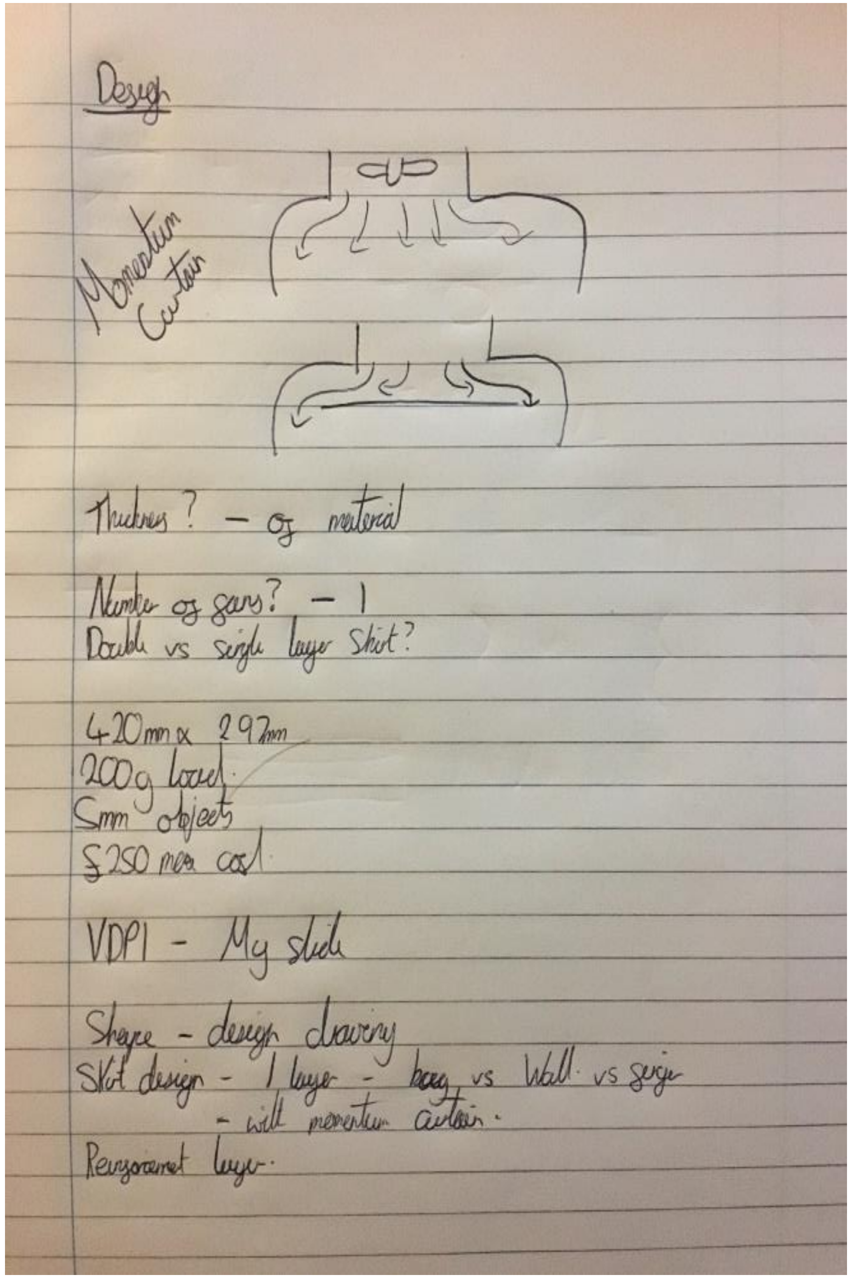
The Law of Sines

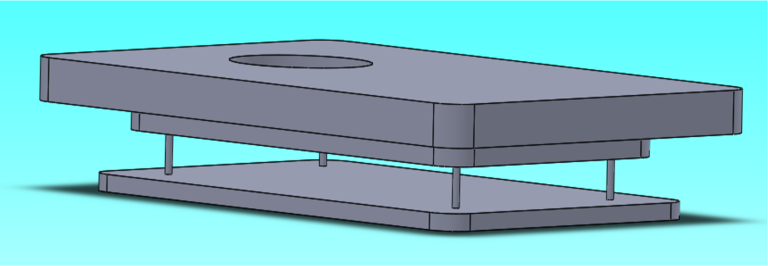
$\sin A / a = \sin B / b = \sin C/c$

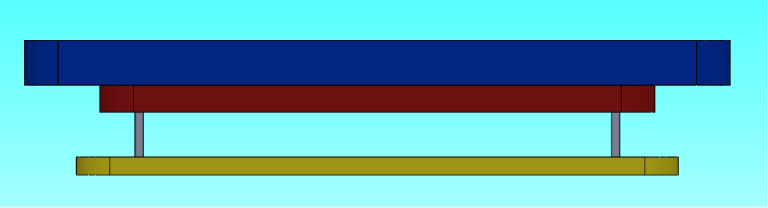


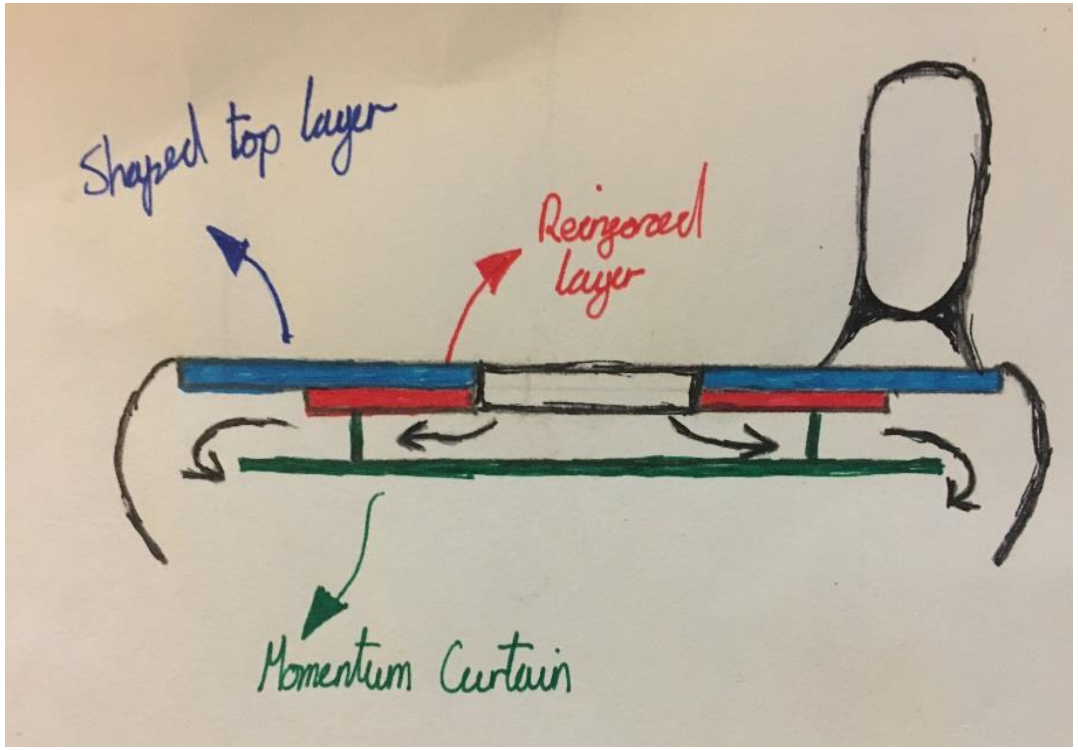


Bradley Blocksidge- Chassis Engineer









Bradley Blocksidge – Chassis Engineer

Body and Skirt – Final Design

Body

Shape

The shaped body will be roughly 418 x 295mm in size, allowing for the thickness of the skirt.
It will be a rounded rectangle shape.

Reinforcement layer

This layer will attached to the bottom of the hovercraft providing support to the structure.

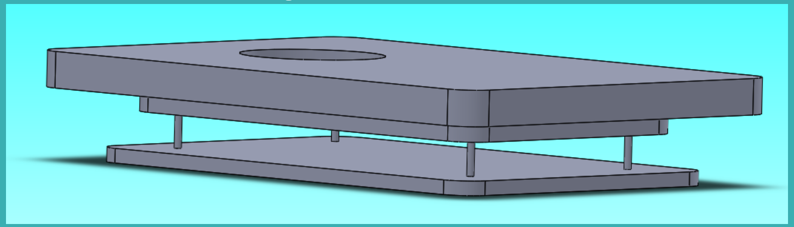
Momentum Curtain

This final layer increases the velocity of the air under the hovercraft therefore increasing the pressure giving it more lift.

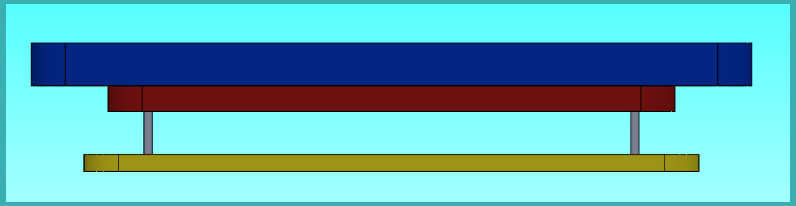
Skirt

A bag skirt design will be used.
+Less material- Lighter, cheaper.
+Simple design-Less time consuming.

Completed Chassis



Chassis Layers



Shaped Top Layer
Reinforcement Layer
Momentum Curtain