Sapphire Voyager

MakerBay Concept Electric Vehicle Lab

Date and version: 2016/09/10 Version 0.2.

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This document URL: https://goo.gl/EIYTYV

Table of contents

Introduction

Introduction

“The best way to predict the future is to create it.” *Peter Drucker*

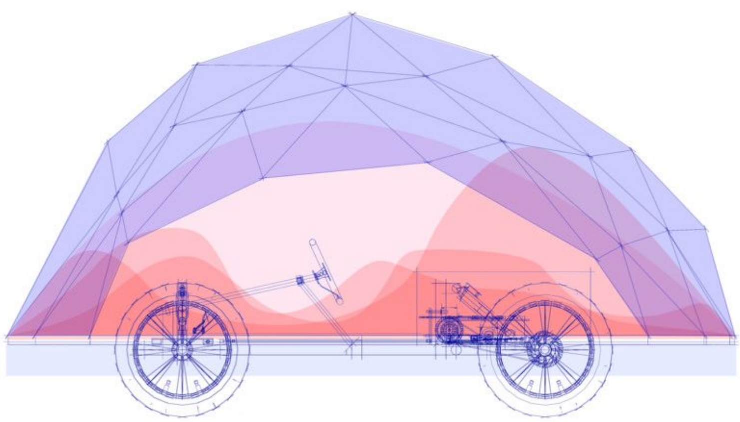
What would mobility be like in the future? How will you get from point A to point B? What would be the experience of driving? At MakerBay Electric Vehicle Lab we started with a small set of assumptions of what that future of mobility would be like in our concept vehicle.

1. Our vehicle is Electric, battery powered.
2. Our vehicle is Self-driving. It has sensors, computer vision, Artificial Intelligence.
3. Our vehicle will make the 2 assumptions above obvious in its design. It will provide an entire new experience of mobility, one that appeals to the senses, manifesting a strong aesthetic experience. It will be a concept vehicle as much as it would be a modular and immersive artwork. It would be what science fiction is to science, to extent what we assume is possible towards a vision of what could be done.

Videos

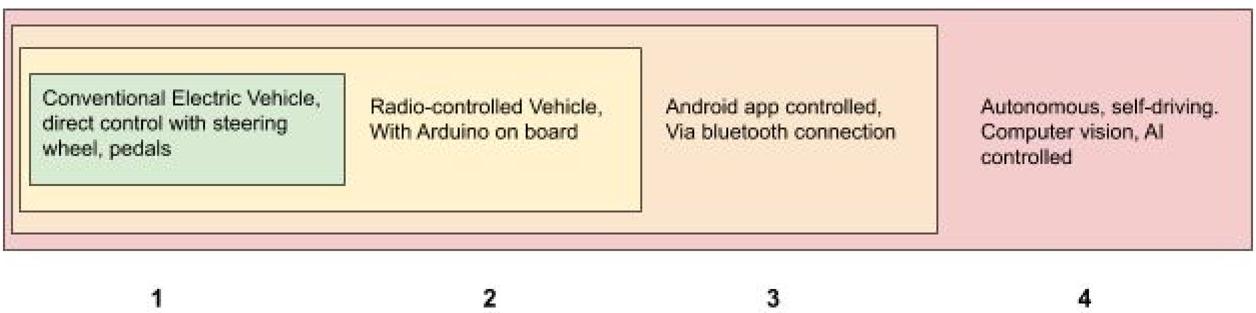
- Promotional Video: https://youtu.be/xKIA9x2i1H0
- Making of: https://youtu.be/mrqmr40GIfl
- 360 VR 4K: https://youtu.be/5YR5PTfIfhs

Goals, Stages of development



We aimed for the design to be futuristic, aesthetic, and original, both in the exterior as in the interior.
Assumptions:
- self-driving vehicle
- modular interior
- bright, soft interior
- protective, hard exterior

In terms of functionality, we worked in stages. Some



Inspirations

Formula E

http://www.hkformulae.com/

MakerBay

http://www.Makerbay.org

OSVehicle

https://www.osvehicle.com

Mentors

- Tom Chi, Former Google X, Self Driving Car Team
- Lucille Wilson Whitaker, Artist
- Tin Hang Li, Open Source Vehicle
- Roberto, Open Source Vehicle

Partners, Supporters & Thank you

- UBS: https://www.ubs.com/hk/en.html
- OSVehicle: http://oSVehicle.com
- Hong Long Science and Technology Park: https://www.hkstp.org/
- Robotics Garage: http://www.robotics-garage.com/
- Arrow, Electronic Components: https://www.arrow.com
- HILTI: https://www.hilti.com
- MakerBot: http://www.makerbot.com/
- QFE, Batteries: http://www.qfengineering.com
- OwnAcademy.com: http://ownacademy.co
- Le Comptoir de l'Innovation: http://www.lecomptoirdelinnovation.com/

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Hardware

Open Hardware, CERN
Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. Ideally, open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.
http://www.ohwr.org/attachments/2388/cern_ohl_v_1_2.txt

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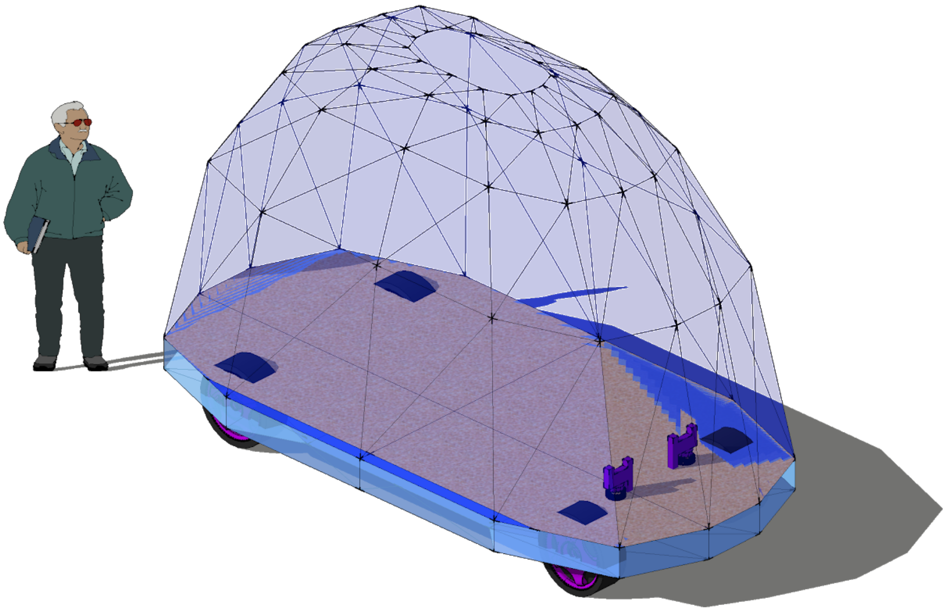
General Specs

General Specifications [James, Benny]

Item	Value	Remarks
Dimension	3873 x 1900 x 2690mm	Body is removable
Clearance	Clearance 14cm to battery rack	With no load
Weight	Estimated 550kg	Including batteries
Number of passengers	Chassis rated for 6 passengers	Tested 13 static passengers
Top Speed	20 km / hour	
Maximum range	~100km ~3hrs	By calculation
Battery Type	Li-ion battery	Supported by QFE
Motor	~3KW, ~4HP	Brushed DC Motor

Design

Design [Cesar, Joy, David, Nicole, Maria, Mason]



Concept

Why do we want to do it this way
Outer Shell: Sharp edges, mineral look

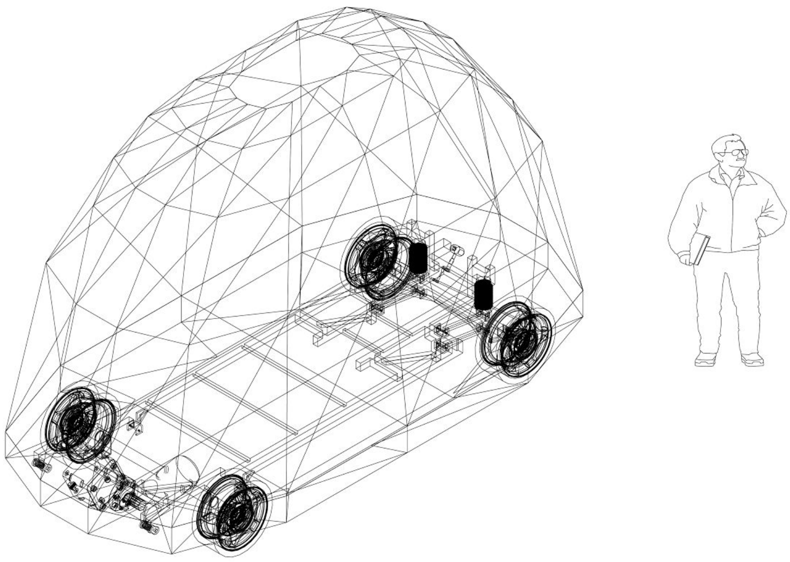
Photographs

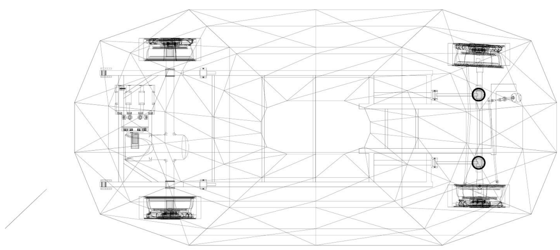
External Photograph

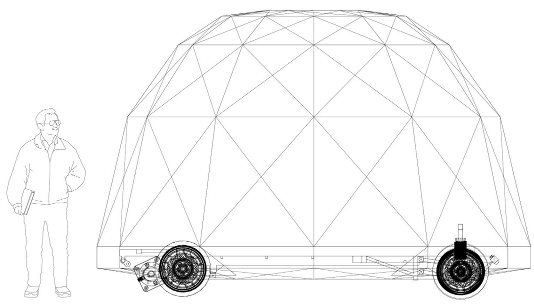
Internal Photographs

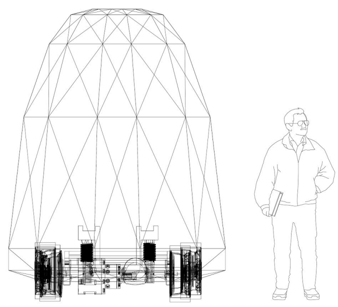
Technical Drawings

External design





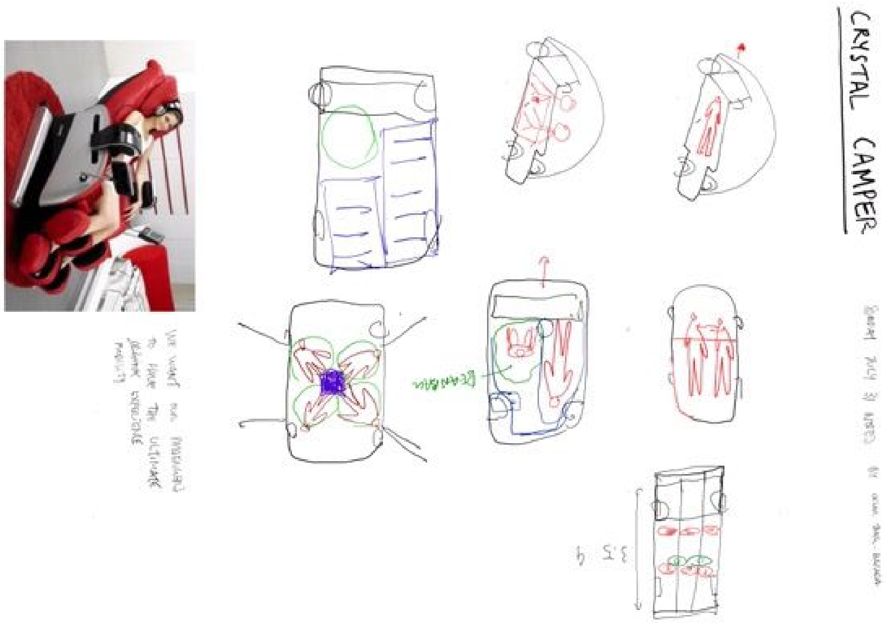


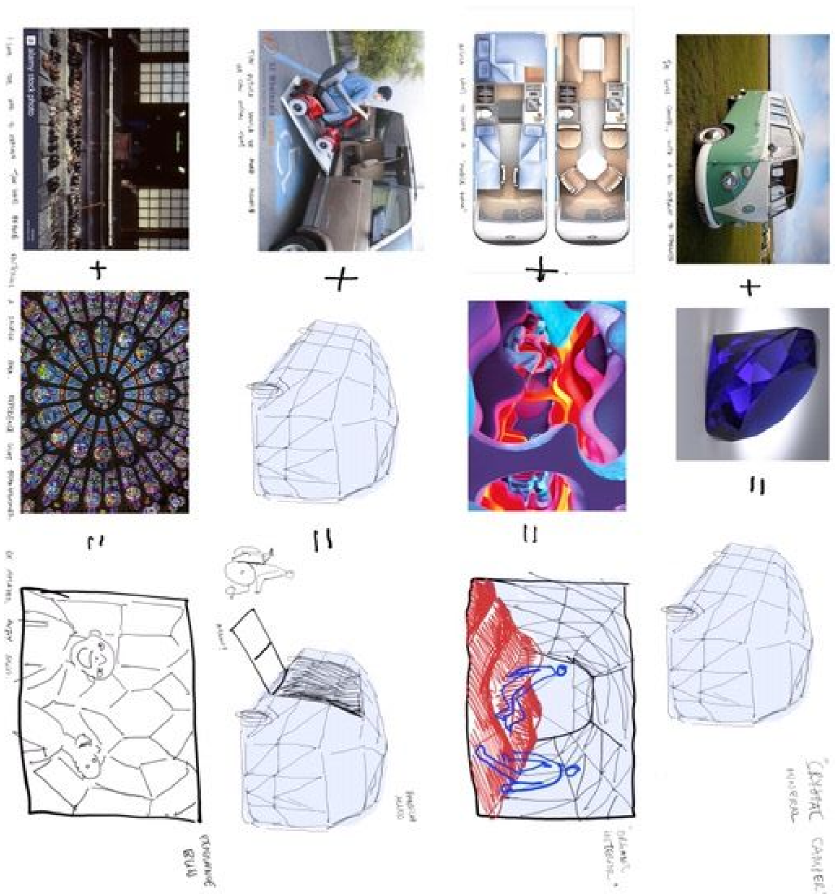


https://sites.google.com/a/makerbay.org/wiki/projects/electric-vehicle-lab/design

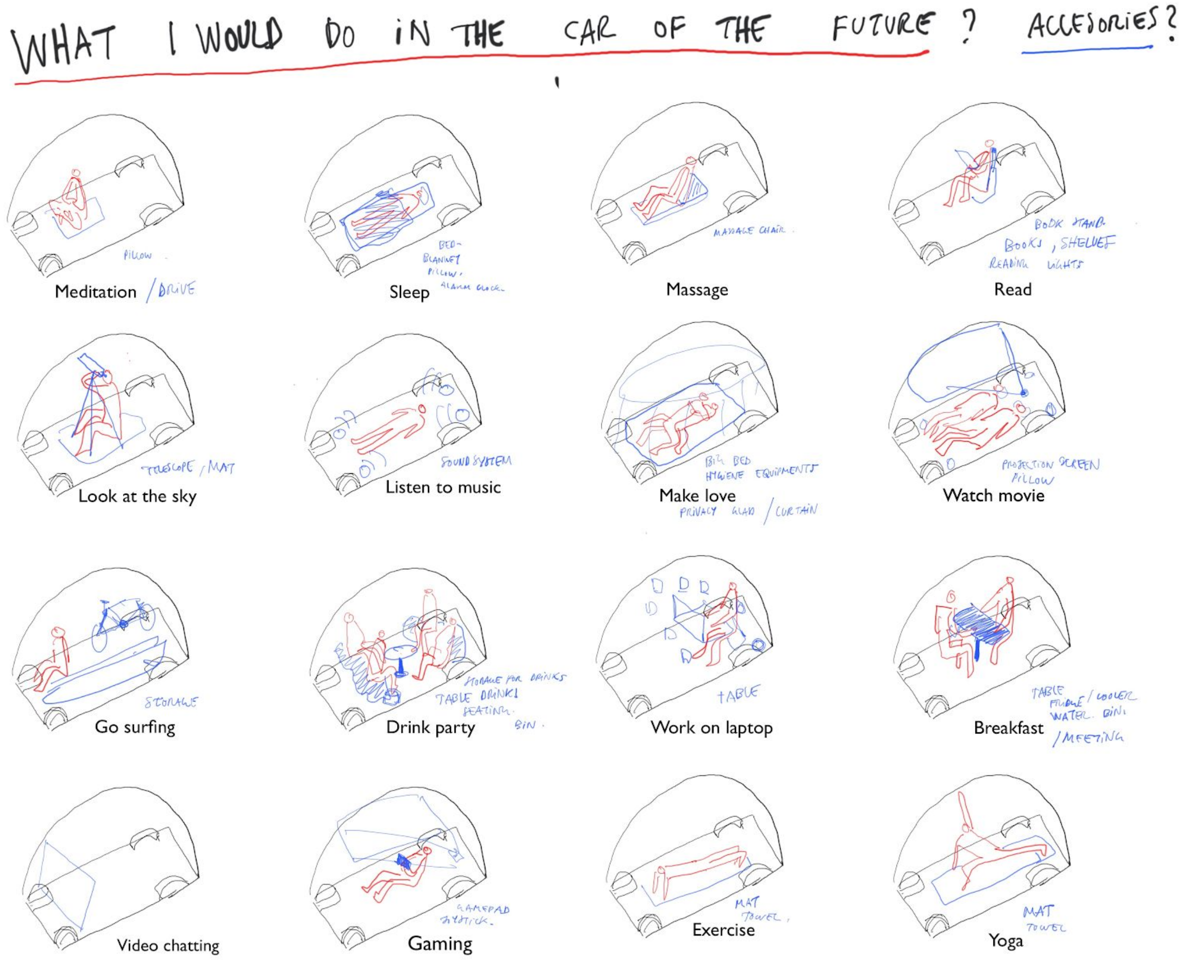
Internal Design

Inspiration





Scenarios of usage



Materials

Method of fabrication

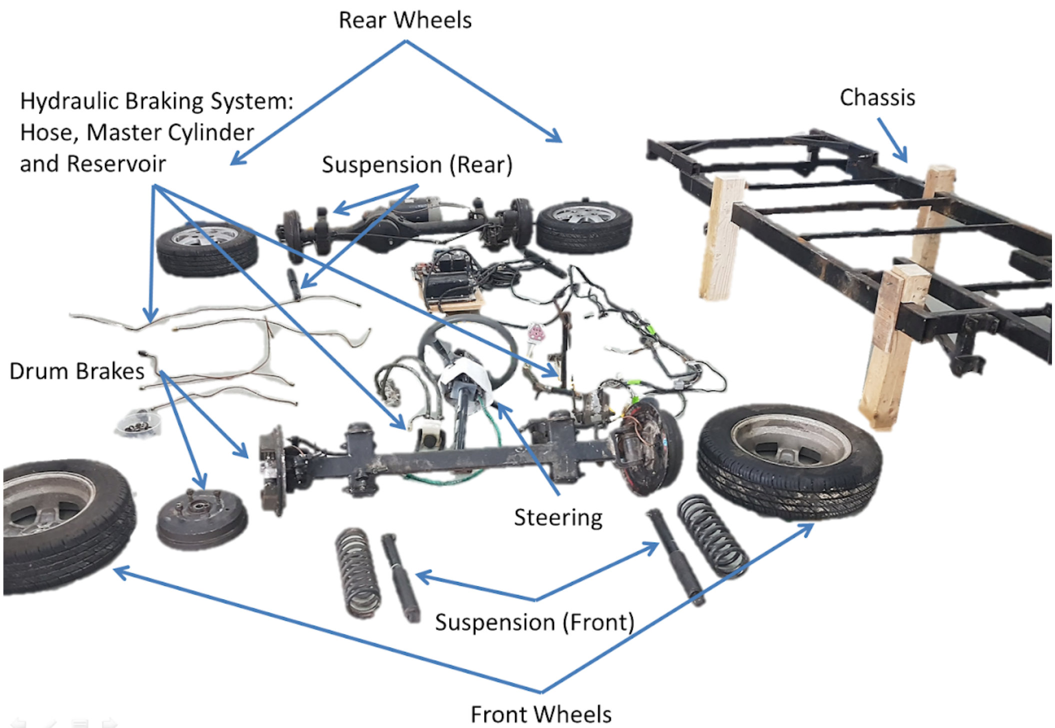
Quantities of materials

How to hack the design of this vehicle?

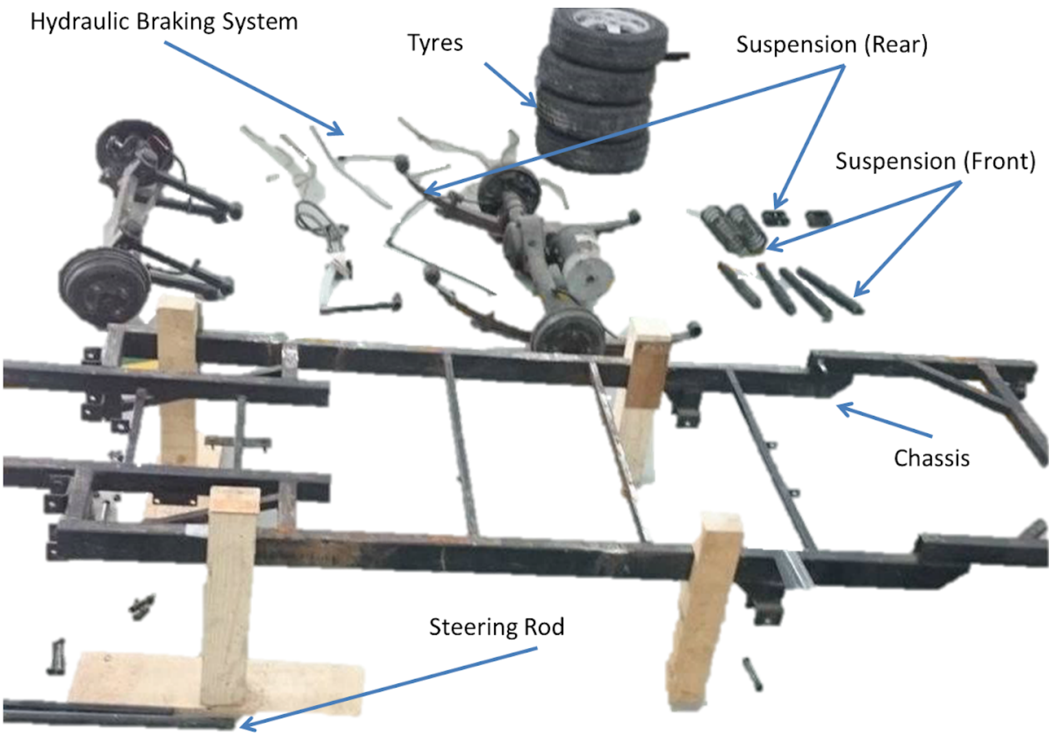
Design files, link to download original files

Mechanics

Mechanics



Layout of different parts and systems.



Another view of different components and systems.

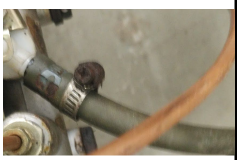
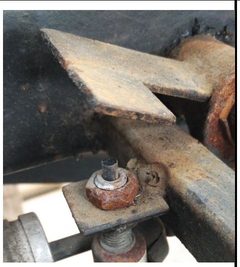
Overview of the EV

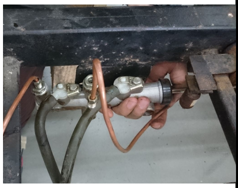
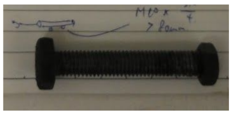
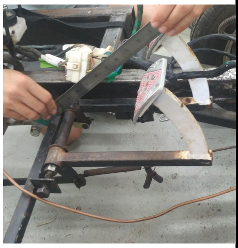
We started with a second-hand golf cart for 6 passengers without technical documentation. We removed all the unnecessary parts. What is see above is the bare chassis, without the batteries. By reverse-engineering, we drew a CAD drawing which is shown above.
When the golf cart was received and reduced to bare chassis, it had the following systems:

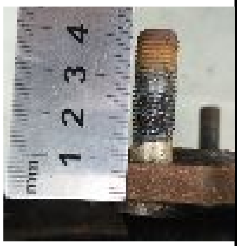
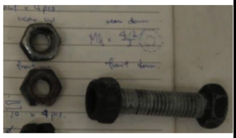
- ***Suspension System***
  Suspension struts comprising of coil springs, shock absorbers at the front; and arc strut bars and shock absorbers at the back.
- ***Braking System***
  Hydraulic braking comprising of a master cylinder, copper tubes that make use of fluid to push out the brake shoes; and a handbrake connected to parking brake cables.
- ***Steering System***
  Steering wheel connected to steering rod, gearbox and steering knuckle. Two anti-sway bar were also present.
- ***Driving Mechanism***
  A 48V geared DC brushed motor connected to differential driving shaft driving the two rear wheels.

After modification to the chassis, we replaced the steering wheel and acceleration pedal with digitally controlled stepper motor. A digitally controlled stepper motor is also attached to the braking pedal using pulley. The chassis was extended both on the side and at the end.

List of Mechanical Parts

System	Photo	Item Name	Diameter/size	Width	Length	Height	Qt	Notes
Hydraulic braking		Copper hose	5.5mm outer diameter 1.24mm thick		630mm		2	Front left & right
					1130mm		1	Front
					2030mm		1	Rear
					360mm		2	Drum brake
					320mm		2	Drum brake
		Screw joint	10.0mm screw		12.0mm		20	
		Hose connector	14.72mm thick	27.24mm	35.8mm			
			9.32mm inner					
			10.48mm outer					
		Spring	12.3mm diameter		130mm		2	
		Hose Clamp	8mm				4	
		Nut for stopping light switch	M10*1.25				2	
		Rubber tube with spring	13.42mm outer diameter, 10mm inner diameter		360mm		2	

			M16*1.5 nuts				4	
		Master Cylinder	28mm		180mm	55mm	1	
		Bolts and nuts	M10*1.5		80mm			
		Pedal		19mm	200mm	330mm	1	
		Bolts and nuts for pedal	M8*1.25		45mm		2	
		Pivot rod	20mm		205mm		1	
	 	Pivot pin	8.62mm		20mm		2	With 2.7mm diameter cotter pins, 17.44mm away from top, washer and spring washer
Drum Brakes & Tyres		Bolts & nuts	M12*1.75 nuts				16	
			M12*1.75		15mm smooth, 30mm screw		16	
		Nut for bearing	M16*1.25				4	Castellated nuts with cotter pins
		Washer for bearing	35.4mm outer diameter, 15.4mm inner diameter				4	

								
		Tyre	490mm	140mm			4	
Suspension	 	Bolts & nuts for arc suspension	M12*1.75				10	4+4 for front wheels; 2 for rear wheel front support
		Nuts for rear wheel rear support	M10*1.5				2	
		Connector for rear suspension		9mm	110mm	40mm	4	
		Rubber ring	37.26mm;13.1 mm; 30mm		31.36mm		4	
		Front suspension rods		30mm	390mm	30mm	4	
		Shock absorbers						
		Nuts for shock absorbers	M10*1.5				6	
			M8*1.5				2	For lower rear cylinders

		Arc-attached shaft with motor		50mm	940mm	50mm	2	
		Coil springs	11mm			270mm	2	Static without loading
		Nuts for suspension-wheel connection	M14*1.5					Castellated nuts with cotter pins
Steering		Steering Wheel	diameter 360mm		580mm	360mm	1	
		Connector to steering mechanism	M14*1.5					
		Steering rods	25mm		700mm/620mm		2	
	 	Nuts for steering mechanism	M12*1.25				4	Castellated nuts with cotter pins

List of Bolts and Nuts

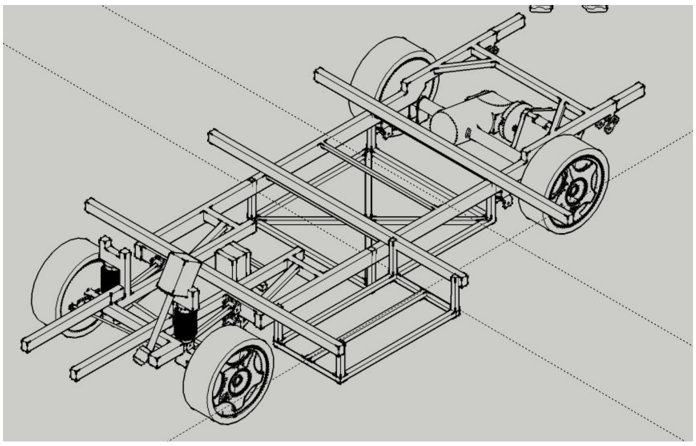
Specification	Quantity	Remarks
M8*1*45mm with nuts	2	Accelerator mounting, with spring ring
M8*1.25 nuts	2	Lower rear suspension cylinder
M10*1.5*80mm with nuts	2	Hydraulic master cylinder mounting

M10*1.25*100mm	4	Footrest
M10*1.25*180mm	6	Mounting of platform
M10*1.25 nuts	26	Upper front suspension cylinder, Upper rear suspension cylinder, Rear suspension arc, Switch for stopping light
M12*1.25*37mm with nuts	16	Wheels
M12*1.25*70mm with nuts	2	pedal pivot shaft, with spring ring and washer
M12*1.5 castellated nuts with cotter pins	4	Nuts for steering
M12*1.5*110mm with nuts	10	Suspension
M12*1.75*56mm with nuts	2	Lower front suspension cylinder
M14*1.5 nuts	2	Shaft
M16*1.25 nuts	8	Rubber tubing fixture
M16*1.5 castellated nuts with cotter pins	4	Bearing of wheels
⌀35mm*19mm thick washer	4	

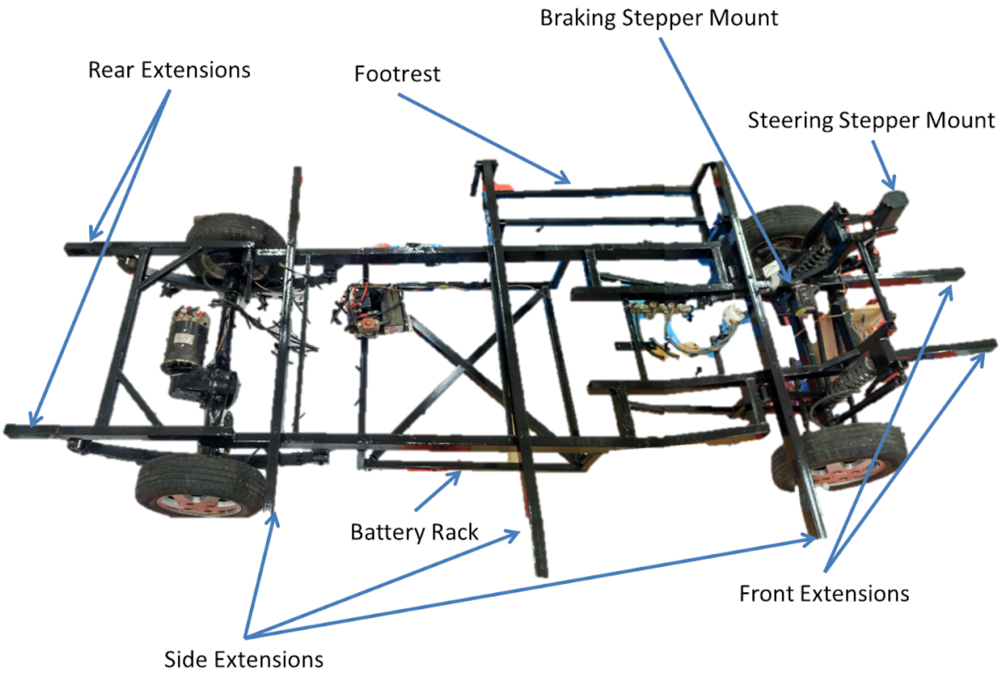
Chassis

Outlook of the original chassis. *CAD drawing of the original chassis.*

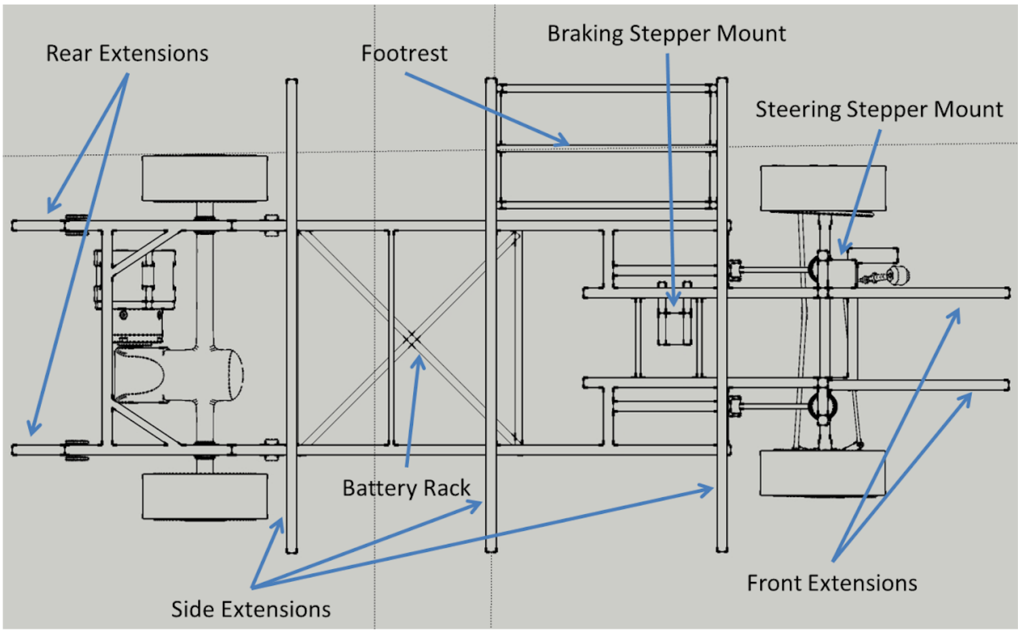
The painted and modified chassis.



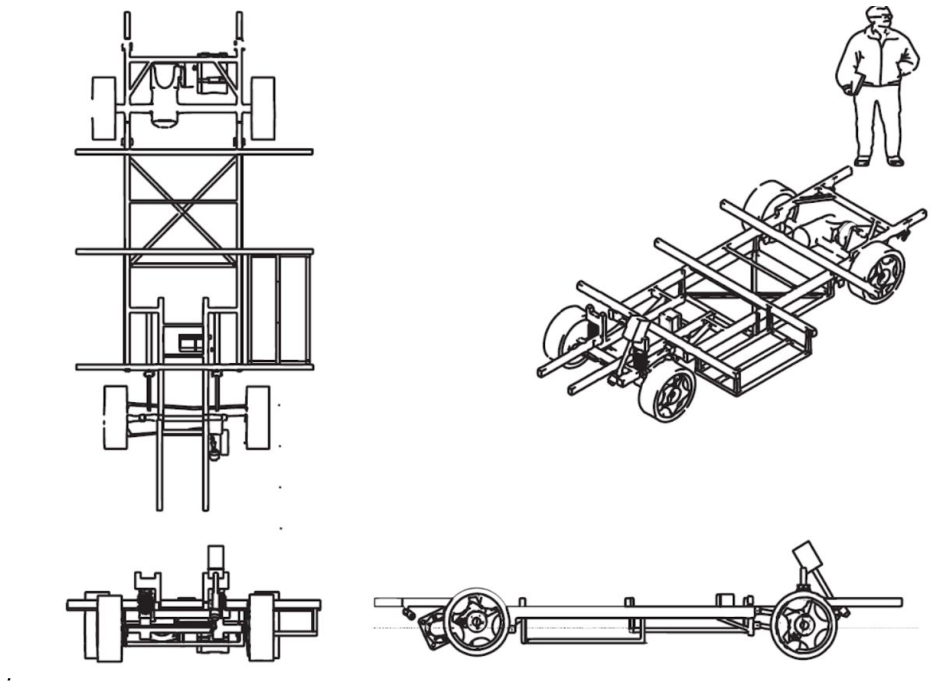
CAD drawing of the modified chassis.



Chassis after modification and painting and all the add-on features.



CAD drawing of the modified chassis and all the add-on features.

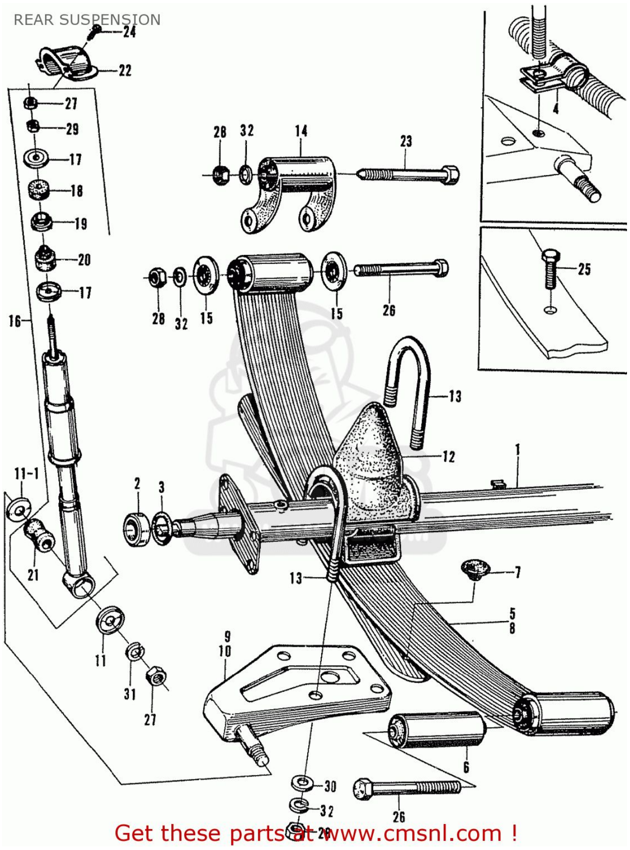


Top view, front view and side view of the CAD drawing.
The CAD model can be found via the following link: https://skfb.ly/SBJo

The chassis is extended by welding 40 x 60mm steel tubes to both the end (210mm long) and the front (725mm long on the left; 650mm long on the right) of the EV, three more 1900mm-long tubes are fastened on top to provide support to the floor and footrest. Thus, the dimension of the chassis is **3873 x 1900 x 534mm**.

Suspension System

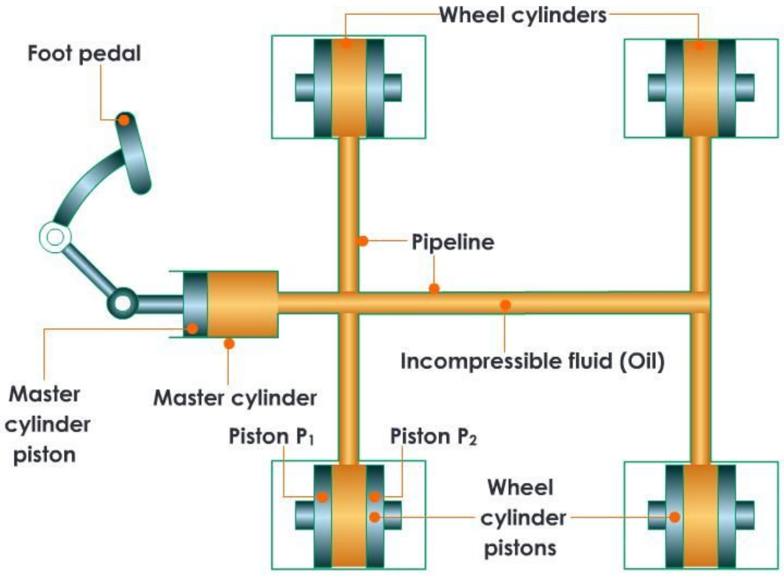
The suspension system of the EV is similar to the one shown below. It consists of 5 layers of arc made of steel and shock absorber.



Rear suspension schematic Honda N360 Coupe Stationwagon obtained from:
http://www.cmsnl.com/honda-n360-coupe-stationwagon_model14497/partslist/B30.html

Braking System

Hydraulic Braking System



Schematic diagram of the hydraulic braking system: http://www.ustudy.in/node/3432

The hydraulic braking system make use of incompressible fluid to push out the pistons of wheel cylinders and thus expanding the drum brakes to brake the EV.

Copper Hose

Photo of copper hose and connectors bought.

The hydraulic system consists of double-flared, 1.24mm-thick copper hose of 5.5mm outer diameter.
We didn't changed the hydraulic system but replaced the old copper hoses.
For the front left and right wheels, two 630mm-long hose are needed.
For the connection from master cylinder to the front, one 1130mm-long hose is needed.

As for the connection to the rear, one 2030mm-long hose is required.
While for the connection on the drum brake, two 320mm long and two 360mm long hose are required.

Things to Note:

1. If the copper purchased are not long enough, connectors can be used to join together shorter hoses.
2. The advantage of getting shorter hose is that they will be sent in straight, while longer hoses usually come in rolls, unwind and straighten them will take extra time and effort.
3. Double flare can be made by using double flare tools, but it would be more convenient to order double flared hose in the first place.
4. Although the copper hoses are soft and can be bent using bare hands, it is recommended to use hose-bending tools so that the bending is smooth and reduces the chance of leakage in the future.

Drum Brake

Photo showing a disassembled drum brake.

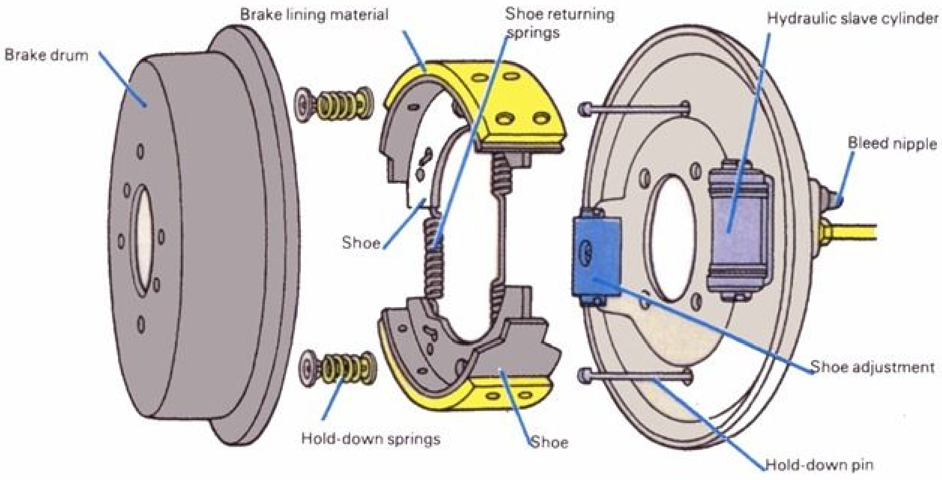


Diagram showing the construction of a drum brake from online source:
http://www.mapeng.net/news/mechanical_English_article/2015/11/mapeng_1511221745292649.html

The drum brakes are working fine, so we just opened it, cleaned it and reassembled it. The schematic illustration of different components are shown above.

Applying the Brake

The are two ways to use actuator to imitate the motion of stepping onto the brake pedal, linear and rotary action.

	Linear (pneumatic actuator)	Rotary (stepper motor)
Advantage	Quick response	Simple design
Disadvantage	Complicated system comprising air pump and extra tubings	May not have sufficient torque during emergency when brake pedal needs to be stepped hard in a short time

The rotary action was chosen because it's simpler and we believe that its disadvantage can be compensated by purchasing a stepper motor with larger torque and using program to increase the degree of turning to achieve quick motion. Another reason is that pedal can be preserved to function as an emergency manual brake.

A pulley was made from soldering two washers to coupler, and the stepper motor is then mounted to the chassis and connected to the bottom of the pedal via the pulley.

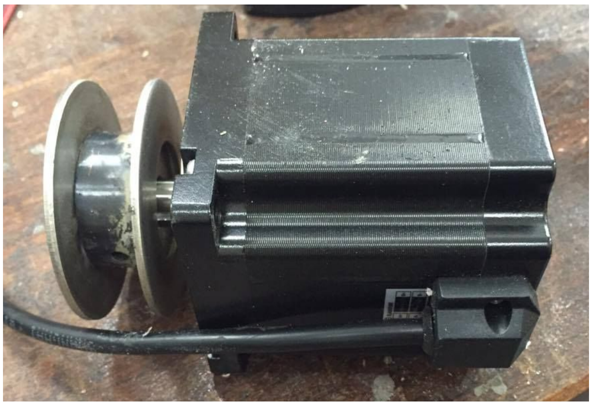
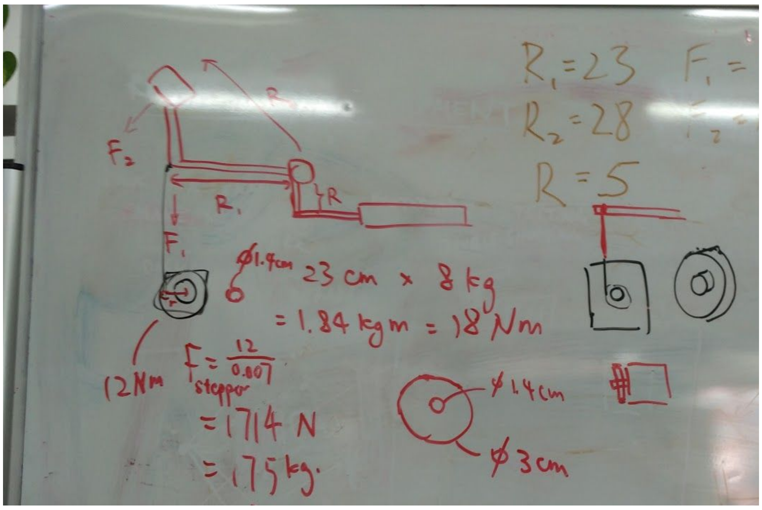


Photo showing the pulley being attached to the shaft of the motor.

The result was promising, the brake is applied within half a second when the signal was sent.

Calculation of Force to Apply the Brake



The required force is measured to be 8kg (78N) by pulling horizontal bar downwards, given the length of the moment arm, which is the bar, is 230mm, the torque required would be 18Nm.

Since the stepper would be pulling from below the pedal at around 45°, the force required is calculated by finding the new moment arm. The new moment arm is 260mm, thus the force required is 7.08kg (69N).

And the radius of the pulley is 44mm, so the torque of the stepper motor needs to be 3.1Nm.

Handbrake

Photo showing the removed handbrake.

Handbrake (aka Parking Brake) was used to prevent the EV from moving when it is at rest. Since we will be controlling the EV digitally, it was removed for aesthetic consideration because it would be an eyesore if there is an extra handle sticking out of the comfortable interior which has a flat platform. Instead, we plan to use an alternative parking solution: triangular-shaped wooden block would stop the EV from moving.

Reference shape of the wooden block:
https://images-na.ssl-images-amazon.com/images/I/51JBjx4WH2L._SY355_.jpg

Steering Mechanism

To control the EV digitally, we need motors to turn the steering wheel.

Choice of Motor

We first have considered whether to use DC motor or stepper motor for actuating the turning. Their advantages and disadvantages are listed below:

	DC Motor	Stepper Motor
Pros	- Free rotation when it is not powered	- Higher torque
Cons	- Lower torque, gearbox is thus required and no more free rotation	- High resistance to turning when it is not powered and thus requires a disengagement mechanism, such as gearbox, belt drive or electric clutch

Digital Versus Manual

We then have to decide whether it will be fully controlled by digital signals or both digitally and manually. The concerns are listed as follows:

	All digital	Both digital and manual
Pros	- Simpler because only stepper motor is needed and no disengagement needed	- Safer because passengers on board can steer manually in emergency
Cons	- Dangerous when electronic signal system fails, redundancy needed	- Complicated because disengagement of stepper is needed

Stepper Motor Specifications

The steering force required was measured to be 4kg times 140mm (radius of the steering wheel) by experiment. The torque required is thus 5.6Nm. A stepper motor with 12Nm torque was bought via the following link:
https://world.taobao.com/item/43817828449.htm?fromSite=main&_u=pvl099tbfc4

Model no.	86BYG250H-150
Driver	DM860H

Torque	12Nm
Load	20kg
Max. speed	1000 rpm
Max. current	7.2A
Optimal power supply	DC48V
Max. subdivision	256

Diagram showing the mechanical dimension of the stepper motor from supplier:
https://world.taobao.com/item/520785743223.htm?fromSite=main&_u=pvl099t051f

The Coupler Joining the Stepper Motor with Steering Rod

The motor is then connected to the steering rod, replacing the steering wheel.
A pair of coupler was used:
https://world.taobao.com/item/520785743223.htm?fromSite=main&_u=pvl099t051f

Photo showing the coupler from the supplier:
https://world.taobao.com/item/520785743223.htm?fromSite=main&_u=pvl099t051f

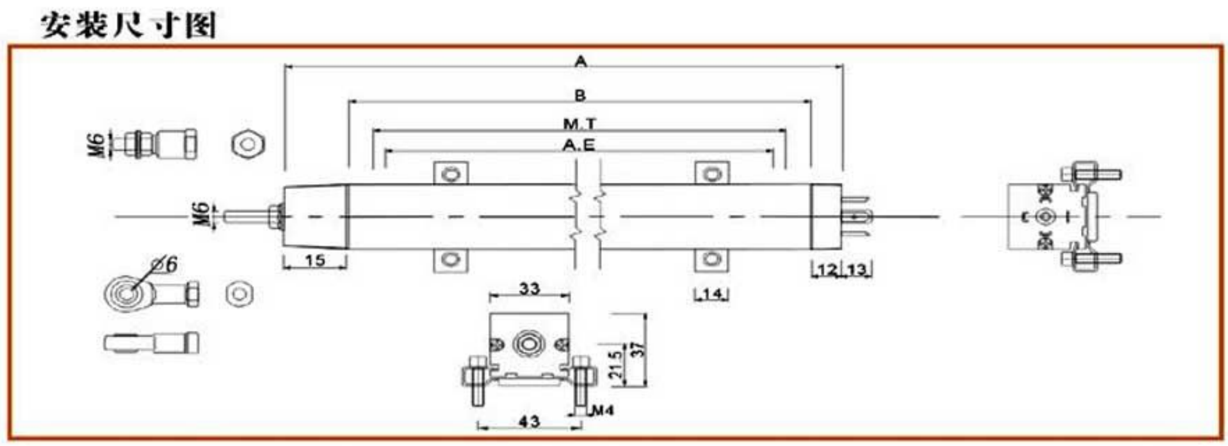
L-type coupler: L075

Outer diameter	44.5mm
Length	51mm
Inner diameter	14mm, 5mm key slot, M5 to 18mm, 5mm key slot, M5
Rated torque	11.9Nm
Max. rpm	3600

Weight	0.48kg

Measurement of How Much the Wheel Turned

Given the motor, we need to know how much the stepper motor turned and thus the degree that the wheel are turned. To do so, we need a linear potentiometer, which we bought via this link:
https://world.taobao.com/item/37267784136.htm?fromSite=main&_u=pvl099t42bc



Supplier technical drawing showing the dimensions:
https://world.taobao.com/item/37267784136.htm?fromSite=main&_u=pvl099t42bc

Voltage	0-24V
:Range	1500mm
Resistance	0-5KΩ (0-550mm); 0-10KΩ (600-1500mm)
Working temperature	-40-110℃
Force required to pull	3-5N
Accuracy	0.02%

From Mechanical Drive to Drive-By-Wire

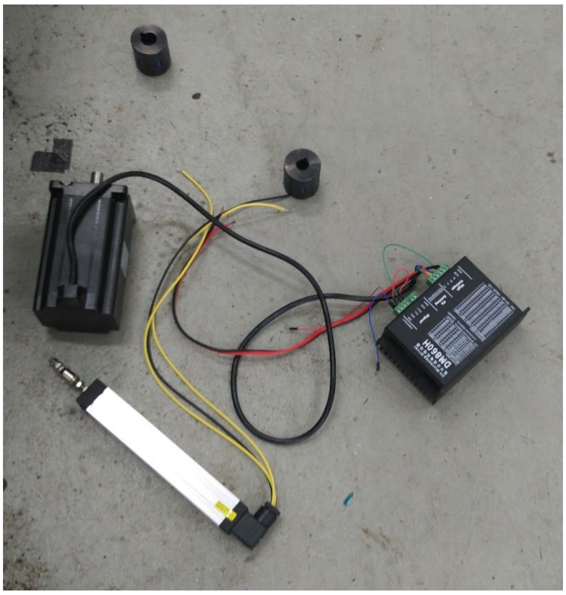


Photo showing the stepper motor, couplers and linear pod.

The steering wheel is replaced by a stepper motor and the degree of how much it turned is measured by a linear pod. The brake pedal is now actuated by another stepper motor.

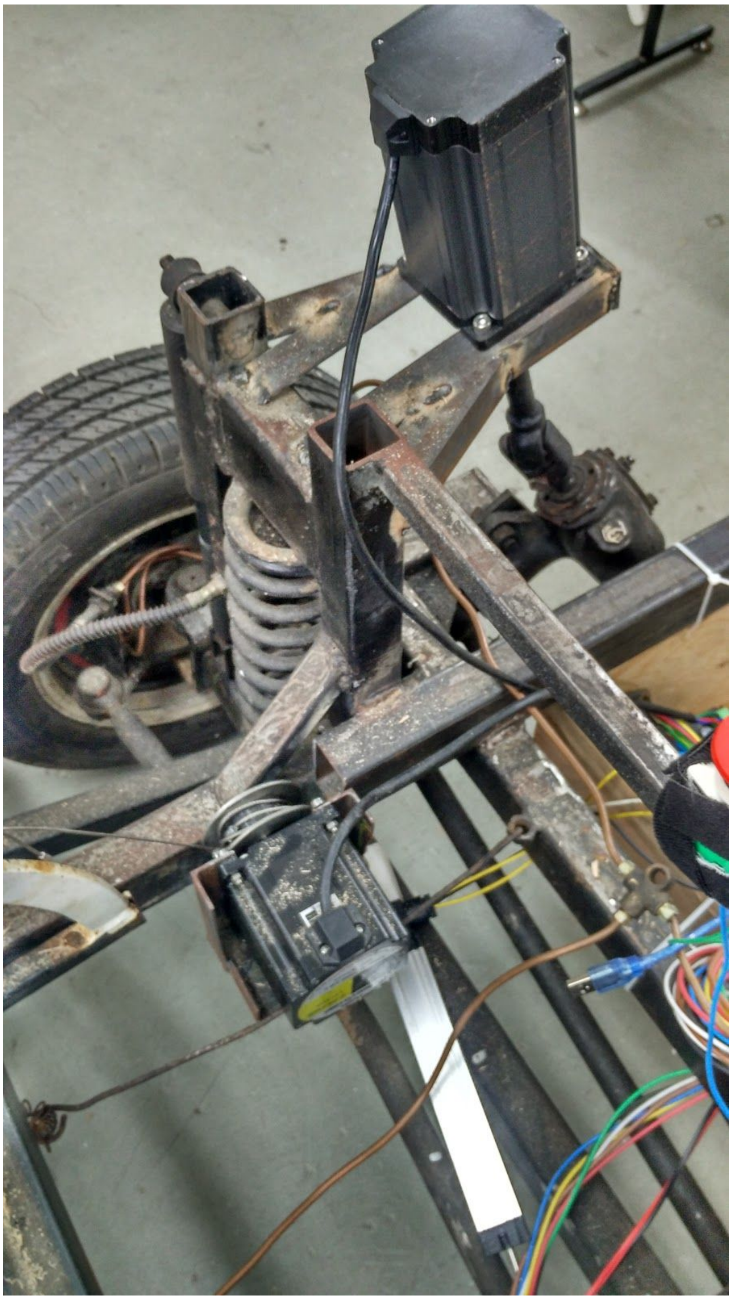
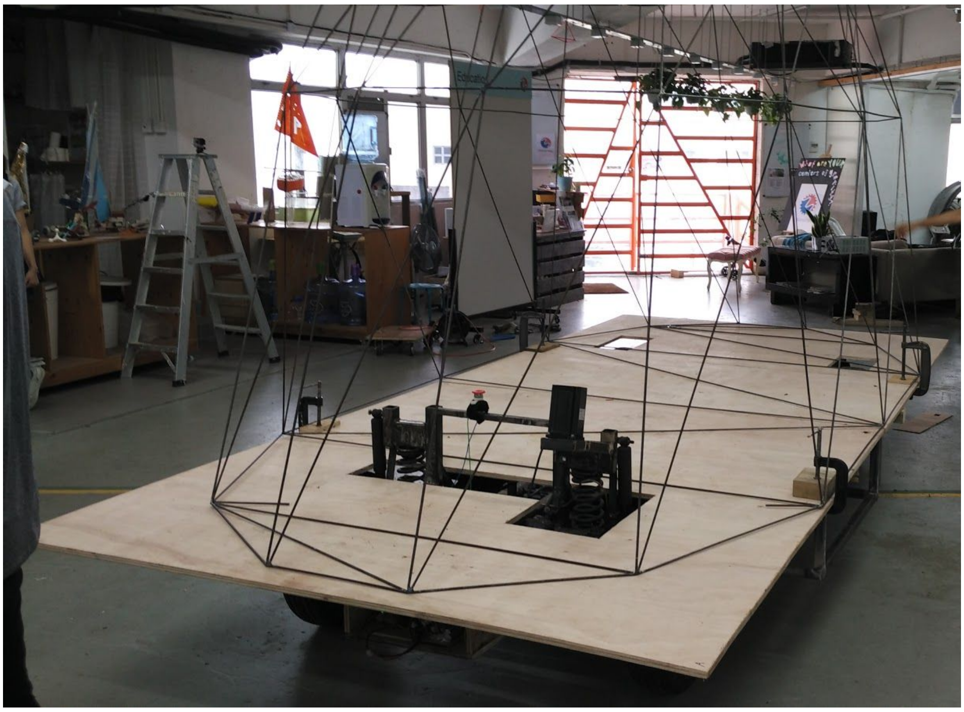


Photo showing all the implemented stepper motors and linear potentiometer.

Platform and Body



18mm thick MDF on top of chassis.

The platform is formed by 4 pieces of 18mm-thick MDF board cut into the shape of the body shell, and placed on top of the chassis.
The body shell built with steel rods is explained in the External Design session.

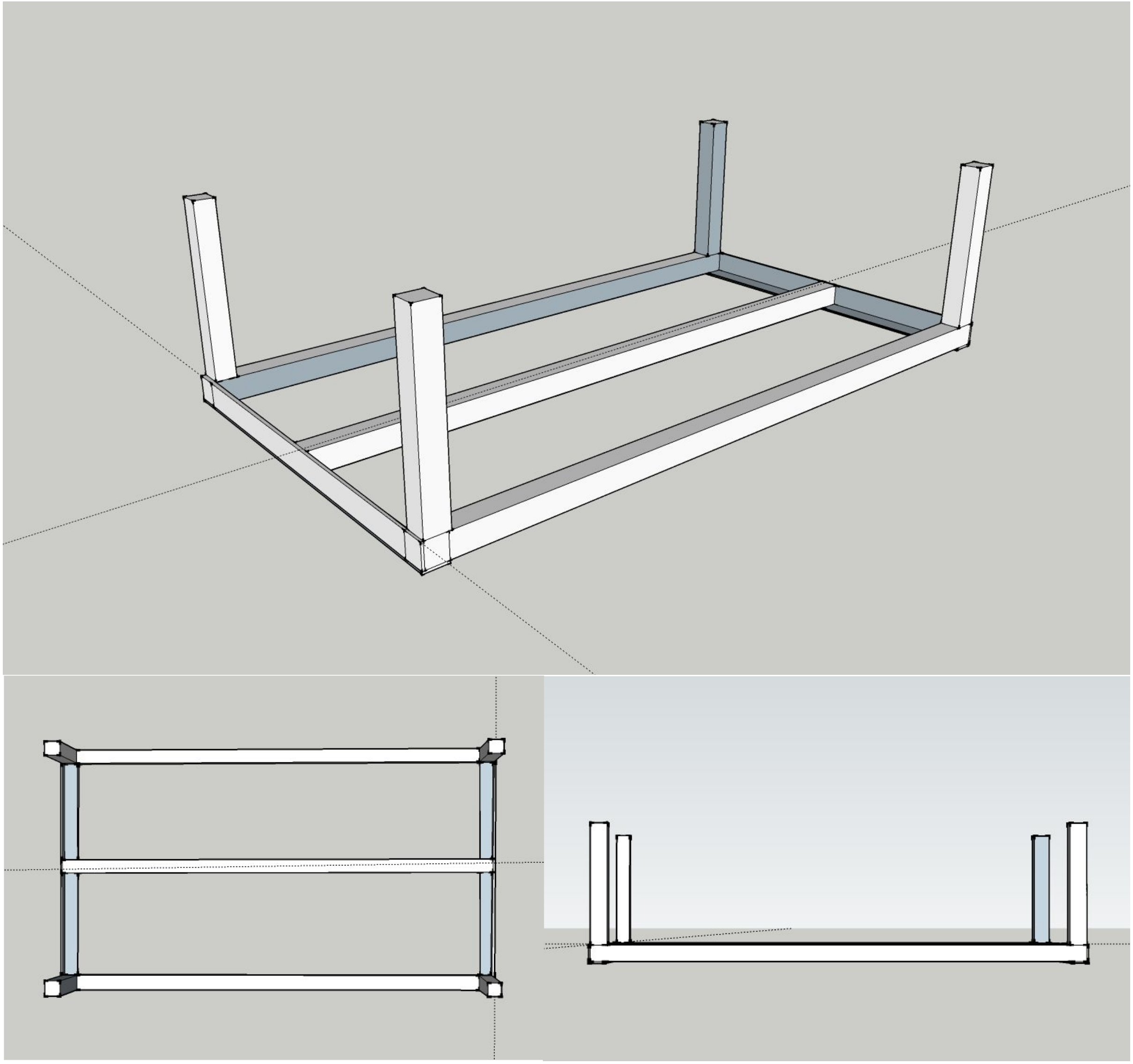
Subsystems

Foot Rest

Foot rest mounted on the front left of the chassis.

We have come up with several designs to allow passengers to rest their feet when taking off their shoes before getting into the EV. We did experiment on the optimal height of the foot step and the most comfortable bending angle of human knees.

Final Design



CAD drawing of battery mount a) Isometric view, b) Top view, c) Side view

Design consideration:
The final design is a design that integrated the shoe holder and foot rest. In the meantime, this is a optimal design for both comfort and space. Detail as below:

Dimension (LxWxH)	920x400x250mm
Outer Length	920mm
Inner Length	834mm

Outer Width	400mm
Inner Width	337mm
Height (Top to Bottom)	250mm
Materials	1. Square metal tube (30x30mm, 3mm thick) 2. Angle metal bar (30x30mm, 3mm thick)

Tools List

- Angle grinder
- Abrasive saw
- Drilling machine / Hand drill
- Arc welding machine
- G-clamp

Material Cutting List

- The following list is the material enough for making one foot rest.
  For **material 1**, cut 4 pillar in 220mm long, cut 3 in 900mm long as the horizontal part
  For **material 2**, cut 2 in 400mm long.

Construction Method

1. Drill Hole on pillars
2. Drill Hole at the Beam of the EV
3. Screw the beam of the foot rest to the beam of the chassis
4. Weld the front and the rear metal tube under the pillar
5. Weld the parts together
6. Put it on the EV with nuts and bolts

Things to note

1. The pillar of footrest can be not exactly 220mm. However, the distance between the surface of the beam to the end of the pillar need to be exactly 220mm, the total height of the foot rest
2. The distance between beams could be different, the actual length of the foot rest can be different as well.
3. To provide the best experience when using the foot rest, it is highly recommended to cut a hole on the floor which is near the foot rest. The recommended depth of the hole will be 70mm.

Mounting

DC Motor Mount

Photo showing the DC motor mounted to the shaft.

We did not make any modification to the DC motor, so there was no need to change its mounting.

Stepper Motor Mount for Steering

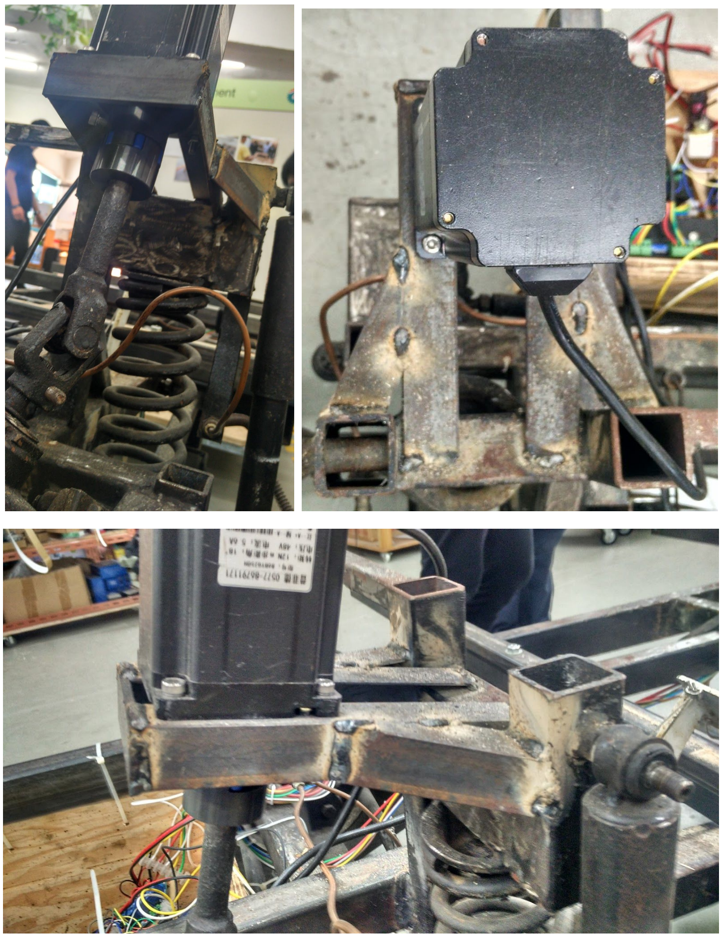


Photo showing the isometric view, top view and side view of the stepper mount.

Dimension

Dimension (LxWxH)	210x100x30mm (excluding stepper motor)
Materials	1. Angle metal bar (30x30mm, 3mm thick) 2. Metal strip (3x30mm) 3. M5 bolts and nuts

Tools List

- Angle grinder
- Arc welding machine
- Drilling machine / Hand drill
- Abrasive saw
- G-clamp

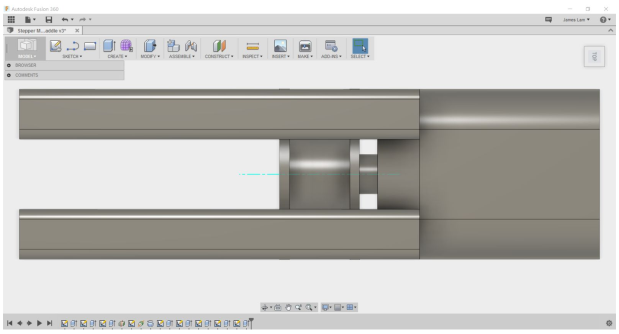
Material Cutting List

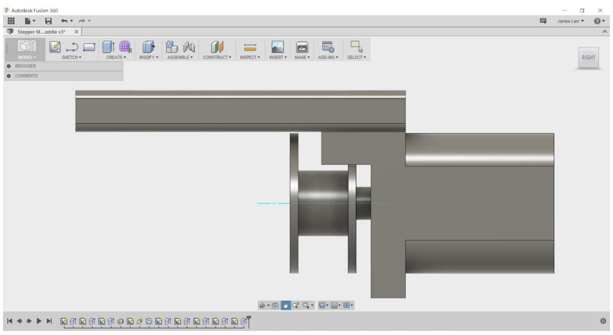
- The following list is the material enough for making steering mount.
  For **material 1**, cut two angle bar into 210mm long, and two into 100mm long. Then further cut the two 100mm bars into trapezoidal shape, with 28mm upper side, 70mm and 30mm for left and right. And remove 20mm of one side of the two 210mm bars to make that part into strip.
  For **material 2**, cut one strip of 100mm long.

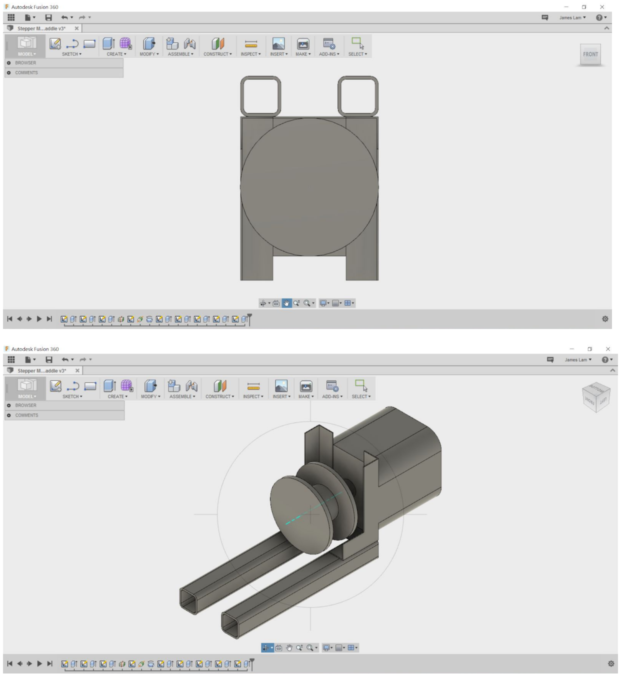
Construction Method

1. Drill two holes on each of the two angle bars according the motor's four position holes.
2. Weld the two angle bar to two ends of the metal strip, forming a U-shaped structure.
3. Weld the 70mm sides of the two trapezoidally-cut angle bars to the side of the U-shaped structure.
4. Attach the stepper motor to the mount and connect the motor to the steering gear box by coupler, make sure the inclination of the motor is the same as the removed steering wheel.
5. Weld the structure in place to form the mounting, welding spots including 30mm side of the trapezoidal bars, and the 20mm long strips of the 210mm bars.

Stepper Motor Mount for Brake pedal [James]







CAD design of the stepper motor mount for pedal brake, top left: top view; top right: side view; bottom left: front view; bottom right: orthogonal view.
The 3D model is available online: http://a360.co/2baEmqg

Dimension

Dimension (LxWxH)	210x85x131mm (excluding stepper motor)
Materials	1. Square metal tube (30x30mm, 3mm thick) 2. Angle metal bar (30x30mm, 3mm thick) 3. Metal strip (3x30mm) 4. M5 bolts and nuts

Tools List

- Angle grinder
- Arc welding machine
- Drilling machine / Hand drill
- Abrasive saw
- G-clamp
- Screwdriver

Material Cutting List

- The following list is the material enough for making steering mount.
  For **material 1**, cut two 210mm long square metal tubes, and drill two holes on each tube.
  For **material 2**, cut two angle bar into 110mm long, and two into 30mm long. Then drill two holes on each of the 110-mm angle bar for screwing the stepper motor in position; drill one hole on each of the 30-mm bar.

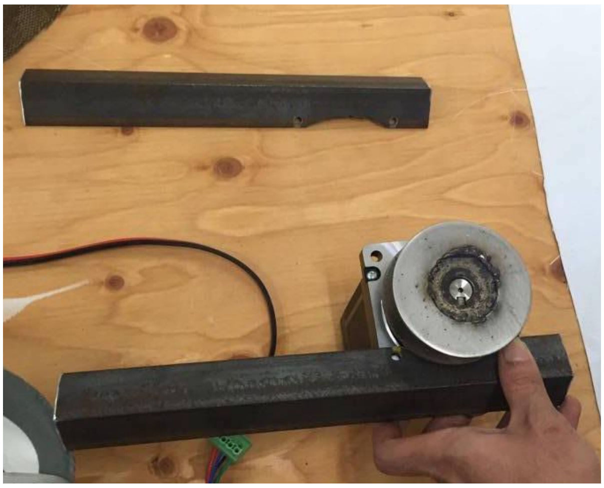
For **material 3**, cut one strip of 85mm long and drill one hole towards each end of the strip.

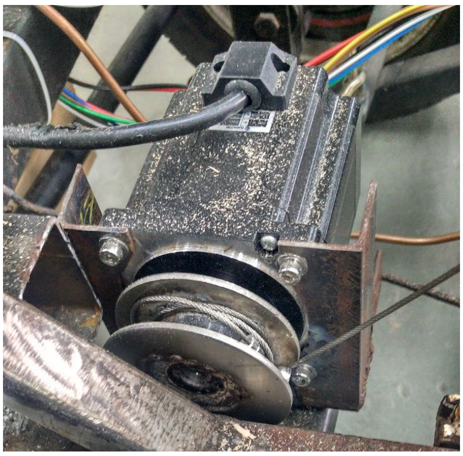
Construction Method

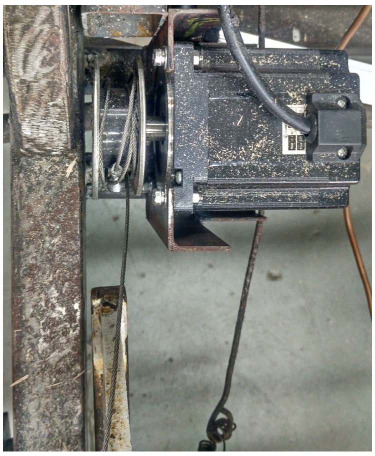
1. Weld two washers to the coupler that fits the diameter of the stepper motor’s shaft, making a pulley.
2. Weld the 85-mm strip to the two 110-mm angle bars forming an U-shaped structure.
3. Weld another two piece of angle bar to extend the structure perpendicularly, forming a L-shaped rack.
4. Weld the two metal tube horizontally onto the chassis, make sure the pulley is aligned with the brake pedal.

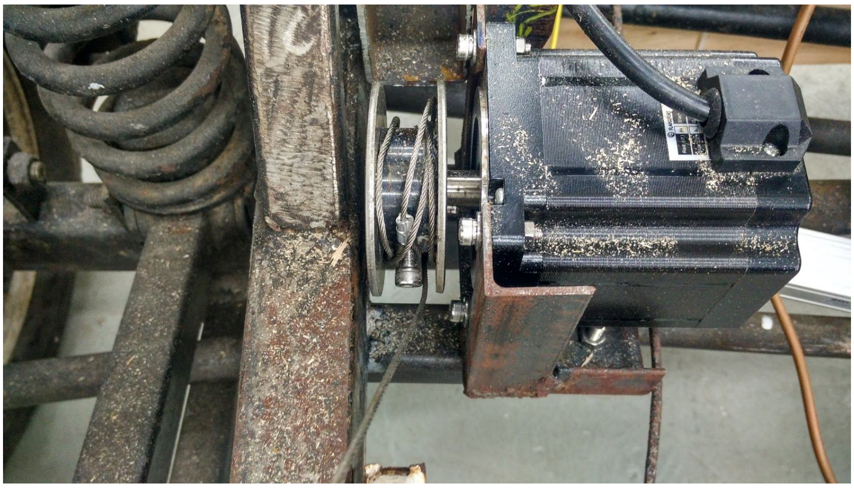
Things to Note

1. Make sure the four holes drilled onto the L-shaped rack and through two 3x3mm metal tube are aligned.



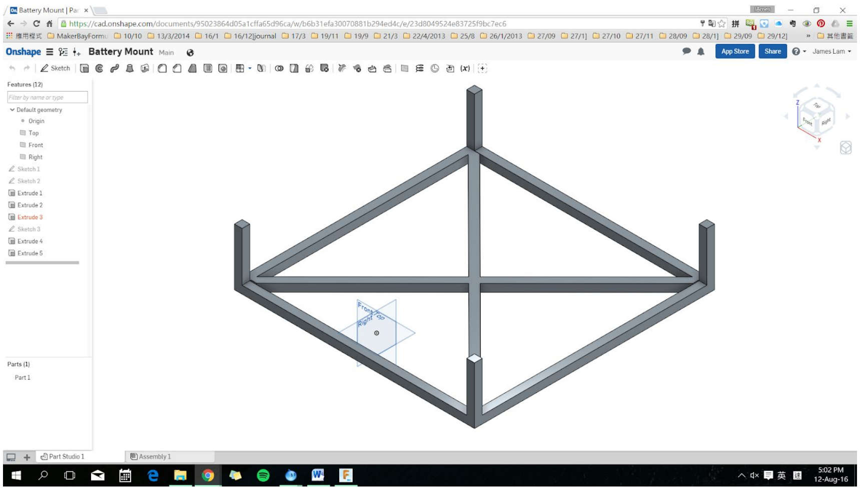






Different views of the mount on the chassis.

Battery Rack



CAD design of the battery rack
3D model is available online:
https://cad.onshape.com/documents/95023864d05a1cffa65d96ca/w/b6b31efa30070881b294ed4c/e/23d8049524e83725f9bc7ec6

Photo showing the welded battery rack.

Design consideration:
The design of the battery rack aims to provide a space to hold the two types of battery that we have. It also aims to hold the DC motor controller as well.

Dimension (LxWxH)	930x930x250mm
Outer Length	930mm
Inner Length	870mm
Outer Width	930mm
Inner Width	870mm
Height (From the Top to the Bottom)	250mm
Materials	1. Square metal tubes (30mm in diameter, 3mm thick) 2. Angle metal bar (30mm in diameter, 3mm thick) 3. MDF (18mm thick)

Material Cut List

- For **material 1**, cut four 220mm long metal tube as pillar, cut two 930mm and 870mm long metal tube for forming the floor of the battery rack.

- For **material 2**, make one 1230mm long bar and two 600mm long for the X-shape supporting structure for the floor.
- For **material 3**, make one square in 930x930mm, cut a 3.5x3.5mm square away from four corner afterward. After cutting the corner, make a cut at the middle to cut the wood into 2 pieces.

Construction Method

1. Cut the metal tubes and angle bar
2. Assemble these metal tubes together with welding, shorter tube should be weld at the end of the longer tube.
3. Measure the actual size of the completed metal frame
4. Cut or adjust the size so that the MDF will fit the size of the actual metal frame
5. Weld the metal frame onto the chassis
6. Put the MDF into the metal frame as floor

Things to note

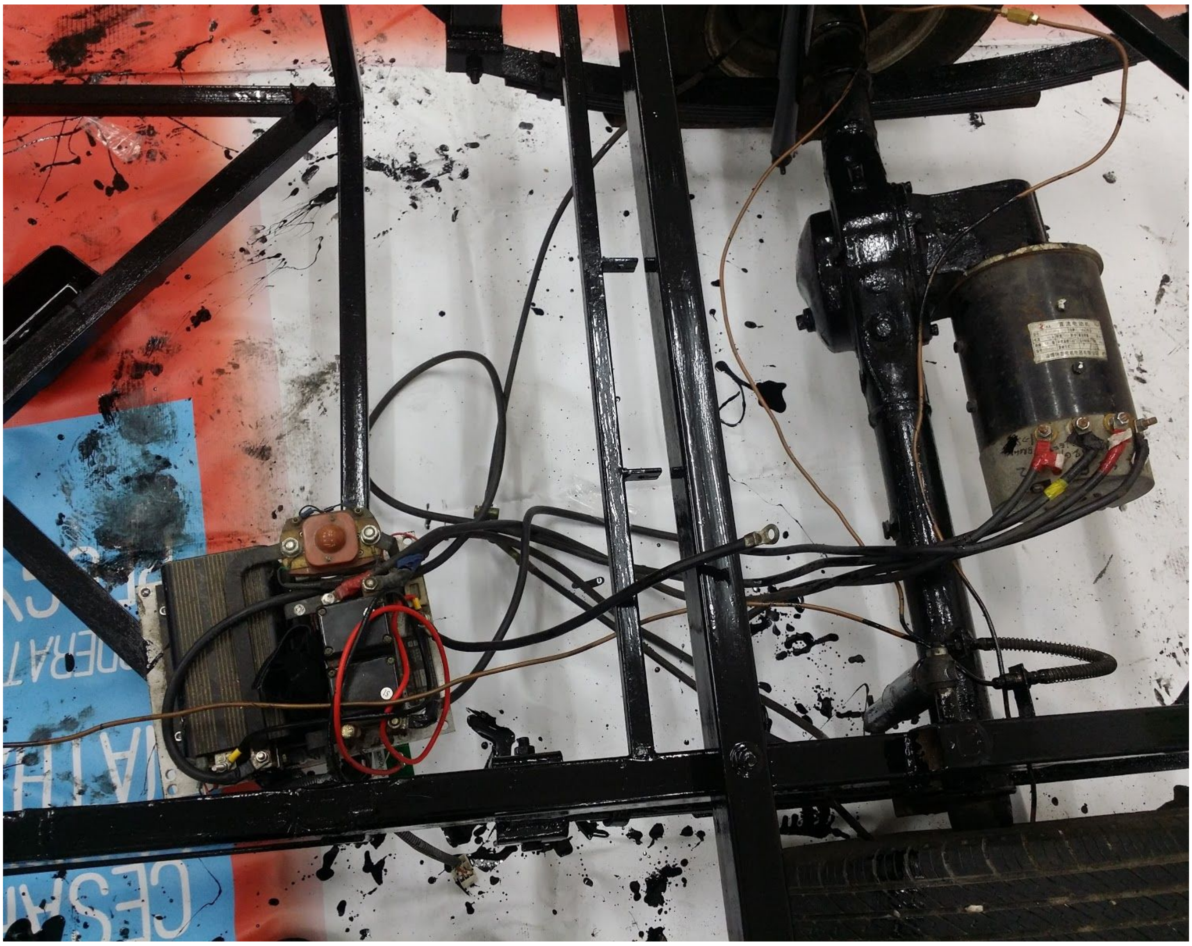
1. It is highly recommended to have a very straight cut with the metal tube.
2. It is highly recommended to cut the MDF according the actual size so that you can have a better MDF that fit the size of the metal frame.

How to hack the mechanics of this vehicle?

1. Think of ways to mechanically disengage the steering stepper motor, so that a steering wheel can be installed for emergency manual turning even if electric system failed.
2. The suspension system can be improved to Double Wishbone or MacPherson System, which are more commonly adopted in automobile industry.

Electric

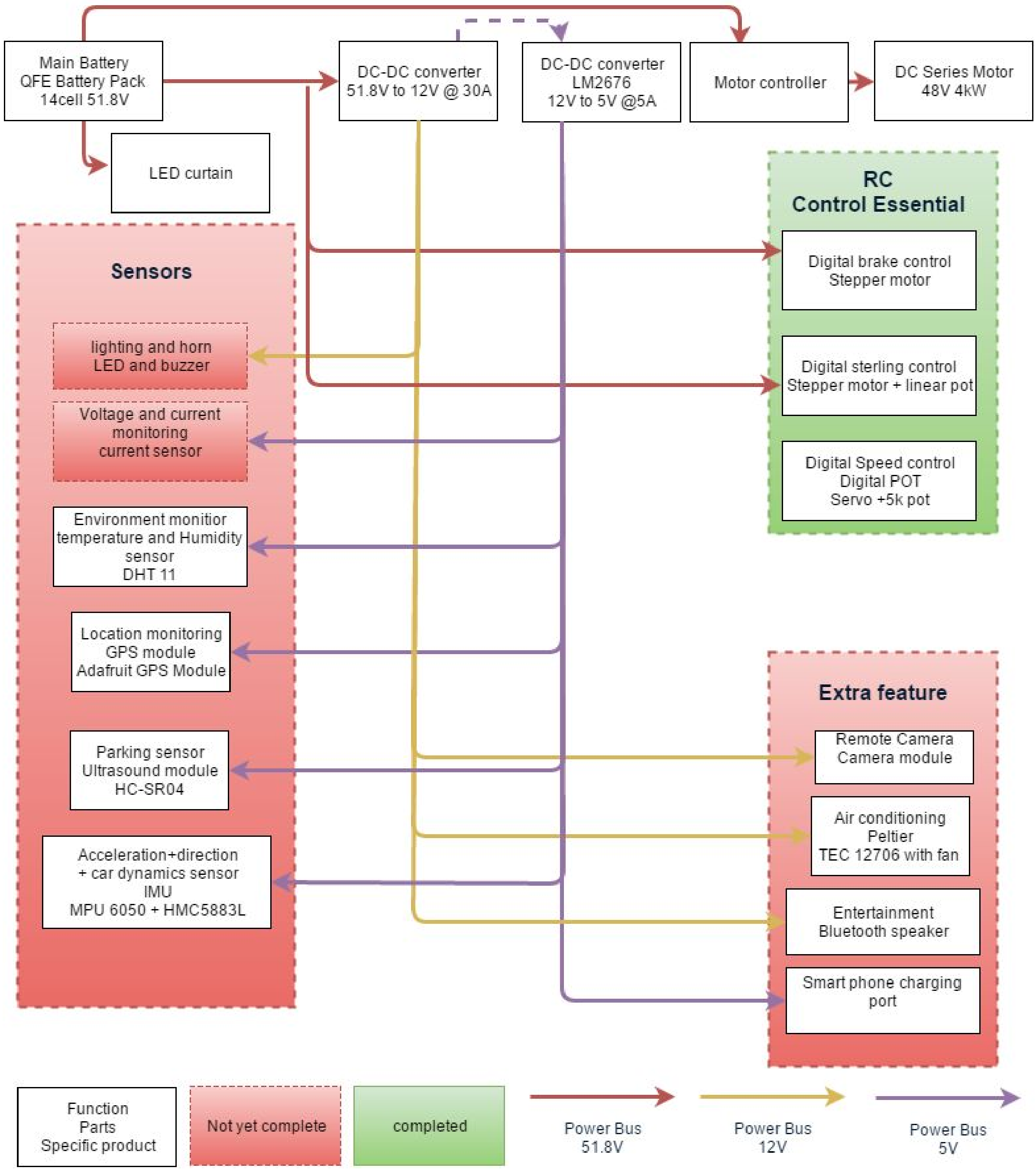
High power electric system



This photo show the existing motor driver and DC brushed motor. The motor is connected through 4 wires (field +ve, field -ve, armature +ve, armature -ve)

The EV have a relatively simple high power system. It is designed in this way to allow maximum flexibility for hacking and future development. It can be separated into five parts: motor controllers, LED curtain, sensors, control and extra feature. The block diagram of such system are attached below.

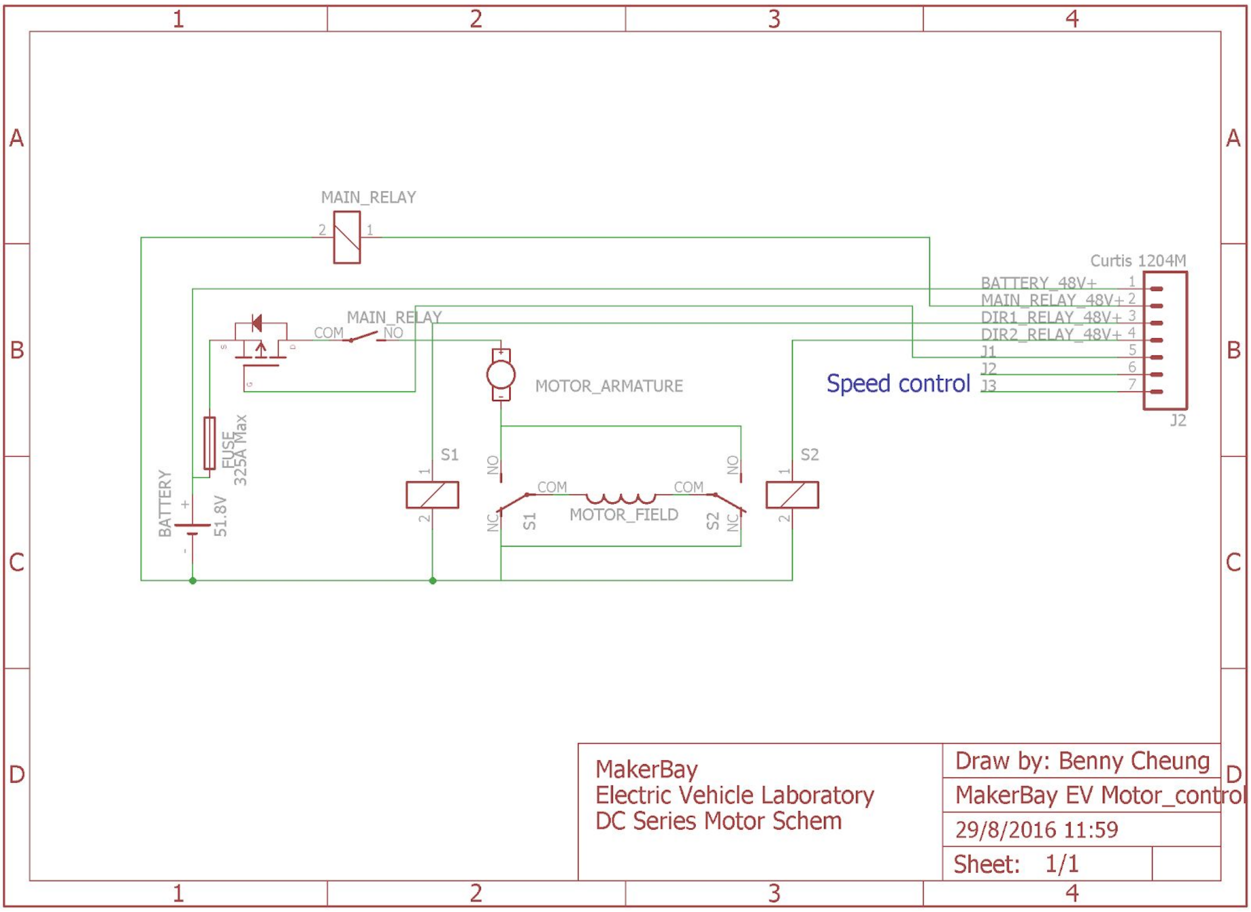
Power distribution block diagram

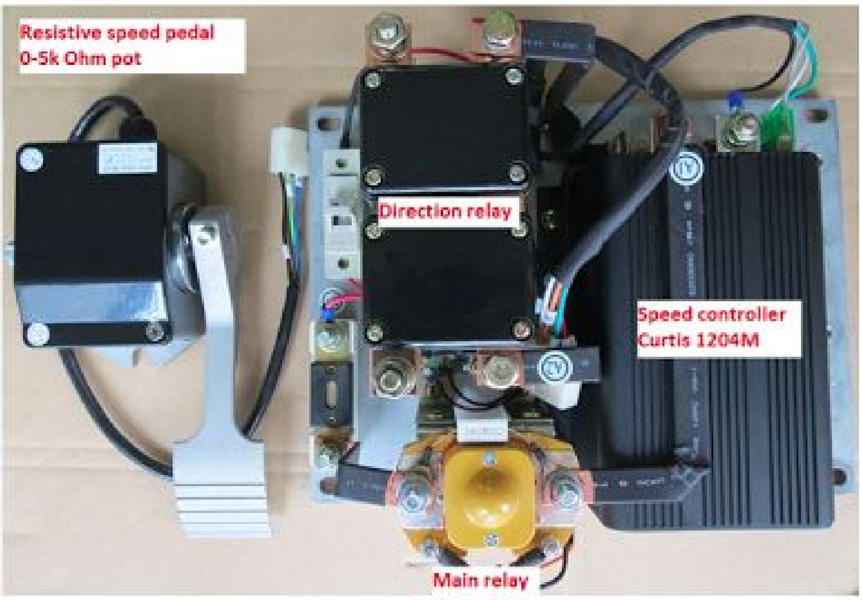


The EV power system mainly consists of three voltage level: 51.8V (battery voltage), 12V (normal voltage for car perphanical) and 5V (normal voltage for sensor and electronics). 2 distinct buck converters are responsible for voltage conversion from 51.8V to 12V and 12V to 5V. LED curtain, motor controller and stepper motor which control the steering and brake use 51.8V power bus while the sensors use 5V.

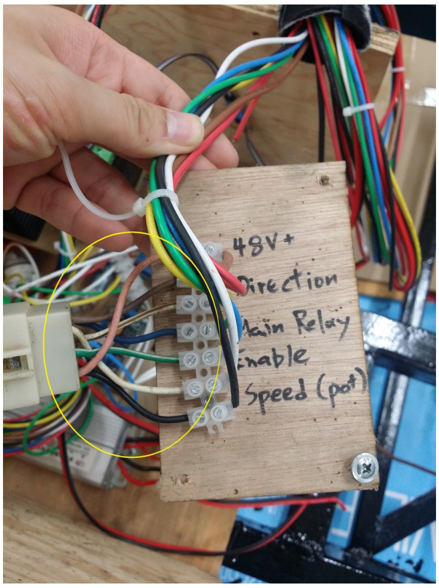
Motor controller

The motor controller responsible for controlling the direction and speed of brushed DC motor. The schematic and photo of motor controller are attached below.





The motor controller mainly consists of relays and speed controller. There are three relays on motor controller. Two of them change motor direction. The remaining one is used for power on/off. We can control the relays with separate control wire with 51.6V High/Low signal (brown and white brown wire are for direction control, blue wire is for main relay control). When power enable pin with 48V, the speed controller will activate and provide the necessary control towards DC brushed motor. J2 and J3(white and black wire) are connected to a 5k Ohm potentiometer for speed control. The 48V power bus is for signal supply purpose.



Speed Controller(Curtis 1204M)

The speed controller is the device used to enable and control the speed of brushed DC motor. The device is attached on the motor controller. For detail specification, please refer to the datasheet of Curtis 1204M. In normal situations, you don't need to modify the setting of this speed controller.

Li-ion battery from QFE

Thank you for QFE generous support, they support three energy storage module(ESM) as the backbone of MakerBay EV. The three battery module are connected in parallel to provide larger current and capacity. The specification of each energy storage module are listed below.

Item	Specification
Type	Lithium-ion platform for stationary and renewable energy storage
Nominal Capacity	42 Ah
End-of-charge Voltage	57.4 V
Nominal Voltage	50.4 V
Discharge Cut-Off Voltage	42.0 V
Maximum Charge Current	25 A
Peak Discharge Current	60 A
Module Weight	17.4 kg
Module Dimensions	423 x 398 x 96 mm
Battery Cell	18650,2600 mAh, 3.6V

A battery management system(BMS) is included in the ESM. The data (Temperature, voltage of each cell, current draw, SOC,SOH etc) can be access by RJ45 plug located in the main battery plug. RS485 protocol are used in this feature and the link of software are below. https://drive.google.com/file/d/0Bx9sZxsv8g5qRDZYUnpncGNVYmM/view?usp=sharing

Motor

The motor is the original motor from second-hand golf cart. It have four terminal which represent two pairs of coil(armature coil and field coil). Four wires are attached to the motor controller for direction and speed control.The specification of motor is listed below.

Item	Specs
Type	DC Brush Motor
Power	4kW
Voltage	48V
Peak Current Draw	270 A
Normal Current Draw	90 A

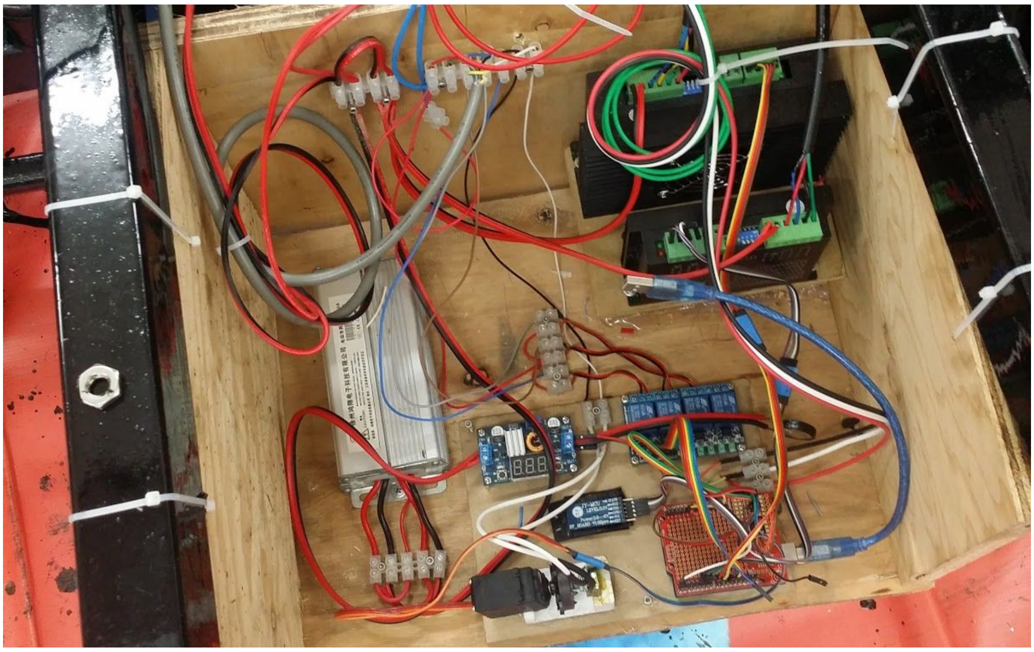
LED curtain

A LED curtain is planned in our project as a showcase. A total 20 LED strips will be attached

to the shell as indicated on the left photo. The LED curtain will cover one side of the EV. The LED curtain used WS2818 with arduino controller and library. Users can create their own patterns with existing library and software to show different image. The 1031 pixels LED curtain will provide a flexible external decoration. The power of LED curtain is obtained from the main battery power bus. A hack is possible with a separate power systems and suitable supply voltage (5V).

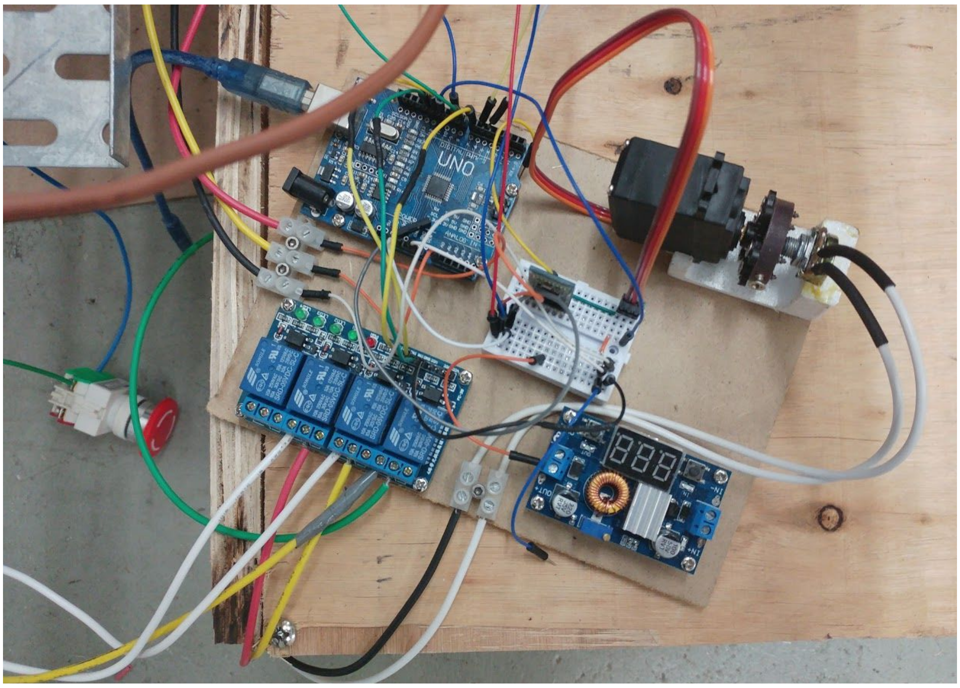
Electronic

Electronics



Control Hub

The Control Hub separates into 3 main components: digital speed control, digital steering control and digital brake control. The three systems join together to provide a complete control hub for car control. The control hub consists of MCU, relays, servo for potentiometer and speed control, and necessary power supply. The control hub draw power directly through a E-switch. By killing the E-switch in the front, the whole 51.8V power bus will be shut down and cause the control system power out.



Digital Steering Control

Digital steering consist of a stepper motor, linear pot as a feedback. The stepper motor use PPM control (each pulse should larger than 10us). With PD control with linear pot as a feedback, a command can be send to control the position of steering.

Digital Speed Control

In this EV, the responsibility of speed control is bear by motor controller. The motor controller provide direction and speed control.

As mention before, 3 relays are located in the motor controller which responsible for main switching and direction control. As the relays require 48V to operate, a secondary level of relay are installed in the control hub for controlling relays on motor controller. By changing the direction relay signal, we can change the direction (forward/backward) of the car.

The original speed controller used rheostat as a signal. In out setup, such system are mimic by servo motor and rotational potentiometer. A 5k Ohm potentiometer are connected to speed controller J2 and J3 terminal. The servo motor are connected to potentiometer which change the position of rotational potentiometer and change the resistance of speed controller.

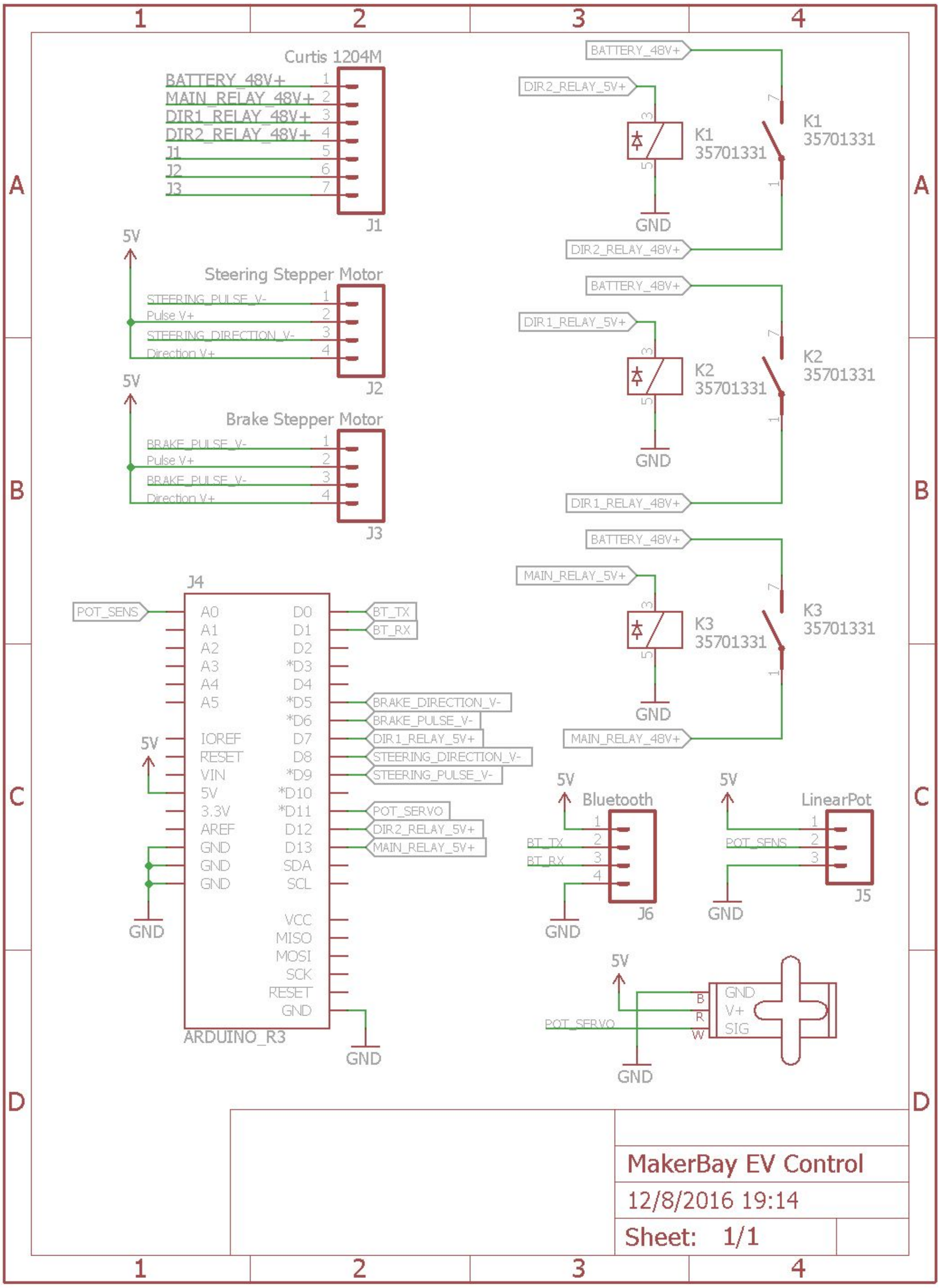
Digital Brake Control

Compare with steering and speed control, brake control is related simple. Digital brake control use a direct mapping method. The previous value will be stored in EEPROM and call out in the beginning of program.

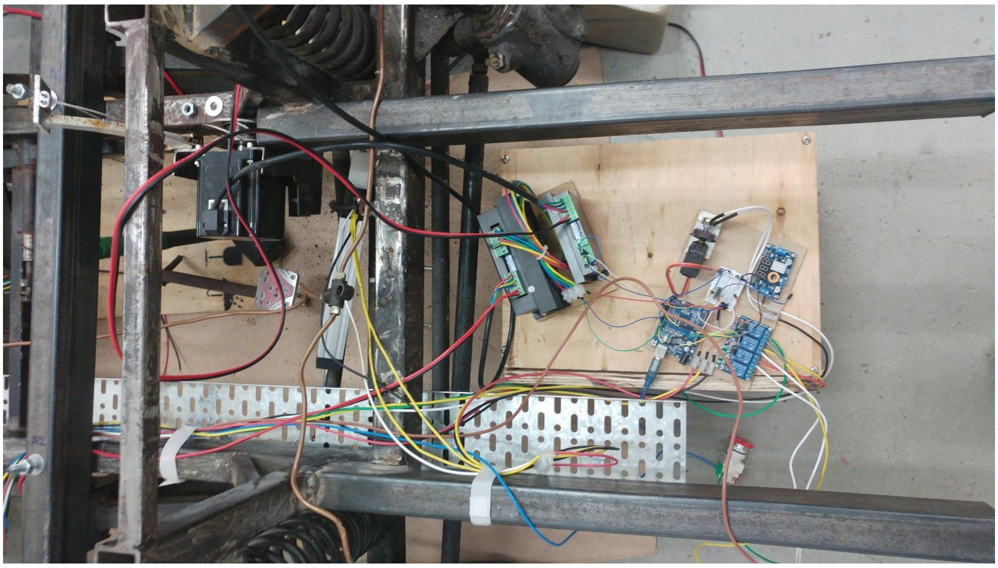
Data format of Control hub

The control hub use UART as the interface .The following show the communication protocol of control hub.
Baud rate: 9600
format: steering, speed, brakes#
All value are 0-255(ASCII encoding)
Steering: 0-255, char array type, mid pos 128,3 byte
Speed: 0-255, char array type, mid pos 128,3 byte
Brake: 0-255, char array type,3 byte
Separator: ,
End character: #
E.G. : 128,128,0# (steering in middle position, no acceleration, no brake enable)

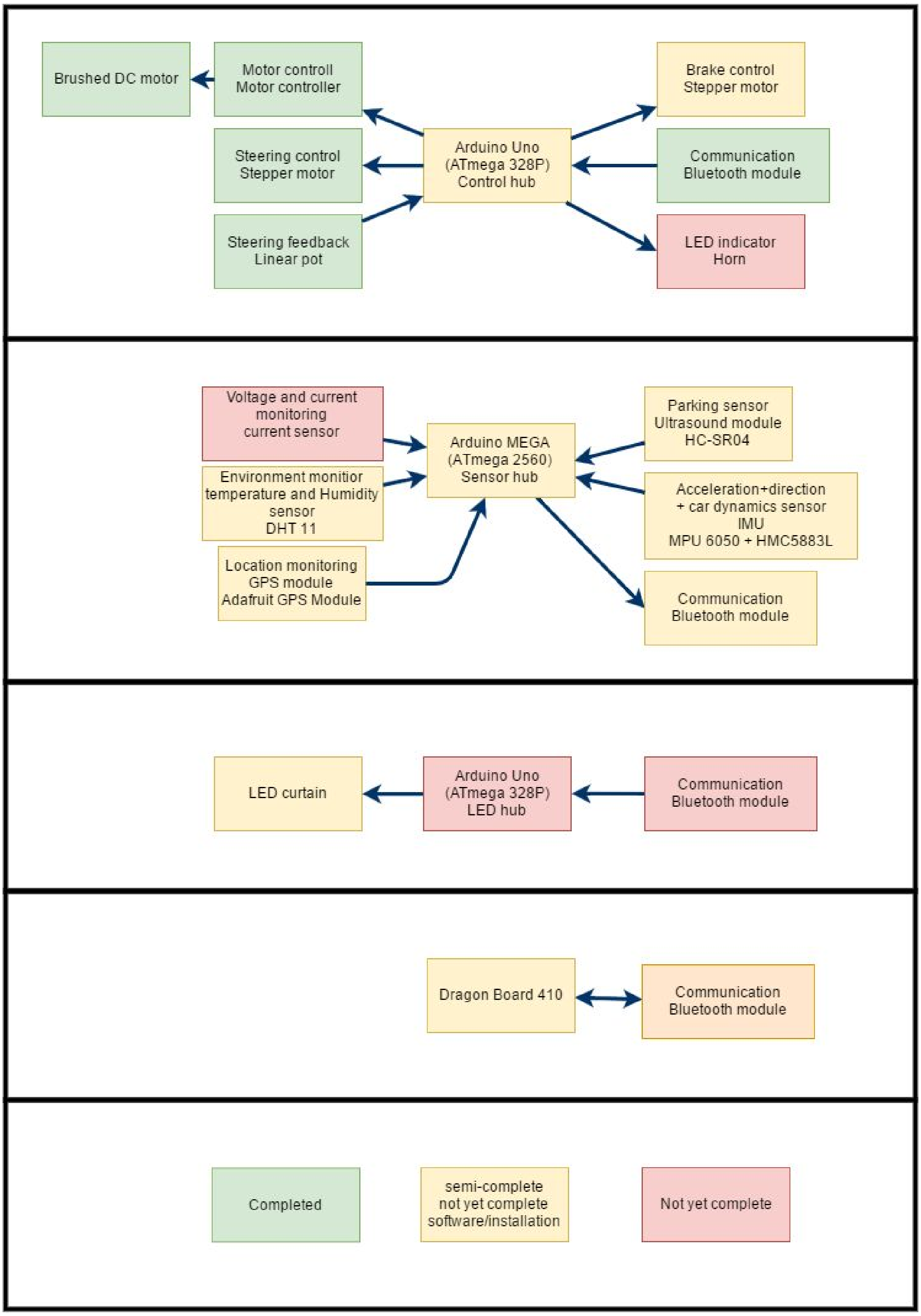
Schematic



Sensor Hub



Signal Diagram



Sensor Type

- 8 ultrasonic transducers: 6 HC-SR04 units, 1 HY-SRF05 unit, 1 US-015 unit;
    - Effective distance = 1.5 meter
    - http://www.micropik.com/PDF/HCSR04.pdf

- 1 temperature & humidity sensors: DHT 11 model
    - Accuracy: +-2 degree C +-5% RH
    - Temperature range: 0- 50 degree celsius
    - Humidity range: 20% to 90% RH
    - update rate: maximum of every 2 seconds, long response time of ~500ms; intended for climate control
    - http://www.micropik.com/PDF/dht11.pdf

- 2 PIR sensors: HC-SR501 model
    - Adjustable range up to 8 meters; adjustable delay; intended for detection of human presence in the vehicle
    - https://www.mpja.com/download/31227sc.pdf

- Inertial measurement unit: MPU 6050 6 axis gyroscope + accelerometer
    - I2c communication
    - slight problem with FIFO buffer overflow
    - Output: yaw, pitch, roll, x axis acceleration, y axis acceleration, z axis acceleration
    - https://www.invensense.com/products/motion-tracking/6-axis/mpu-6050/

- Existing sensors within QFE battery packages: battery state of charge (SOC) monitor, battery health, charge balancing, temperature sensors...etc.

Arduino Sensor Processing

- Sensor hub based on an Arduino Mega board
- Code available on Github [Link]
- Speed limited by ultrasonic transducers and sensor information processing
- Additional board needed for further sensor integration
- Output sensor data via Serial to control board and DragonBoard
- Further expansion possible with integrated package of MCU, sensor unit and Bluetooth module for wireless communication

  Control (digital)

  Arduino/RC steering and speed control

  Protocol of communication

How to hack the electronics of this vehicle?

Software

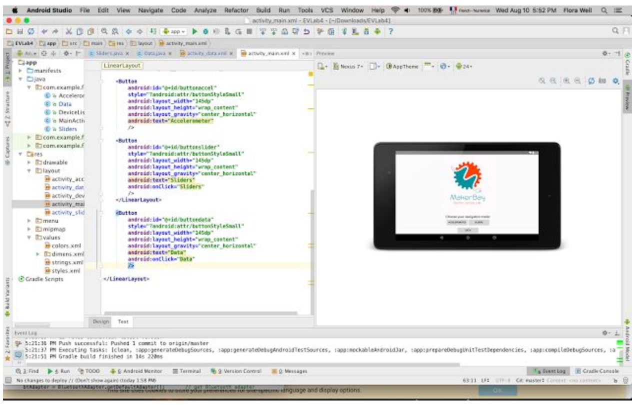
Software

All the code is under

- General group page: https://github.com/MakerBay
- Android App: https://github.com/MakerBay/EVLab_android
- Arduino App: https://github.com/MakerBay/EVLab_arduino
    - Sensor hub
    - Control hub
- Protocol

General informal

Android App



Github link to source code : https://github.com/flora-wl/EVLab4

Environment

- Android Studio 2.1.2
- Compile SDK version 24
- Build Tools Version “24.0.1”
- ApplicationID “com.example.flora.evlab4”
- minSDK Version 15

Activities

- DeviceList
- MainActivity
- Sliders
- Accelerometer
- Data

Methods

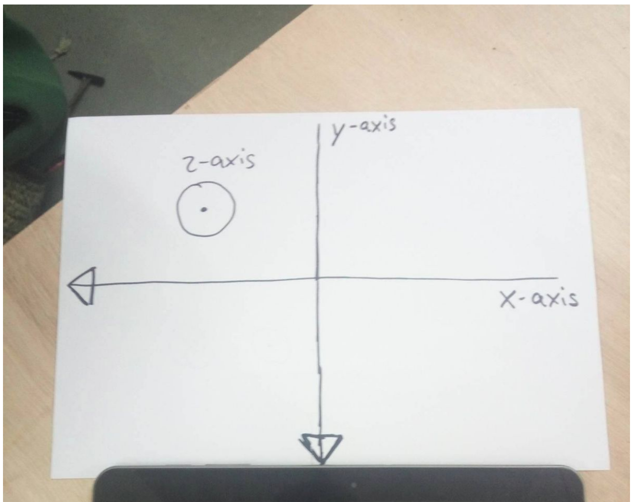
- pairedDevicesList() - View paired Bluetooth devices as a list and retrieve address by selecting.
- putExtra() - Passing address from one activity to another.
- ConnectBT() - Bluetooth connection after device address is retrieved, called at every activity after MainActiviy.
- Disconnect() - Disconnect Bluetooth socket on click.
- addValues() - Set up and combine data to send over via Bluetooth and send using Android getOutputStream() method.
- turnBack() - Send byte to change output to relay to change direction
- turnFront() - Send byte to change output to relay to change direction

Usage

1. Open application.
2. Select paired Bluetooth device: currently HC-09.
3. Select control method: currently Accelerometer and Sliders
4. Wait for “Connected” toast.
5. Control

Accelerometer and Calibration

The device used during the development is a Samsung Galaxy 10.1 Tablet (Model GT-P7510). The natural orientation of the device is landscape and the orientation of the three axes can be seen below. All explanations below will be made in reference to this orientation.



Accelerometer

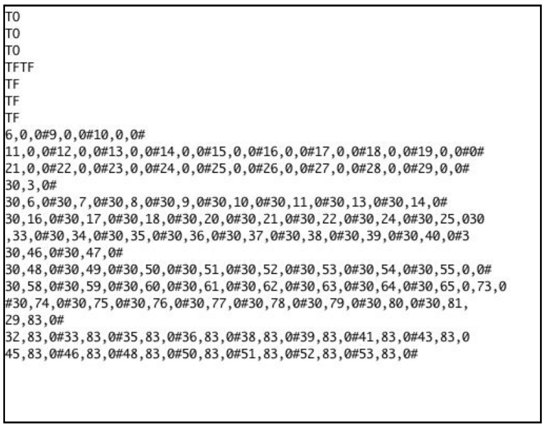
The app uses the accelerometer of the tablet to detect its motion for controlling either steering or throttle and brake. The accelerometer measures the acceleration force (m/s^2) along its three axis, including the force of gravity.
For steering, the angle of rotation around the z-axis in the x-y-plane is measured by using the inverse trigonometric functions of arcsine for the x-axis and arccosine or the y-axis. Analogously, throttle and brake are derived by detecting the angle of rotation around the x-axis in the y-z-plane by calculating the arccosine of the y-axis and the arcsine of the z-axis. The maximum values the forces have been tested experimentally and are used as 'hypotenuse' in the calculation of arcsine and arccosine.

Calibration

If the app is to be changed to be used on a different device, the orientation of the axis as well as the maximum values of each axis (positive and negative) have to be reconfigured in the strings.xml.

Output Format

Each time a change is detected a new set of values is sent to the Bluetooth socket in the format:
111,222,333,666#
1st value: steering
2nd value: speed
3rd value: brake
4th value: check sum(value1+value2+value3)
Range: 0-255 (0-127 back, 127-255 front)



```
TO
TO
TO
TFTF
TF
TF
TF
6,0,0#9,0,0#10,0,0#
11,0,0#12,0,0#13,0,0#14,0,0#15,0,0#16,0,0#17,0,0#18,0,0#19,0,0#0#
21,0,0#22,0,0#23,0,0#24,0,0#25,0,0#26,0,0#27,0,0#28,0,0#29,0,0#
30,3,0#
30,6,0#30,7,0#30,8,0#30,9,0#30,10,0#30,11,0#30,13,0#30,14,0#
30,16,0#30,17,0#30,18,0#30,20,0#30,21,0#30,22,0#30,24,0#30,25,030
,33,0#30,34,0#30,35,0#30,36,0#30,37,0#30,38,0#30,39,0#30,40,0#3
30,46,0#30,47,0#
30,48,0#30,49,0#30,50,0#30,51,0#30,52,0#30,53,0#30,54,0#30,55,0,0#
30,58,0#30,59,0#30,60,0#30,61,0#30,62,0#30,63,0#30,64,0#30,65,0,73,0
#30,74,0#30,75,0#30,76,0#30,77,0#30,78,0#30,79,0#30,80,0#30,81,
29,83,0#
32,83,0#33,83,0#35,83,0#36,83,0#38,83,0#39,83,0#41,83,0#43,83,0
45,83,0#46,83,0#48,83,0#50,83,0#51,83,0#52,83,0#53,83,0#
```


Improvements

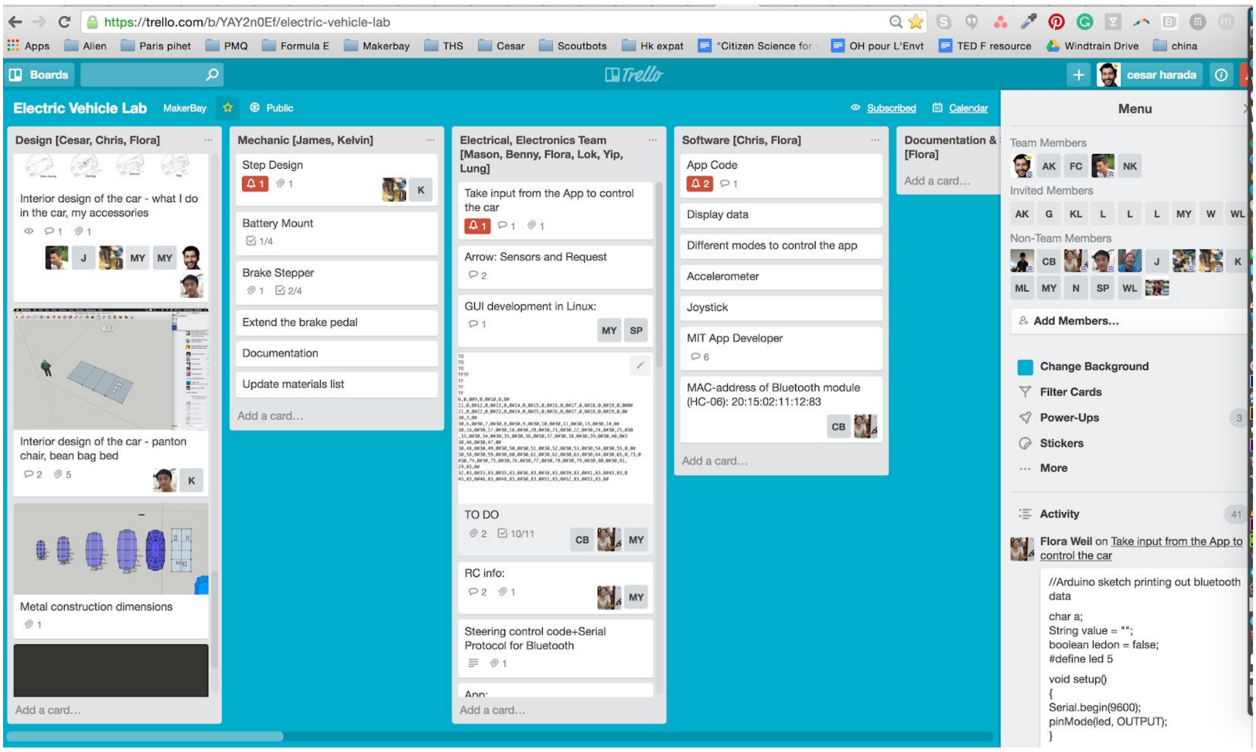
- Data collection and display
- Accelerometer calibration
- Gyroscope implementation
- UI (vertical sliders)
- Google Maps

How to hack the software of this vehicle?

Management

Management

Project management

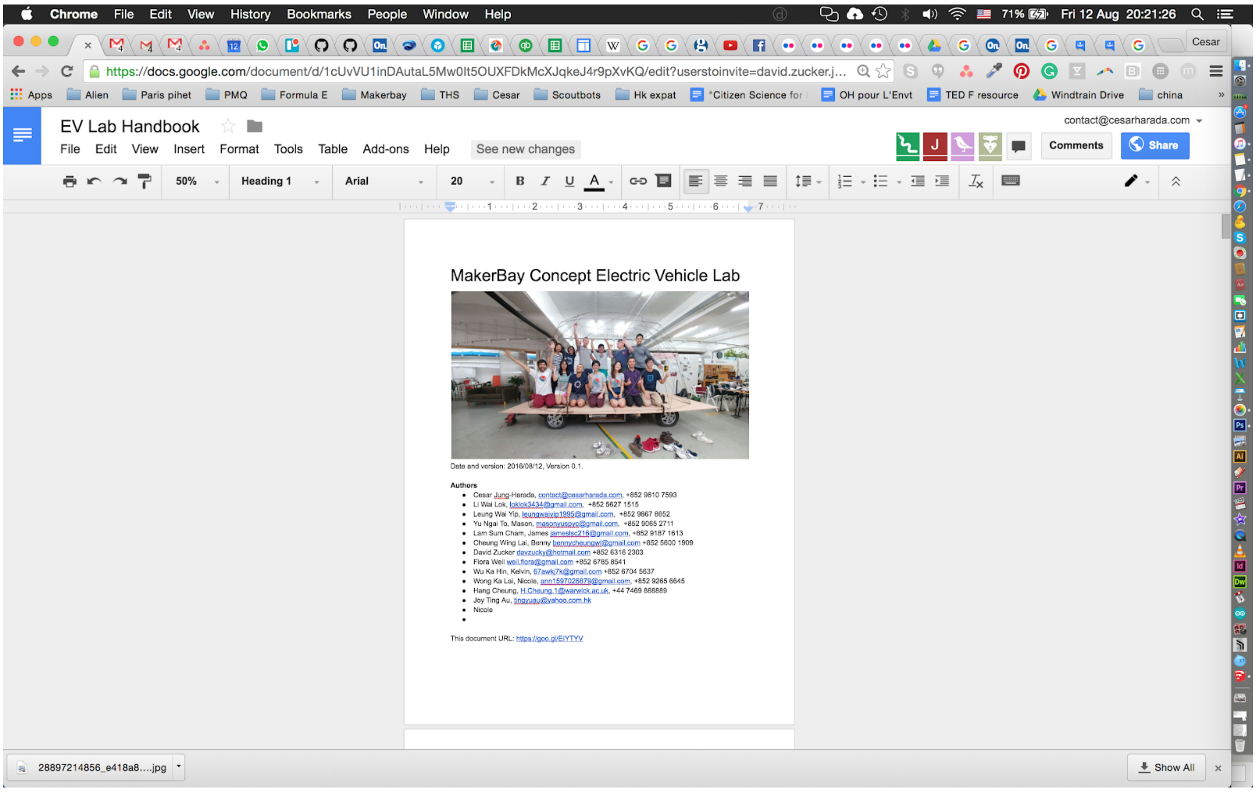


https://trello.com/b/YAY2n0Ef/electric-vehicle-lab

Leadership

Rotating leadership and task tracking

Documentation



How to hack the management of this vehicle?

Future Developments

- ❖ **Magnetic solenoid lock**
- It was planned to replace the parking brake with a magnetic solenoid lock which pulls the wire when it is not powered, and releases the wire when it is turned on. However, due to limited time, the device was not ready by the time this report is written.
- ❖ **Digital door lock/ Security system**
- ❖ **Wireless charging**:
- Inductively coupled coils which transfer power through a resonant magnetic field archived via a compensating capacitor network hd
- Capacitor topology: series-parallel
- Fed by power supplies outputting 50V at 80A maximum from 220V mains
- 50V DC current then drives a full-bridge inverter with fast IGBTs at 100kHz of nominal frequency, output peak-to-peak voltage: 50V
- H-shaped core with laminated silicon steel as flux pipe
- Expected field strength: <27 uH, with aluminium sheet to shield components and users from leakage flux
- Target efficiency at 160 to 200mm air gap = 90%
- Schottky diode rectifier and boost converter with regulator for current and voltage
- Nominal charging state for battery: 57.4V at < 5A
- Expected power output: 1kw nominal, maximum power ~ 2.5 kW
- ❖ **Pixel processing:**
- ❖ **Air Conditioning and fans:**
- Possible Peltier device powered solid state air conditioning based on 4 60W peltier device chips
- Water cooling and radiator needed
- Conventional solution: Four 12V 0.8A fans or a 1hp conventional air conditioner
- ❖ **Additional sensors:**

- New inertial measurement unit: MPU 9150 9 axis gyroscope + accelerometer + magnetometer

- Magnetometer data can be used to determine heading in the world frame of reference in a faster and more reliable way, can detect wireless charger's leakage magnetic field too (if the charger is built)

- Current sensor: CJMCU - 109 model intended for APM flight control boards

- Hall effect based sensor with measurement range up to 90A; not intended for use in main motor controller (existing sensor available), can be used for other high power parts such as the charging circuit, lighting circuit...

- FM radio: TEA5767 module from Philips

- Can be adjusted and controlled through I2c and/or analog input (to change frequency), outputs stereo audio signals to amplifier

- Audio amplifier: PAM8406 digital 5W*2 amplifier (subject to upgrade depending on speaker size)

- Dual channel output, has on-board volume adjustment
- Current audio solution is to use a custom Bluetooth speaker (built and tested already) to play audio directly from the Android tablet (in which case the amplifier will not be needed)

- **Ambient light intensity sensor**: BH1750 breakout board:

- Standard I2c communication; measurable illuminance range from 1 lux to 65535 lux with accuracy in high resolution mode of down to 0.5 lux
- Ordinary photoresistors also available
- Used to relay information for lighting control (feedback intensity control)

- Ambient light color sensor: GY-31TCS230 package, based on TCS3200 light-to-frequency converter

- RGB color detection via array of photodiodes; directly controllable by MCU using digital commands to select RGBW component; Output intensity of measured component as frequency of square wave; board is programmable, and comes with 4 white LEDs built-in
- Intended for mood and dynamic lighting control; may encounter issue with range and complex colors, further testing needed before integration.

- Infrared-based remote temperature sensor: GY-MCU90615 model

- Functions via serial communication; able to measure environment temperature and target object temperature (like human body, seat heater...) with 16 bit resolution (typical hardware-limited accuracy ~ 0.5 degree C); 10hz update rate
- Intended for more accurate climate control (replacing the much slower and less accurate DHT11 sensor) and temperature measurement of specific hot components.

- **Capacitive touch panel for LED lighting control via PWM**:

- Custom PCB with adjustable capacitive options for different overlaid material; Can act as a switch and a dimmer; may be used to directly drive LEDs with a maximum output current of 500mA
- Used as an innovative user interface; it is also a more direct and simpler solution than doing the same thing through the main control screen

- **Raindrop detection module**:

- Custom 5cm * 4cm board (with controller board) to detect presence of water; analog output also available to detect water amount
- Intended for the detection of rainy weather to control mood lighting and additional smart functionalities in car

- **Microphone with fixed gain amplifier**: MAX9812 model

- Single output, gain fixed at 20dB
- Intended for voice recognition and recording

- Biosensor: pulse sensor from www.pulsesensor.com

- Needs to be in touch with capillary tissue (like fingers or earlobes) to properly function; detects heart pulses via LED and a light sensor, outputs pulse waveform as an analog signal after on-board amplification and normalization; ready to be used with Arduino

- Intended to monitor the state of driver, may be implemented as part of the massage seat/chair

❖ **Improved User Interface:**

- 7” touch screen powered by DragonBoard 410c provided by Arrow Electronics
- GUI based in Linux
- Display of sensor data and vehicle status information depending on the state of the vehicle
- Holographic display by projection of touchscreen image

❖ **Assisted / automatic driving modes:**

- Lane detection with camera (combined with pixel processing techniques)
- Tracking of car with LiDAR or Radar system
- Smart cruise control with automatic brakes and accelerations
- Advance towards a fully self-driving car

Observations

Limitations

Mistakes & Learning

Method and critic of the method

Conclusion

Further reading

OSV in Rennes University: https://camposv-labfab-ur1.ietr.fr/
Comma.ia open source self driving AI data https://github.com/commaai/research
George Hotzhttp://www.bloomberg.com/features/2015-george-hotz-self-driving-car/
“Protei” Sailing robot documentation: www.issuu.com/cesarharada/docs/protei-handbook-a4
Remotely controlling a Jeep: https://www.youtube.com/watch?v=MK0SrxBC1xs

Appendix

Parts list

Master Material List

A detailed parts list can be found in the following link.
https://docs.google.com/document/d/1-q7aPszNsuSkyQk5ijSwxumWZtAeWvsWESgMdnXPy2A/edit?usp=sharing

Suppliers list in Hong Kong

Here, the addresses of our suppliers and sponsors

Kingsway (威哥) +852 91950806
Fanling

新力汽車零件公司 +852 23432090
G/F, 11 Tung Ming Street, Kwun Tong, Kowloon, Hong Kong

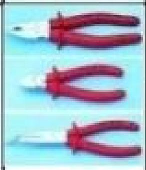
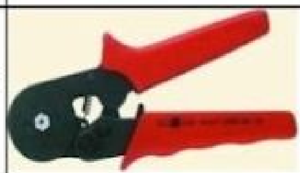
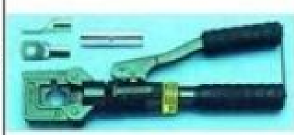
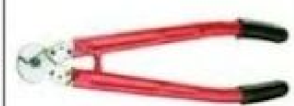
Hardware stores in Reclamation Street, Mongkok, Kowloon, Hong Kong

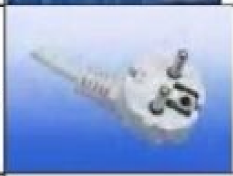
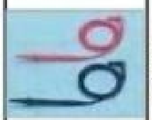
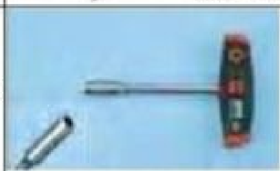
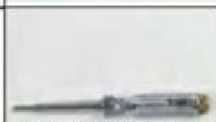
Tools list

中文	英文	英文刻字	图片
水管钳	Groove Joint Pliers	Groove Joint Pliers	
斜嘴钳	Diagonal cutting pliers	Diagonal cutting pliers	
尖嘴钳	Long Nose Pliers	Long Nose Pliers	
锂鱼钳	Slip Joint Pliers	Slip Joint Pliers	
大力钳	Locking Pliers	Locking Pliers	
电线钳	Wire Crimper		
套筒棘轮手柄	Ratchet Handle	Ratchet Handle	
套筒延长接杆	Extension Bar	Extension Bar	
火花塞套筒	Spring Spark	Spring Spark	

中文	英文	英文刻字	图片
四方孔套筒	Socket	Socket	
强力套筒	Nut Driver	Nut Driver	
套筒AD	Adaptor	Adaptor	
五金柄界刀	hardware Knife	Knife	
塑胶柄界刀	Plastic Knife	Knife	
六角匙	Hex Key	Hex Key	
棘轮手柄	Ratchet Handle	Ratchet Handle	
磁性螺丝批柄	Magnetic Screwdriver Handle	Screwdriver Handle	
磁性螺丝批柄	Magnetic Screwdriver Handle	Screwdriver Handle	

中文	英文	英文刻字	图片
罗卜头螺丝批	Screwdriver Handle	Screwdriver Handle	
“T”型螺丝批	T-Bar Ratchet Handle		
螺丝批	Screwdriver Handle	Screwdriver Handle	
精密螺丝批	Precision Screwdriver Handle		
塑胶软管			
弹性软管	Flexible Shaft		
活动扳手	Adjustable Wrench	Adjustable Wrench	
两用扳手	Combination Wrench	Combination Wrench	
卷尺	Tape Measure	Tape Measure	

序号	中文名称	照片	英文名称	中文名称	照片	英文名称
1	自动剥线钳		Automatic Insulation Stripper	剥线钳		Cable Stripper
2	扁线齐口断线钳		Cutter for Ribbon Cable	同轴电缆剥线钳		Coaxial Cable Stripper
3	液压断线钳		Hydraulic Cutter	精密剥线断线钳		Precise Cable Stripper
4	钳子		Plier	压线钳		Crimping Plier
5	斜口钳		Side cutting Plier	六方压线钳		Hexagon Crimping Plier
6	尖嘴钳		Snipe Plier	液压压线钳		Hydraulic Crimping Tool
7	老虎钳		Cutting Plier	电缆剪钳		Cable Cutter
8	螺丝刀		Screwdriver	镊子		Tweezer
9	一字螺丝刀		Slotted Screwdriver	充电器		Charging Unit

10	十字螺丝刀		Philips Screwdriver	手电筒		Flashlight
11	数字万用表		Digital Multimeter	电气插座		Electric Sockets
12	钳形电流表		Current Clamp-on Meter	电气插头		Electric Plugs
13	绝缘表笔		Isulated Prode	双开口扳手		Double Open Ended Spanner
14	秒表		Stopwatch	活扳手		Adjustable Spanner
15	电缆绕线器		Cable Reels	套筒改锥		Nutdriver
16	卡簧钳		Circlip Plier	内六角扳手		Hexagon Key Wrench
17	应急灯		Emergency Light	电笔		Voltage Tester

<table>
<tr><th>品名</th><th>机型名称</th><th>型号名称</th><th colspan="2">英文名称</th></tr>
<tr><td rowspan="3">角向磨光机</td><td>100 角磨机</td><td>S1M-##-100A</td><td colspan="2">ANGLE GRINDER</td></tr>
<tr><td>125 角磨机</td><td>S1M-##-125A</td><td>180 角磨机</td><td>S1M-##-180A</td></tr>
<tr><td>150 角磨机</td><td>S1M-##-150A</td><td>230 角磨机</td><td>S1M-##-230A</td></tr>
<tr><td rowspan="3">石材切割机</td><td>110 切割机</td><td>Z1E-##-110</td><td colspan="2">MARBLE CUTTER</td></tr>
<tr><td>大功率</td><td>Z1E-##-110</td><td colspan="2">MARBLE CUTTER</td></tr>
<tr><td>石材切割机</td><td>Z1E-##-180</td><td colspan="2">MARBLE CUTTER</td></tr>
<tr><td>直向砂轮机</td><td>直向砂轮机</td><td>S1S-##-125B</td><td colspan="2">VERTICAL GRINDER</td></tr>
<tr><td>充电式起子电钻</td><td>充电式电钻</td><td>J0Z-##-10</td><td colspan="2">CORDLESS DRIVER DRILL</td></tr>
<tr><td rowspan="3">手电钻</td><td>6mm/手电钻</td><td>J1Z-##-6A</td><td colspan="2">ELECTRIC DRILL</td></tr>
<tr><td>10mm/手电钻</td><td>J1Z-##-10A</td><td>13mm/手电钻</td><td>16mm/手电钻</td></tr>
<tr><td>13mm/手电钻</td><td>J1Z-##-13A</td><td>J1Z-##-13A</td><td>J1Z-##-16A</td></tr>
<tr><td>冲击电钻</td><td>冲击电钻</td><td>Z1J-##-13</td><td colspan="2">ELECTRIC IMPACT DRILL</td></tr>
<tr><td>搅拌机</td><td>搅拌机</td><td>Q1U-##-160</td><td colspan="2">ELECTRIC MIXER</td></tr>
<tr><td>电锤</td><td>20 电锤</td><td>Z1C-##-20</td><td colspan="2">ELECTRIC ROTARY HAMMER</td></tr>
<tr><td>电锤</td><td>26 电锤</td><td>Z1C-##-26</td><td>38 电锤</td><td>Z1C-##-38</td></tr>
<tr><td>电磨头</td><td>电磨</td><td>S1J-##-25</td><td colspan="2">DIE GRINDER</td></tr>
<tr><td rowspan="4">砂光机</td><td>平板砂光机</td><td>S1B-##-110×100</td><td colspan="2">ORBITAL SANDER</td></tr>
<tr><td>平板砂光机</td><td>S1B-##-93×185</td><td colspan="2">ORBITAL SANDER</td></tr>
<tr><td>平板砂光机</td><td>S1B-##-114×234</td><td colspan="2">ORBITAL SANDER</td></tr>
<tr><td>盘式砂光机</td><td>S1A-##-150</td><td colspan="2">DISC SANDER</td></tr>
<tr><td>电 刨</td><td>电 刨</td><td>M1B—FF-82×1</td><td colspan="2">ELECTRIC PLANER</td></tr>
<tr><td>电木铣</td><td>木工雕刻机</td><td>M1R-##-12</td><td colspan="2">WOOD ROUTER</td></tr>
<tr><td>抛光机</td><td>抛光机</td><td>S1P-##-180</td><td colspan="2">SANDER POLISHER</td></tr>
<tr><td>修边机</td><td>修边机</td><td>S1P-##02-6</td><td colspan="2">TRIMMER</td></tr>
<tr><td>电链锯</td><td>电链锯</td><td>M1L-##-405</td><td colspan="2">ELECTRIC CHAIN SAW</td></tr>
<tr><td>曲线锯</td><td>曲线锯</td><td>M1Q-##-85</td><td colspan="2">JIG SAW</td></tr>
<tr><td>电动板手</td><td>电动板手</td><td>P1B-##-20C-22C</td><td colspan="2">ELECTRIC WRENCH</td></tr>
<tr><td rowspan="2">金刚石钻孔机</td><td>钻孔机</td><td>Z1Z-##-90</td><td colspan="2">DIAMOND CORE DRILL</td></tr>
<tr><td>钻孔机</td><td>130.200.250</td><td colspan="2">DIAMOND CORE DRILL</td></tr>
<tr><td>电圆锯</td><td>电圆锯</td><td>M1Y-##-185-235</td><td colspan="2">ELECTRIC CIRCULAR SAW</td></tr>
<tr><td>电镐</td><td>电镐</td><td>Z1G-##-6</td><td colspan="2">DEMOLITION HAMMER</td></tr>
<tr><td>电镐</td><td>电镐</td><td>Z1G-##02-15</td><td colspan="2">DEMOLITION HAMMER</td></tr>
<tr><td>型材切割机</td><td>型材切割机</td><td>J1G-##02-355</td><td colspan="2">ELECTRIC CUT-OFF MACHINE</td></tr>
<tr><td>斜切割机</td><td>斜切割机</td><td>J1X-##-255</td><td colspan="2">ELECTRIC MITRE</td></tr>
<tr><td>往复锯</td><td>往复锯</td><td>J1F-##-30</td><td colspan="2">RECIPROCATING SAW</td></tr>
<tr><td>电剪刀</td><td>电剪刀</td><td>J1J-##-3.2</td><td colspan="2">ELECTRIC SHEAR</td></tr>
<tr><td>电冲剪</td><td>电冲剪</td><td>J1H-##-3.2</td><td colspan="2">ELECTRIC NIBBLER</td></tr>
</table>

Tool / Category	Design	Mechanics	Hydraulic	Electric	Electronic
Chop saw		√			
Grinder		√			
Drill		√			
Drill Press		√		√	
Welding machine		√			
Soldering Iron				√	
Screw drivers		√	√	√	
Wrenches		√	√		
Measuring tape					
Copper hose bending tool			√		

Power tools

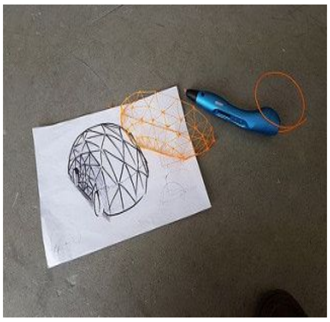
-

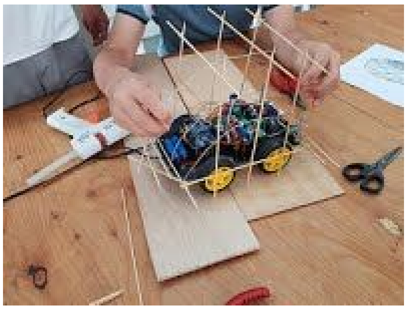
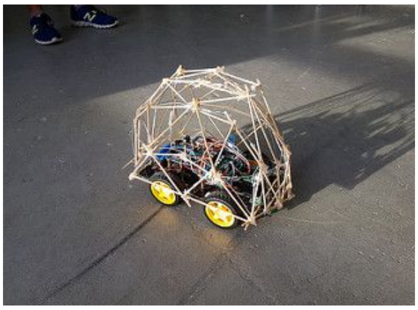
Hand tools

Research by groups

Design Research

3D Model


Using the four-wheeled Arduino-based robotic car as the model vehicle, a scaled version of the dome was built using wooden sticks and plastic panels.

Method A- Overlapping the acrylic

onto the metal frame

Method B- Slotting the acrylic

into the metal frame

Method C- Using tape to

connect the triangles to form a dome

Table below comparing the different methods of fabricating the dome.

	A (overlap)	B (slot)	C (tape)
Waterproof	8	3	2
Can hold shape	10	7	5
Hard	10	8	5
Visibility	6	6	8
Door fabrication (Ease)	7	7	6
Ease of fabrication	4	3	7
Weight	2	3	7

Speed of fabrication	5	4	7
Supply of materials	7	7	9
Experience welding	2	2	-

Scale: 1- least effective, 10- most effective

Testing to see what sized triangles give the best view/ transparency from the driver's perspective (using steel and transparent tape).

Table comparing the different sized triangles and ranking them against each other.

	A (Big)	B (medium)	C (small)
Waterproof	9	6	3
Can hold shape	8	6	4
Hard	8	6	4
Visibility	9	5	2
Door fabrication (Ease)	8	5	3
Ease of fabrication	9	6	3
Weight (given area, 1-lightest, 10-heaviest)	3	6	8

Speed of fabrication	9	7	3
Supply of materials (1- hard to find, 10- easy to find)	3	5	10

White tape

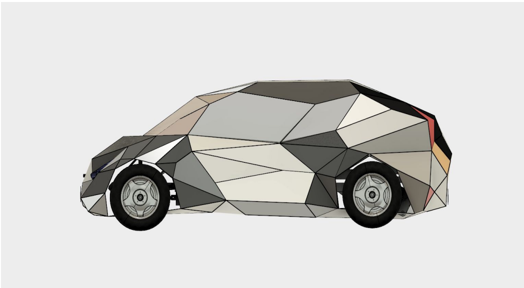
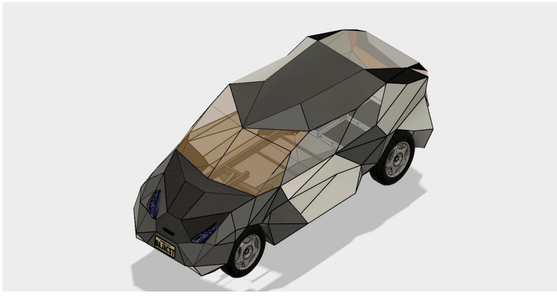
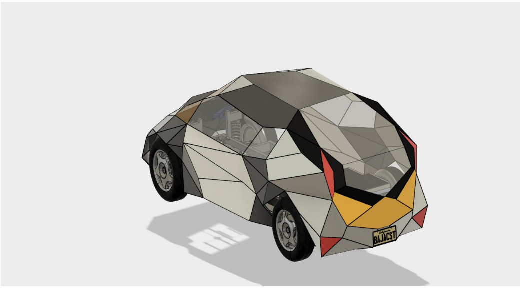
Black tape

Transparent tape and steel

Table below showing the results after investigating the effects of using different methods of combining the pieces of acrylic together.

	A (white tape)	B (black tape)	C (steel)
Visibility	9	3	6
Ease of fabrication (1- easiest, 10- hardest)	2	2	8
Weight (given area, 1-lightest, 10- heaviest)	1	1	9
Speed of fabrication	3	3	8
Supply of materials (1- hard to find, 10- easy to find)	10	10	7

Alternative designs:

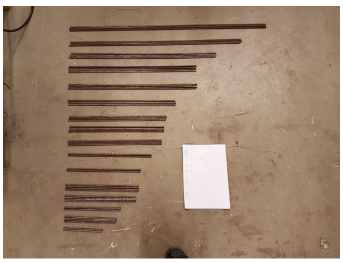
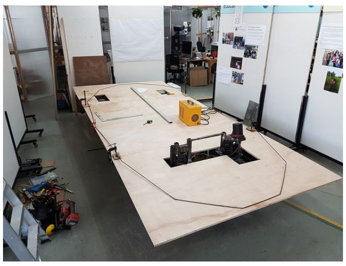
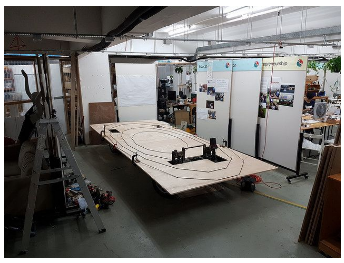




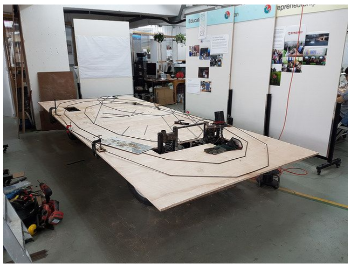
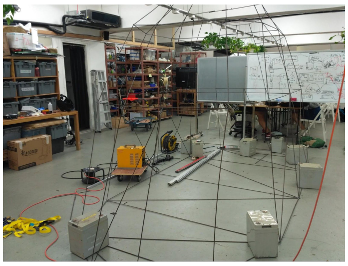
Link to CAD file for alternative design:
http://a360.co/2apoDSF

Building the outer shell

Metal bar of 6.5 mm ~60m

Method

Mechanical Research

Electric Research

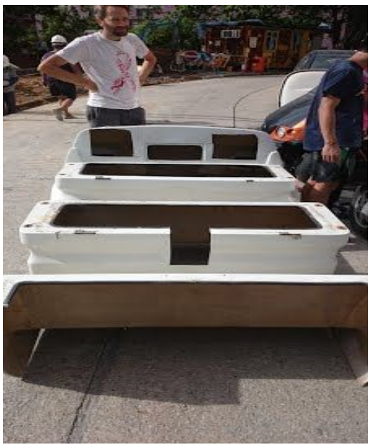
Electronic Research

Software Research

Management Research

- Disassembly of the golf cart :

- Unmounting the golf car to recover the useful parts.




- Cleaning and removal of battery/seat frames

Testing

(Testing lights)

(Testing motors)

(Taking apart the brakes)

(Testing the motor controller)

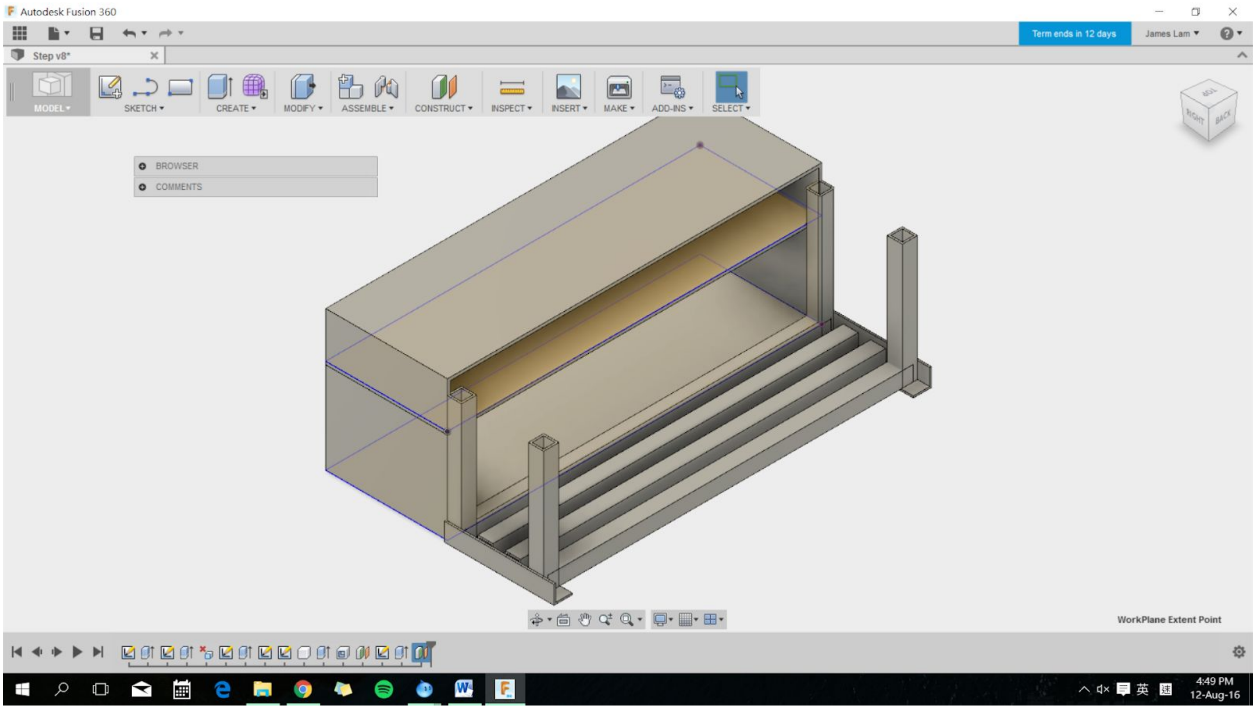
Datasheets
Complete parts list
Pictures

Design Process

Mechanical

Design Process of the foot rest

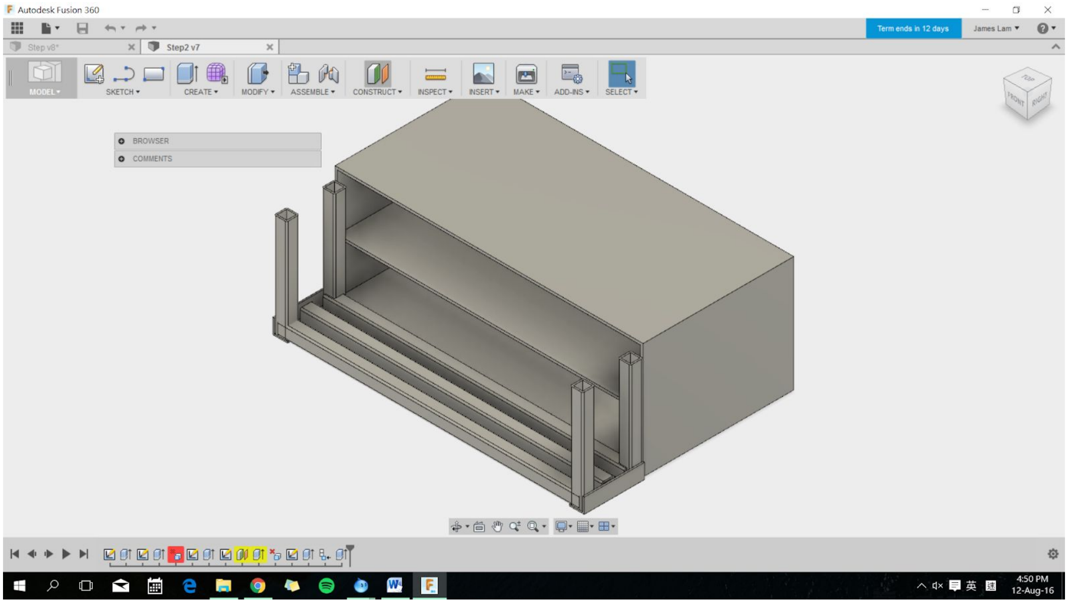
Design 1



http://a360.co/2aOJ1xW

Design 1 is the original idea of a small foot rest in a dimension of 60x30.5x16(cm), the design of this foot rest aims to provide a comfortable place for user's foot. The size of the foot rest is big enough to hold at least 50% area of a foot. In the meantime, the height of the foot rest is high enough to give comfortable space without too much bending.

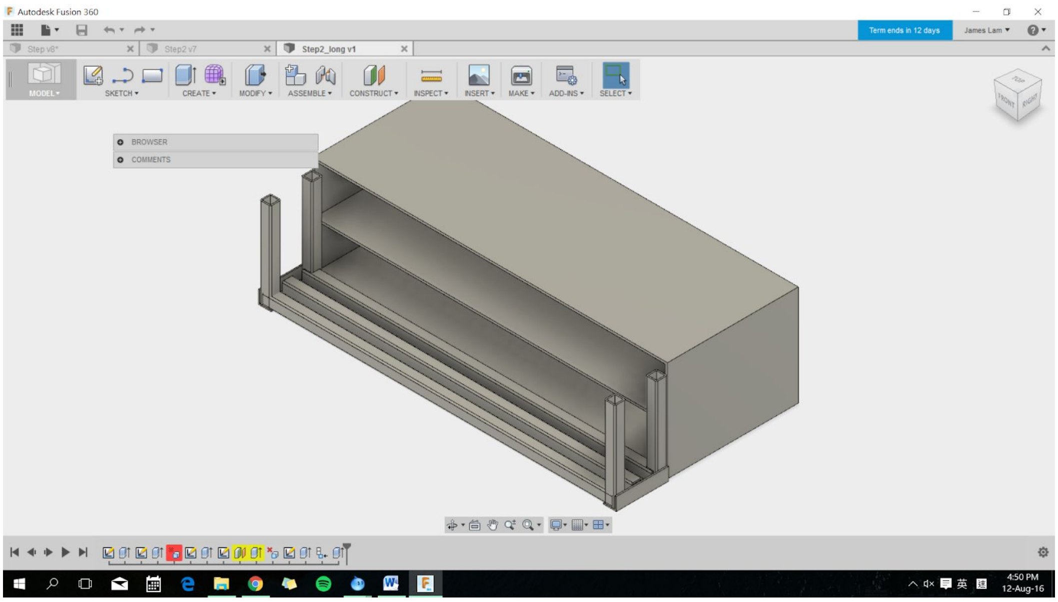
Design 2



http://a360.co/2baCyxS

Design 2 is a smaller foot rest in 60x30.5x10 (cm), this design main changes is that the reduced size to save space for the EV.

Design 3



http://a360.co/2bkNPdp

Design 3 is a length extended version in dimension 80x30.5x10.