Internship Report on

Rocket Motor Static Test Pad

At STAR – Space Technology and Aeronautical Rocketry

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Static Test Pad

What is a Static Test Pad?

Static test pad is basically an instrument with which we can do the static test studies of various types of load, measure the Thrust produced by some means. In this problem statement, we are building it to measure the thrust produced from the Rocket motor.

Basic working principle of Static test Pad:

The Static test Pad does have different components to it , the heart among them is definitely the Load cell. As the load gets applied on the Load cell, the strain guage inside it deforms, and leads to change in resistance which is directly proportional to Potential difference and thereby the force.

The Design section consist of a motor mount where we put our motor to test and the adjust its position accordingly

The micro-controller in the avionics section process the necessary data and provide the required results by giving outputs to terminal.

Why to make Static test Pad?

The basic use of the static test pad is to measure the amount of force a particular object can apply. In the case of rockets, we definitely need to test the rocket engine for not getting any problems during launch. Nowadays, many rocket enthusiasts build their own small level rockets using rocket motors as their engine and go on building test pad by themselves. Not getting the right component at the right time is the problem that most of the people do face. Building a fully functional static test would definitely solve the Problem. On the top of that if it is customisable, then it will definitely be the cherry on the cake.

Architecture:

- Finding whether we want the horizontal mounting system or vertical mounting system
- buiding a basic design

- Taking into considerations different factors that can affrect, modify the design.
- Perform the simulation so as to understand it's properties(The amount of thrust it can withstand)
- Including all the instuments that could be needed
- Setting up the whole module by connecting the avionics section with design
- setting up the code to run certain commands which can give necessary instructions to Avionics system and therby running the whole system
- Analysing the data that is obtained from the electronics system

Basic components, software required to build a Static Test pad:

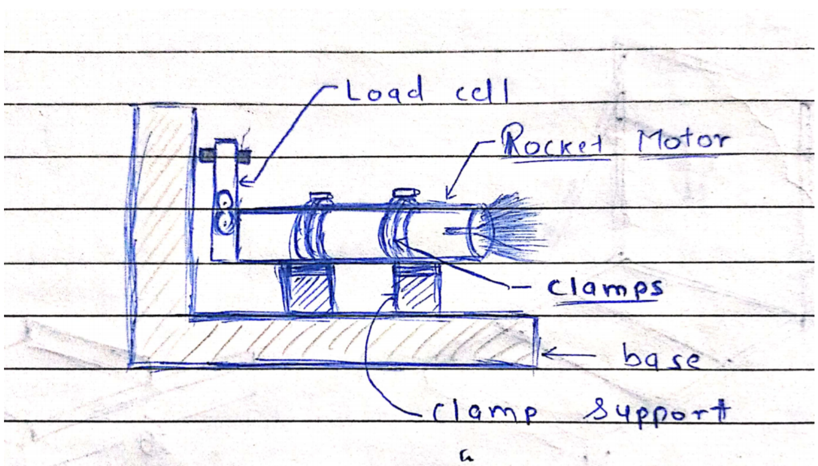
- **List of Components**
  - **Load cell** : It is a force transducer which converts force into electric signals.
  - **Hx711 breakout board** : It is basically a load cell amplifier used to amplify the signals from the load cell.
  - **Max6675 module** : It is basically used to convert the data from the thermocouple to digital form to feed into the arduino board
  - **Arduino board** : It is an open source microcontoller board equipped with a set of digital and analog pins, IC, etc. It mainly used for getting the output data from some input data provided to it.
  - **Thermocouple** : It is a thermo-electric device which is used for mesuring the temperature range.
  - **SD card** : It will be used for storing the output data from the arduino which can be used later for analysis.
  - LEDs, connecting wires,etc

- **List of Softwares**
  - **Autodesk Fusion 360** : It is a 3D modelling software where we can design our model and perform the various types of simulation
  - **Arduino** : It is an Open-source Software where we perform various simulations with respect to electronics and computers by running the code.

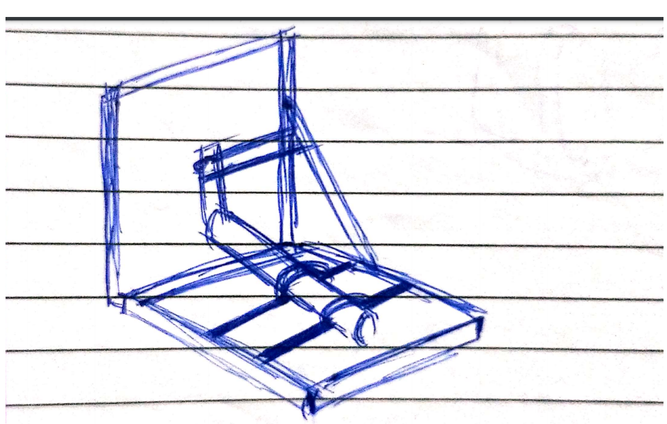
- **Proteus 8 Professional** : It is a software that is used for drawing the schemtics, PCB layout, to code and to even simulate the Schematic integrating it with arduino.
- **EagleEDA** : It is am Autodesk software Primarily used for PCB Design.

Design

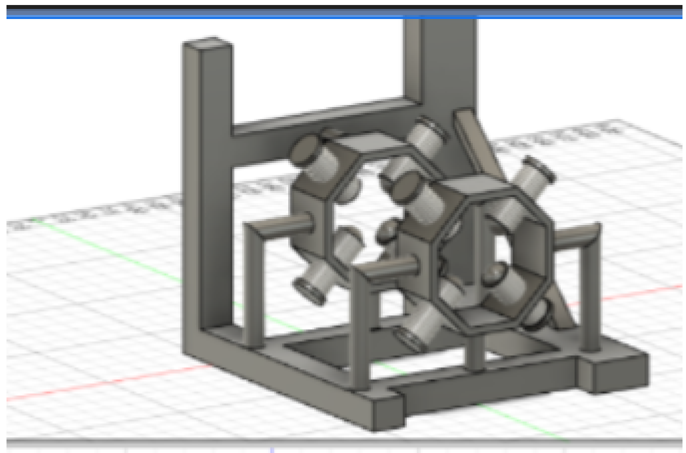
- I have decided to go with the Horizontal mounting system. In this case we basically don't need to worry about the weight factor as it is already getting balanced with the normal reaction.
- The rough design that i have drawn on pen paper is as follows.



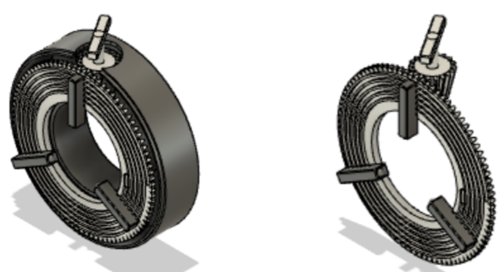
- In this figure i have shown the horizontal mounted system that i had in mind, with the clamps for holding the motor, clamp supports and load cell. I tried to draw a 3D sketch of it.



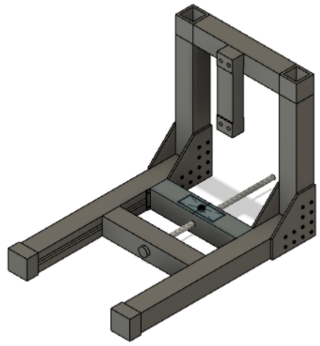
- we have this thing in mind that the rocket motor could be of different radius. So nitish has come up with the following screw mechanism. The following picture is the design made by nitish in fusion 360.

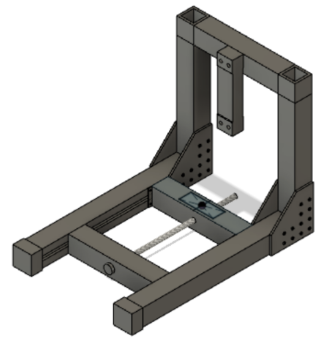


- With the help of the screws shown over here we can adjust the diameter so as to fit in different radius rocket motors. But in this the problem was we have to manually adjust each and every screw to set the position. Instead, the new chuck mechanism that nitish has come upon is something that will solve this problem.

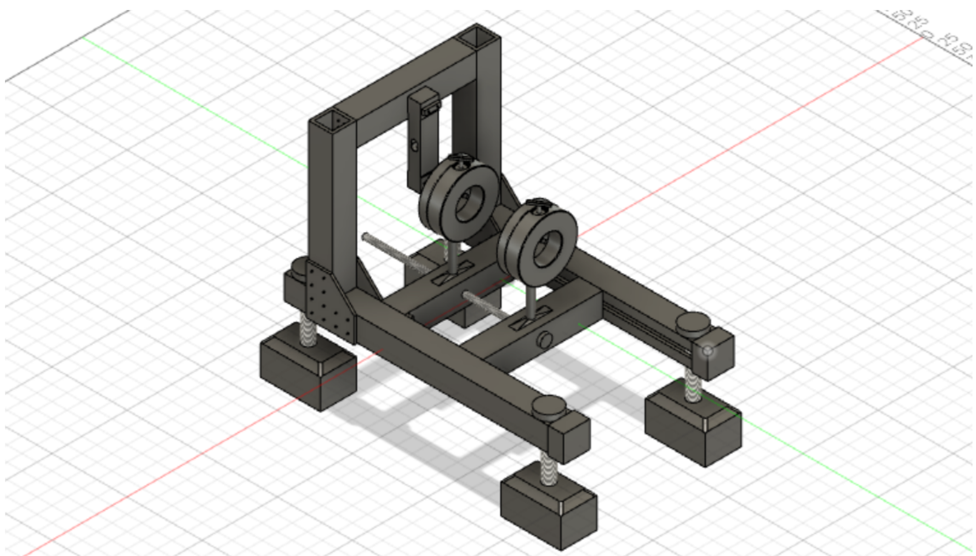


- Here with the movement of the lever we have all the screws rotating going in and coming back together which makes it easy for the user to tighten the motor.
- I had this one thing in mind that, as we can have motors of different radius, we can also have motors of different length. So I wanted to have a mechanism so that the relative distance between the two clamps could be reduced. Then we came up with a mechanism where the clamp supports can be moved with the help a long threaded rod.



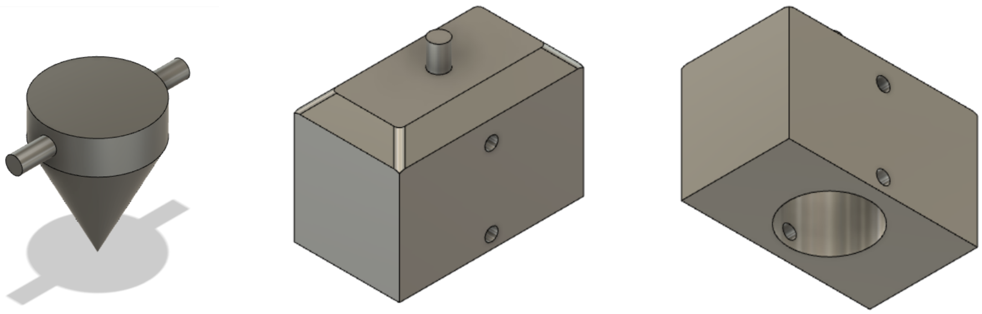


- There could be the chances of having the uneven ground. To encounter that we have used a basic mechanism with the help of Bolts. If one portion of the ground is little higher than the others then the bolts can help in leveling the STP. For stability we have used four base supports which have relatively higher area than the bolts.

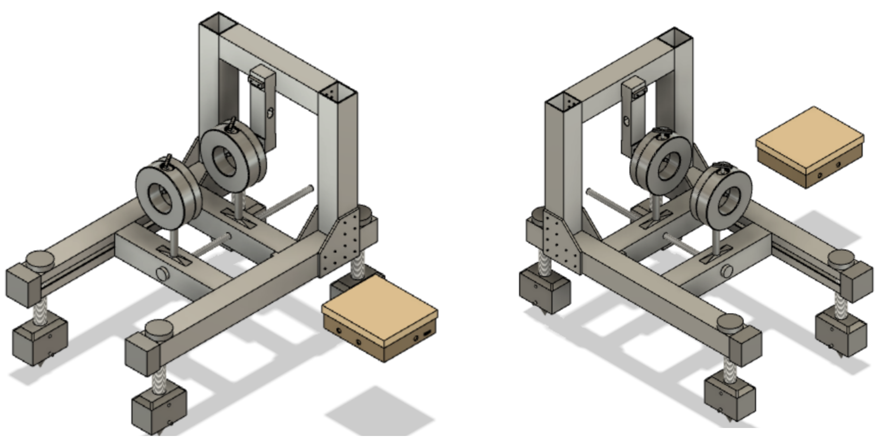


- As our STP can test the high powered rocket motor as well, if we do so, it will not be stable in one position as the only external opposing force i.e. friction force will be very less compared to thrust produced by motor. To takle this we have used spikes in the four leg supports. The spikes are adjustable i.e. they can go in and come out of the leg supports as per the need. (We would need these spikes in a soil ground where we can dig them to fix them properly.

Incase of a plane ground can take the spikes inside the leg supports and can simply give the wall supports for stability.)



- We have on Avionics bay which is modelled in such a way that it has some slots through which we can easily insert our SD card or some wires right from outside and we actually don’t need to cap of the box. The final Design does Come out to be as follows



- For material, we have mainly used Aluminium, Stainless steel, and ABS Plastic:

Components of STP	Quantity	Material	Weight (kg)
Vertical bars	2	Aluminum	0.197
Horizontal bars	2	Aluminum	0.368
Loadcell member	1	Aluminum	0.202
Clamp supports	2	Aluminum	0.207
Slider balls	4	Stainless steel	0.181
Driving shaft	1	Aluminum	0.066
Bar caps	2	Stainless steel	0.354
Leg screws	4	Stainless steel	0.341
Bar connectors	4	Aluminum	0.062
Leg bases	4	Stainless steel	0.854
Spikes	4	Stainless steel	0.106
Spike stopers	4	Stainless steel	0.008
Screws	62	Stainless steel	0.0002
Main Gear	2	ABS Plastic	0.014
Driving gear	2	ABS Plastic	0.004
Clamping members	6	Stainless steel	0.006
Ball joints	6	Stainless steel	0.0003
Clamp cover	2	Stainless steel	0.489
			Total = 10kg

Simulation

The simualtions were performed to analyze the material properties and the amount of thrust the STP can withstand. The different output that are obtained from the simulations results for an applied load of 200N at the centre of the cylindrical structure which reflects the motor are as follows

- Minimum Safety Factor = 3.197
- Maximum displacement = 0.2864 mm
- Maximum Stress = 78.2 MPa

These simulations can be seen from the following pictures:

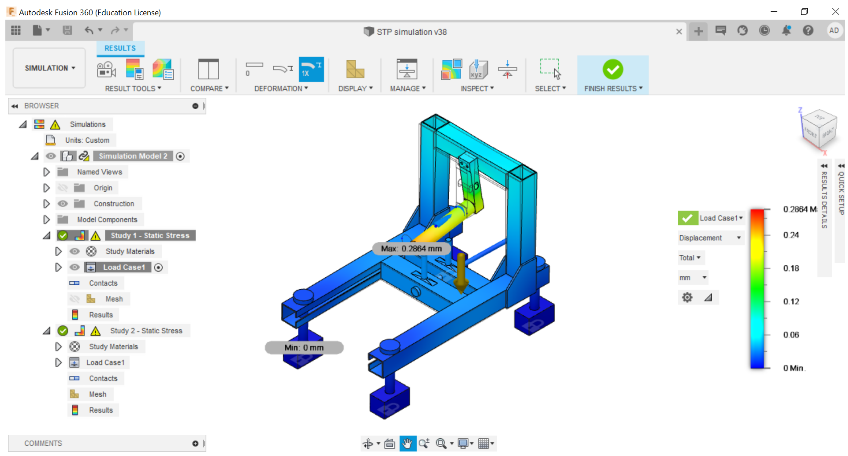


fig : Displacements results

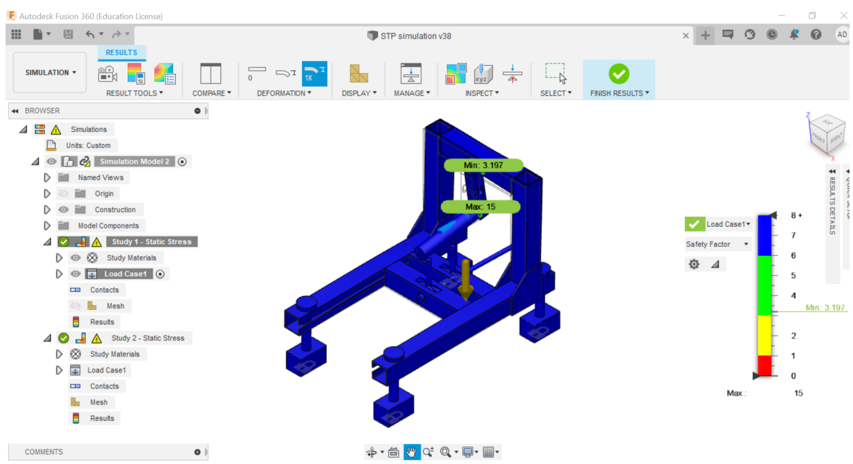


fig : Safety Factor results

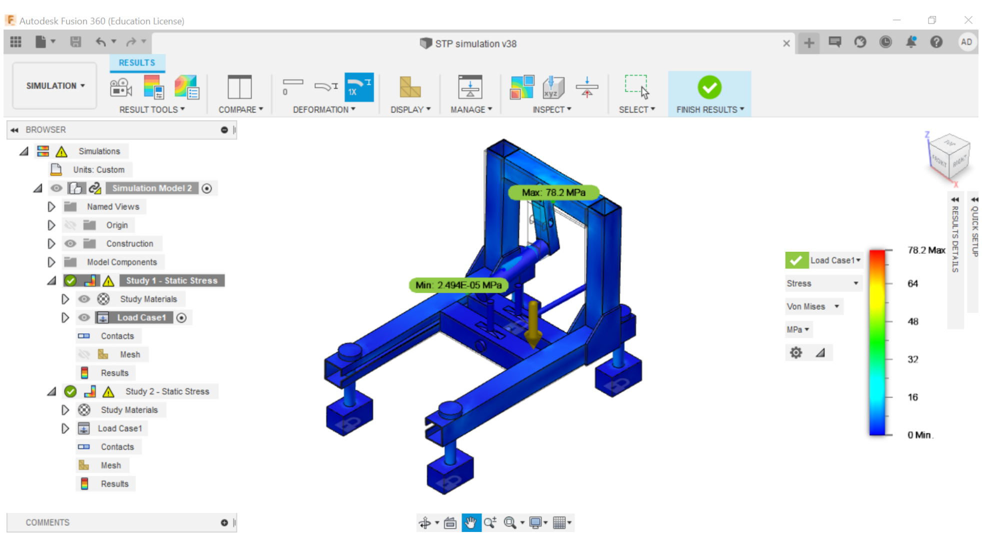


fig : Stress results

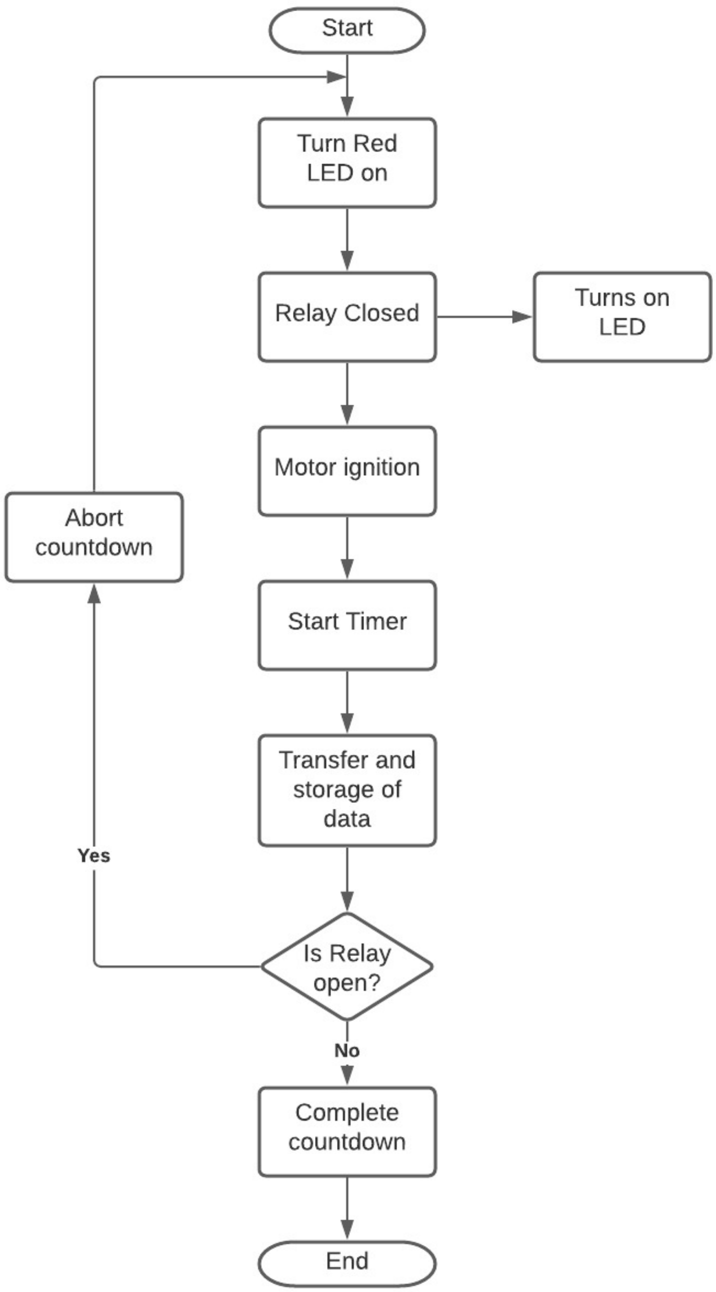
Avionics

- It is very crucial part of the STP. It is the Electronics section of the model which consists of different components that takes input, process the data and gives the Output.
- The first ting that we had to take into account is the components that we could be using. It all starts from the Arduino board and then the components that gives input to it and the component that takes the output.
- The load cell data was the one input to Arduino. But the load cell gives out very low signals, because of which we thought of using an amplifier and after some research we took HX711 breakout board as an amplifier.
- For Temperature measurement we were initially using the LM35 sensor but then I realised that it could not withstand high temperatures. After doing some research i found that k-type thermocouple are actually the ones which can withstand high amount of temprature and therfore we are going with Ni cr/Ni Al, which is one of the best k-type thermocouple which is relatively cheap but measures upto 1150°c.
- As a microcontroller we are using Arduino Uno which we will take the necessary inputs, process the data, and gives the required output.
- For displaying the output and giving the necessary instructions we are using a third party software “Blynk” as a user interface.
- For wireless communication we are using ESP8266 as our wifi Module.

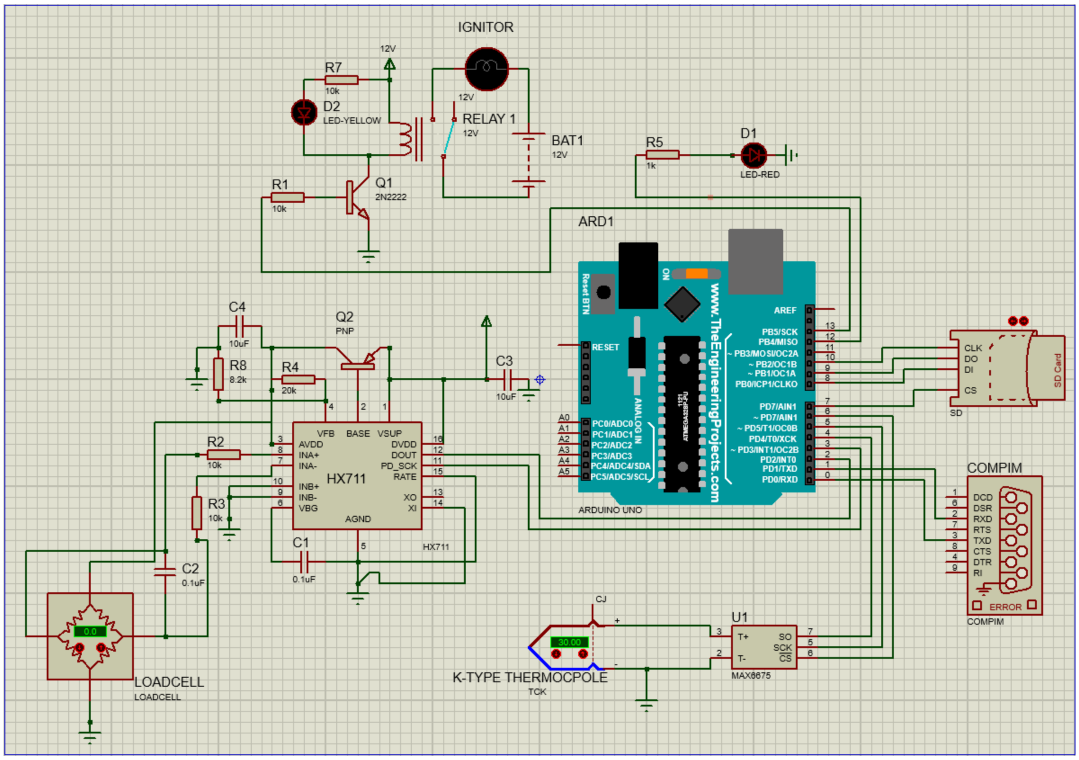
Working

- We will start with turning on the switch on the blynk app which will eventually turn on the ignition switch through the wireless communication. Then we will have a 10 sec delay which is indicated throught the LED light.
- After the delay, the relay will turn on and with the high potential difference the filament will ignite and the the propellant will start to burn and thrust will Produced.
- Thrust produced will deform the load cell and the load cell will convert that into an electrical signal which will then be fed to amplifier which will amplify the signal and send it to Arduino.
- Arduino will take the data, process it and send it to wifi module which will then communicate with the blynk app and we will be able to see the data on the screen.

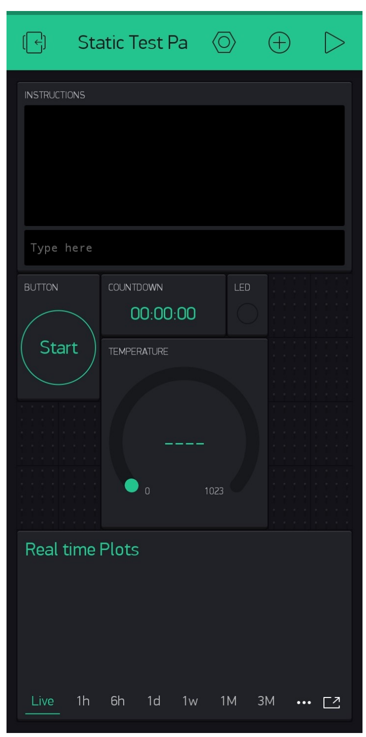
- Similarly thermocouple will also measure the temperature and send that data to arduino and again in the similar manner we can see the temperature data on the screen.
- The flowchart for the above working can be seen as follows:



- The output data will be stored in SD card for future reference. The whole circuit diagram is shown below :



- For our user interface we are using a blynk application where we set it up according to need. The following picture how we have set it to give instructions in the terminal, show the timer, LEDs, temperature values and real rime plots



Price Estimation for the Design can be refered from the below table:

Material	Kg of material	Per kg price	Total price (INR)
Aluminium hollow square bars	1.746	200	350
Aluminium circular rod	0.066	200	13
Aluminium plate	0.3	210	63
Stainless steel spheres	0.725	300	218
Stainless steel circular rods	1.51	180	272
3D printed plastic bevel gears	2 set	500/set	1000
Screws	62 screws	6.77/screw	420
Stainless steel plates	0.703	200	141
Stainless steel rectangular rods	3.835	180	690
Stainless steel spikes	4 spikes	42/spike	168
Machining process			600
			Total = 3934 INR

Price estimation for Electronic components:

- Arduino - 500
- Esp8266 - 120
- Thermocouple+Max6675 - 300
- Load cell - 500
- Hx711 - 70
- SD card module - 80
- Lithium Polymer battery - 1075
- User Interface - 250

Total cost = 2895 INR

Therefore, the total cost of the STP is 3934+2895 = 6829 INR

(Note : The cost could upto 7,500 as well cause we haven’t yet include the connecting wires, LEDs and other small small things.)

Observation and conclusions:

- STP have almost every connection with nuts and bolts which can be easily re-moved and put again leading to easy assembly and dissembly.
- The mechanisms used in this model like the chuck mechanism and the slider mechanism will actually helps any testing wide variety of motors of varying radius or vaying length.
- The chuck mechanism is pretty good, it is very user friendly. User just have to rotate the lever like we do in the tap water case, and all the screws move together.
- It can test the motors of upto maximum length of 250mm and upto maximum diameter of 38mm.
- The Ni Cr / Ni Al (k-type) thermocouple can withstand a temperature of upto 1150°c and measure the same.
- We are using a 40 kg single point load cell which means we can measure thrust upto 400 N. But our STP can withstand higher amount of load as well. we just neet to remove the 40kg load cell and add a load cell which can withstand that much load.

Precautions:

- Make sure all the connections are done properly.
- Make sure to have a wall suppprt if incase we are not digging the spikes into the ground.
- Reading the instructions properly, test only the rocket motors which comes under the range mentioned. taking into consideration the factor of safety is very crucial over here.
- keep a safey distance while performing the test.