Internship Report on

STATIC TEST PAD FOR ROCKET MOTOR TESTING

At STAR – Space Technology and Aeronautical Rocketry

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Problem Statement:

To design a Rocket Motor Static Test Pad for testing and acquiring the required data for the performance analysis of the high powered rocket motors

Static Test Pad

A static test pad, is a designated structure specifically designed for conducting static tests of rocket engines or other propulsion systems. It is a controlled environment where rocket engines are securely mounted and fired to evaluate their performance, functionality, and safety before actual use in a launch vehicle or spacecraft.

Working Principle

The Static Test Pad(STP) consist of 2 systems, Avionics and Mechanical Structure.

Avionic system :- Provides essential monitoring and control capabilities during the testing of rocket engines. Facilitate the collection, analysis, and management of data related to the performance and behaviour of the engine being tested.

Data Acquisition:- The avionic system is responsible for acquiring various data points from sensors and instruments installed on the rocket engine or propulsion system. These sensors measure parameters such as thrust, pressure, temperature, fuel flow rate, vibrations

Control and Monitoring:- Provides interfaces and controls for starting and stopping the engine, adjusting thrust levels, and monitoring critical parameters.

Safety and Emergency Shutdown:- In the event of any abnormal or potentially hazardous situation during the test, the avionic system includes safety features that can trigger an emergency shutdown. This safety mechanism is designed to respond to excessive temperature.

Data Analysis and Visualization:- The avionic system processes the acquired data, performs analysis and generates meaningful insights. It can provide visual representations, graphs, and charts that help us understand the behaviour and performance of the engine, identify problems(if any), and detect anomalies or irregularities.

Mechanical system :- The system on which the Rocket engine is mounted. A space will be designated for the avionic system to be mounted which is close to rocket engine at the same time safe from any potential fire hazard. Sensor and Instruments can be placed at positions conveniently. Designed to withstand the force provided by the rocket engine (max : 5000N) and hold the weight of entire system. Should be easy to assemble and dismantle and have good aesthetics and ergonomics.

Engine Mounting and Support:- The mechanical structure provides a secure platform or mounting system for the rocket engine or propulsion system. It ensures that the engine is firmly fixed in place and properly aligned for the test.

Safety:- The mechanical structure incorporates safety features to contain and control the potential hazards associated with engine testing. Mount for fire extinguisher.

Sensor Mounting:- The mechanical structure have mounting points and provisions for the installation of instrumentation and sensors.

Why to make a Static Test Pad?

Static Test Pad are facilities in which a rocket engine or any other propulsion system is tested. Rocketry is expensive and each rocket launch costs a huge amount. If the engine have some flaws which are undetected because of lack of proper testing can trigger failure in rocket missions. This can incur huge loses to the company and can decrease the credibility of the company. So rocket engine has to be tested.

It provides a controlled environment to assess the performance of rocket engines or propulsion systems before their actual use in a launch vehicle or spacecraft. By conducting static tests, we can measure thrust, pressure, temperature, and other critical parameters to validate the engine's design and performance predictions. This evaluation helps identify any issues or areas for improvement before the engine is integrated into a larger system. It helps us to evaluate the safety aspects of a rocket engine or propulsion system. By conducting controlled firings on the test pad, potential hazards, such as excessive vibration, structural weaknesses, or combustion instabilities, can be identified and addressed. Safety features, including blast walls or containment structures, are incorporated into the test pad to mitigate risks associated with engine testing. It ensures that all components work together as intended and meet the required specifications.

Architecture

Objectives

- To design the static test pad (STP) mechanism with a good strength/weight ratio
- To design a STP with a good aesthetics and ergonomics
- To design a STP which can be assembled and dissembled easily
- To design a structure to install all electronics and power system conveniently
- To perform the required simulations to minimize the errors while operating
- Should be able to test force between 500 to 5000N

1)Considering all these objective a rudimentary design of the system was done. Keeping in mind that the system should be easily dismantled and also should have a high strength and less weight. We decided to make a vertical STP so that the firing can be done upwards and there is no need for a vertical structure to place the system in this way(Can place it on any flat surface).

2)The second problem was the shape of the base of the STP. We had many options but rounded to 3 shapes. Triangle, Square and Hexagon. Triangle has a benefit of using less material while making the STP. But offers less area under the base for placing other system(Avionics..). Hexagon will use more material and can cost more,but offers high surface area under the base. Square at the end came in a balance between these two. It gave good structure at the same time gave enough area under the base.

3)After finalising that the structure will be based on a square i decided to plot the system. For that the dimensions of rocket engine is needed(Height and Diameter). Rocket engines with maximum thrust(5000N and minimum of 500N) ranged a Height of 152mm-1828mm and Diameter of 38mm to 152mm. Very few rockets(only 1 was found) have length more that 1500mm. So we decided to mainly focus on making a structure which can hold a rocket engine of length 1500mm and make an expansion for base structure for engines close to 2000mm.

4)Considering slenderness ratio to be 3 for extra stability the length of the base was taken 500mm. To decrease the weight of structure we decided to make a square shaped frame with a cross shape to hold the centre and cut the rest of materials. The structure is made of Aluminium 6061 and is cut using CNC machine. The centre has a hole threaded for M12 Bolt to fix the S shaped load cell.

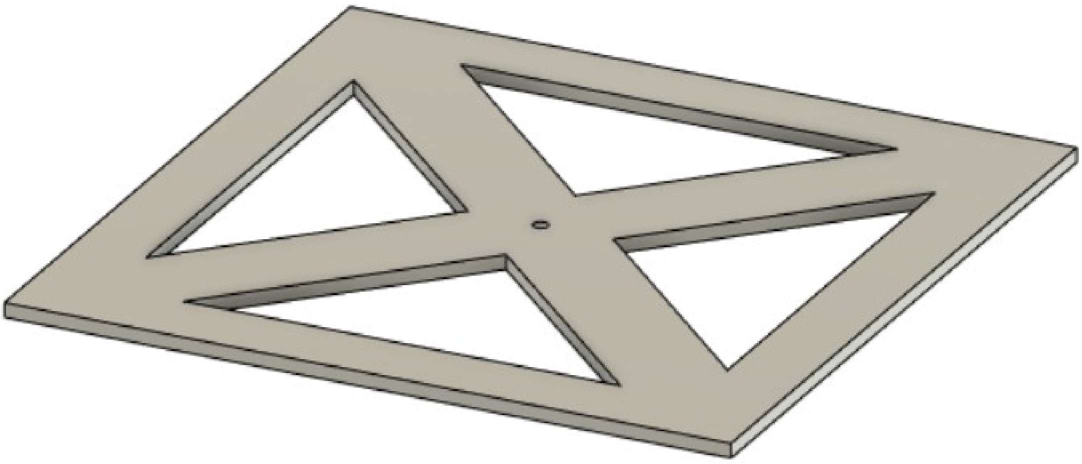


Figure 1: Base Frame

5)Legs has to be fixed and an S- shaped load cell has to be included in the design for find the area where force is acting. Simulations where done and to check the reliability and dimensions where adjusted. A box was also introduced as a designated space for Avionic system.

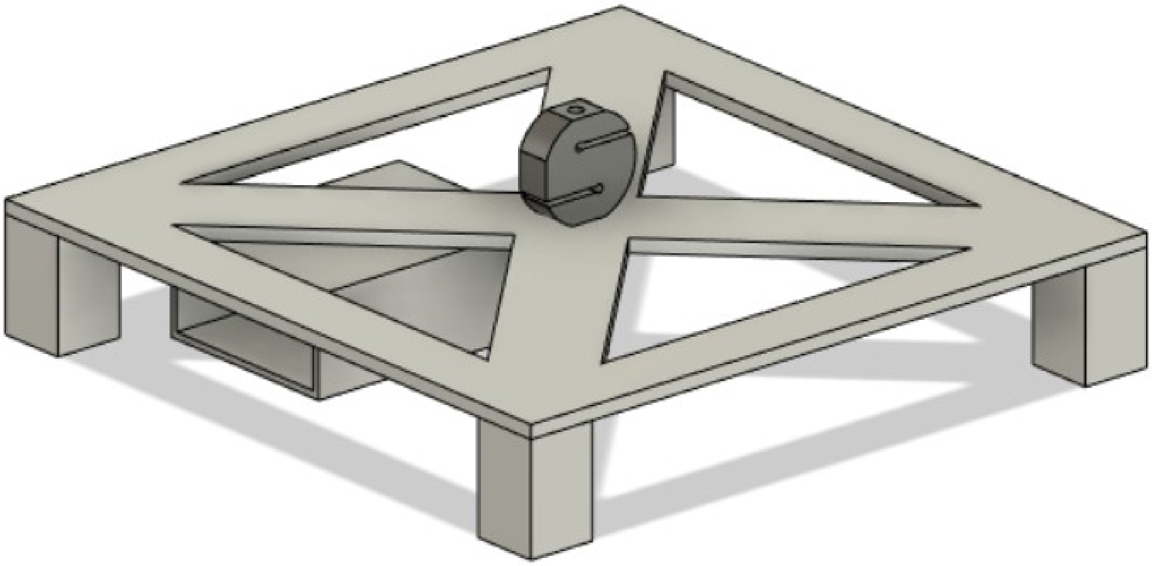


Figure 2: Preliminary Base Structure

6)No we have to create clamping mechanism and Height extension legs. Since Rocket engines a cylindrical mostly the clamping structure should have circle frame. So to convert from square to circle frame we used square aluminium tube which is cut in proper shape to assemble and weld.

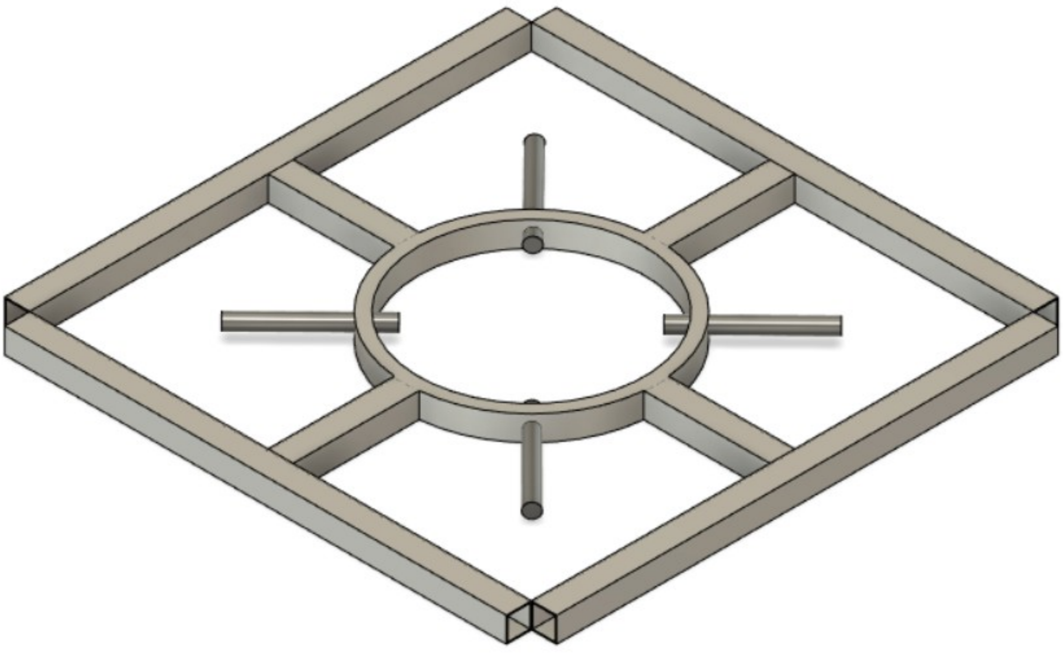


Figure 3: Clamping Frame

7)The clamping frame is using holes with M12 threads which can fix rockets with diameter ranging from 0 to 179 mm.

8) Now the clamping frame and extension leg has to joined which has to be joined with the base. We use L shaped bracket and M5 Bolt(10mm and 20mm) to fix the clamping Frame with Leg and then with base.

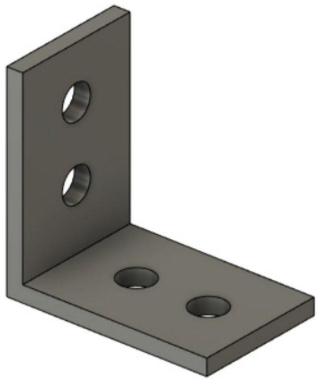


Figure 5: L-shaped Steel Bracket

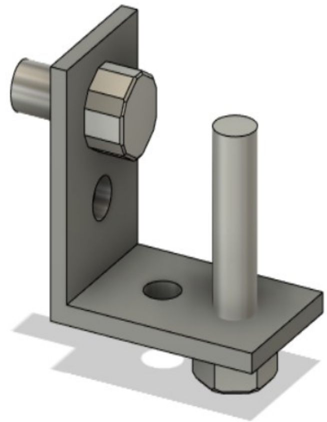


Figure 4: Bracket with Bolts

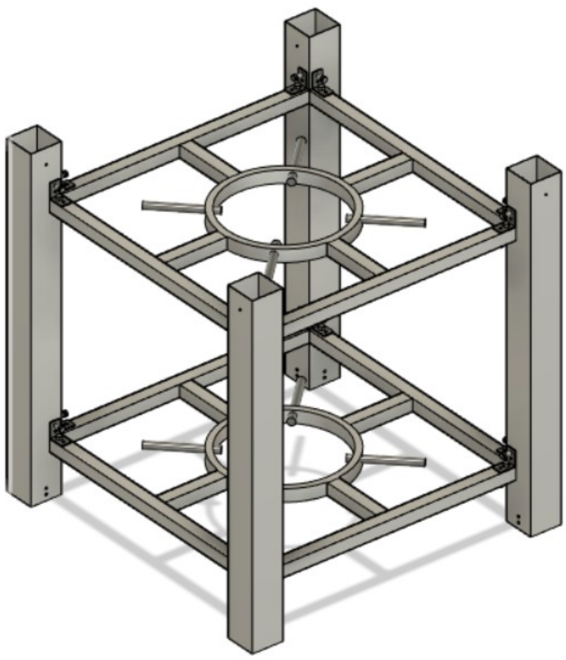


Figure 7: Extension Leg and Clamping Frame connected

9)Figure 7 is connected with base frame for making the system complete. The height extension leg will differ in structure from the base one. There will be an extra extent for the 500mm leg which can be inserted in the leg below and fixed with a M4 bolt.

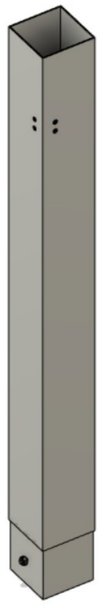


Figure 8: Extension Leg for 5m+ class rocket

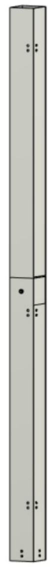


Figure 9: Connection between 2 extension legs

10)The base has an I shaped pillar at the centre for extra weight load. This is fixed with the base frame using 4 M4 nut and bolt which can assembled and removed easily.

Figure 10: I shaped Pillar

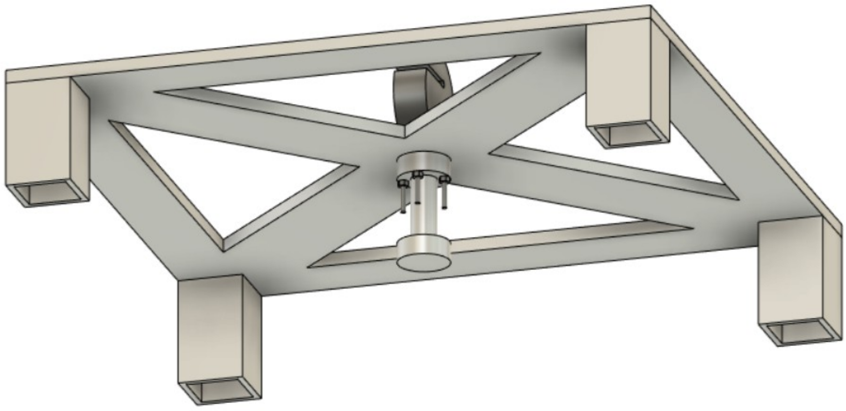


Figure 11: Base with I shaped Pillar

12) There is a small space at the top for M12 nut to fix with the bolt for S shaped Load cell. We first fix the load cell then the I shaped pillar.

13) After uniting all the system we will get the STP.

Basic Components and Pricing of each component

Avionics

Component	Use	Quantity	Cost
ESP32	Data handling and processing	2	₹460
Load Cell	Thrust measurement	1	₹3450
HX711	ADC & Amplifier	1	₹50
MPU6050	Vibration measurement	1	₹150
nRF24L01+PA+LNA	Communications	2	₹300
SD Card Module	Data logging	1	₹135
DS3231 RTC	Accurate Time Keeping	1	₹250
Lipo Battery Pack	Power	1	₹1000
Lock Switch	Physical Arming	1	₹120
Relay	Electrical Arming and ignition	2	₹40
Transistors + Voltage regulator	Relay Activation + Voltage step down	2+1	₹10
Miscellaneous	-	-	₹75
Total			₹6500

Mechanical Components

Components/Other Expense	Use	Price in Rupees
Steel Right Angled Bracket(48 Pieces)	To connect extension leg, clamping frame and base frame	760
Aluminium 6061(27kg)	To make the clamping frame and Base Frame	10125
M4 Nut and Bolt(12 pieces)	To connect extension legs	540
M5 Nut and Bolt(96 pieces)	To connect claming frame and extension leg also with Base	648
M12 Nut and Bolt(13 pieces)	Used to fix Rocket motor and Load cell	3150
Aluminium Square tube pipe	To make clamping frame and extension leg	1600
CNC Cutting Expense	To make circular frame and Base frame	2000
Miscellaneous	Includes cutting and welding expenses and other expenses	1000
Total		19823

Software used to design the STP

1)Autodesk Fusion 360:- This software was used for complete designing and simulation of STP.

2)Open Rocket:- For reference of dimensions of the Rocket engines.

3)Arduino IDE:- Used for coding the avionic system

4)Proteus:- Circuit design of avionic system.

5)Eagle:- For designing PCB’s

Observations

1)The system can handle 5000N thrust and more. The I shaped pillar works effectively in withstanding the rocket thrust
2)The system can be used for checking thrust of 5 classes of rockets according to height.

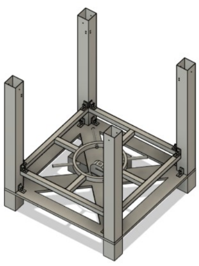
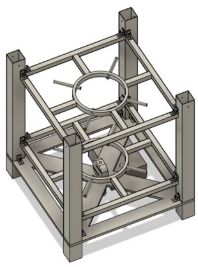
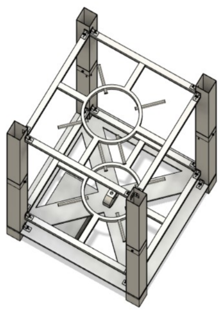
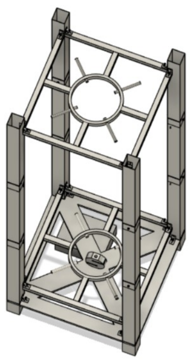
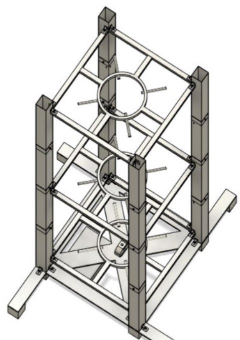
●0-0.5 meter Engine
●0.5 meter to 1 meter class Engine
●1 to 1.5 meter class Engine
●1.5 to 2 meter class Engine
●2 meter+ class Engine

3)The STP can be assembled easily according to the needs because of nut and bolt used in the system.
4)Total weight of Test Pad ranges from 11.28kg to 18.06kg(The smallest STP and largest STP)
5)Total Price of the system is ₹26323/-

Procedure to Build the STP

1) The base frame is made by cutting an Aluminium 6061 plate of thickness 10mm using CNC machine
2) The clamping circle is made by cutting Aluminium 6061 plate of thickness 20mm using CNC machine.(4 frames can be made from one plate)
3)Extension base plate for 2m class rocket can be made from scrap in first process in CNC Machine itself.
4)The Aluminum square tube rod is cut using a angle grinder to suitable length.
5) The leg and base is welded together.
6)Extension legs are assembled at proper positions and locked using brackets and bolts
7)Clamping frame is locked with Extension leg at suitable place.
8)The system is assembled using M4,M5 and M12 nuts and bolts at suitable positions.

5 classes of STP in order

Simulation Analysis

1)The simulation of the static test pad base is given. This simulation was succesful with a minimum safety of 5.849

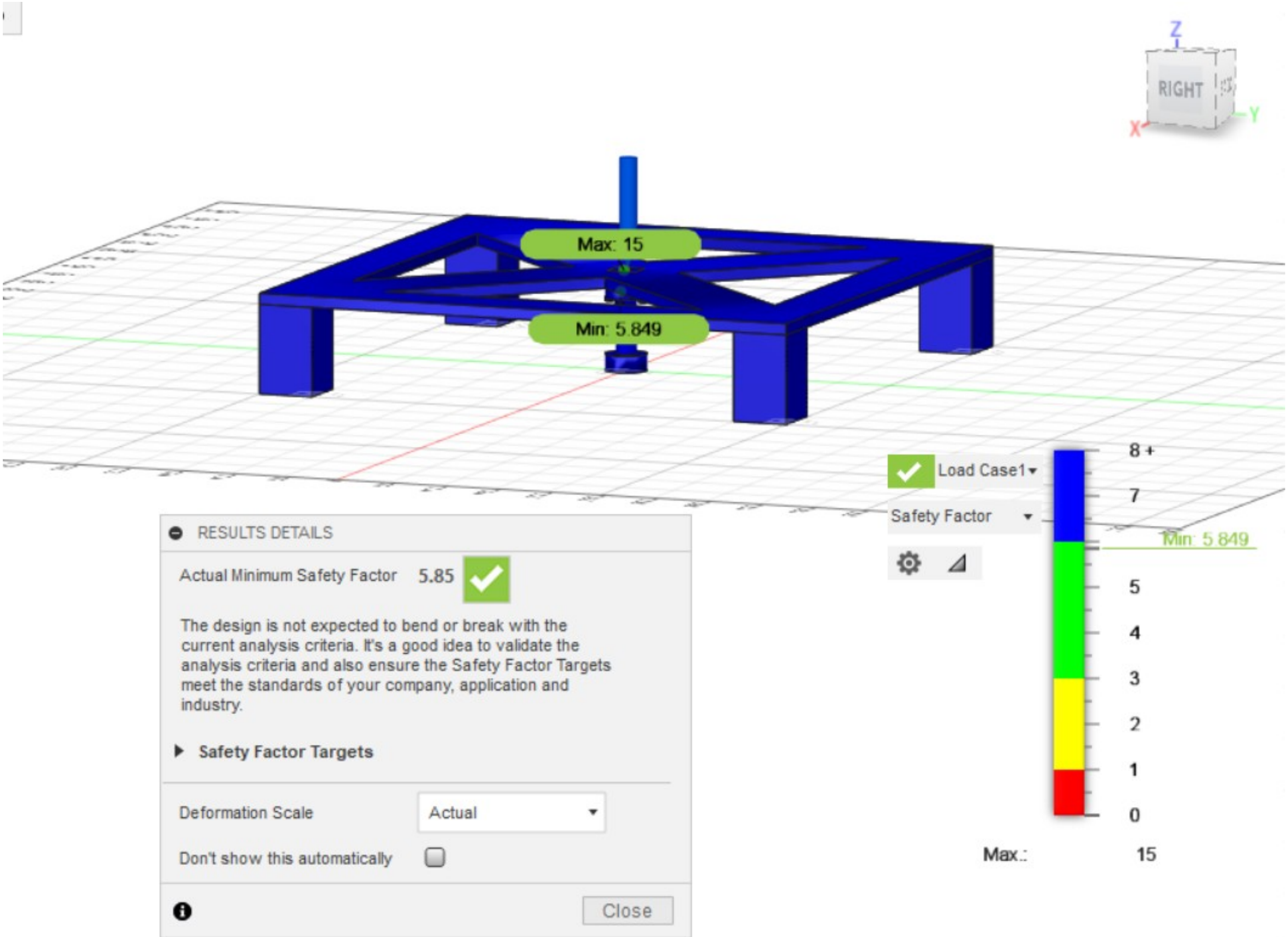


Figure 12: Simulation Analysis of whole base frame. Force is applied on focus of Load cell(The area where load cell is in contact with Base frame)

2) The Simulation analysis of leg. Ifthe system tend tilt one side the leg can withstand the force since it can handle 3000N force.

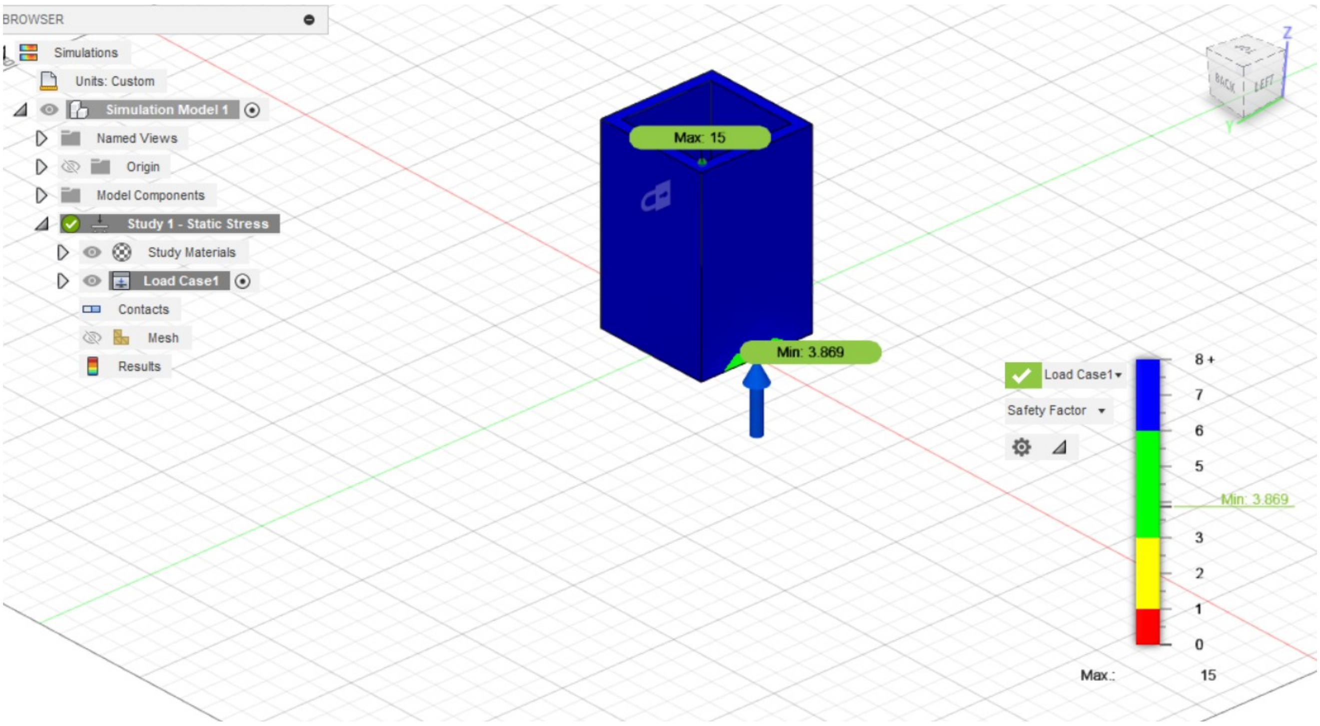


Figure 13: Simulation Analysis for strength of if the system gives some side force of upto 3000N)

Results

The Static Test Pad can test rocket with thrust ranging from 500N to 5000N with the combined system of Avionics and Mechanics. The simulation varified the efficiency of the system. The multi usability of the design is a key and is explained in detail in the report.

Conclusion

The combined efforts of the Avionics and Mechanical design team has helped in creating a viable STP. The structural integrity of the design and the efficiency of the avionic system will surely help in getting a good estimation of parameter while testing without safety risk. The problem statements were completed with teammates Krishna and Bhuwan under the guidance of STAR.

Precausions

1)The design should be made with accuracy especially the CNC cutting and Welding.

2)The Nuts and Bolts should be tight and fixed.

3)Fire proof paint can be used to paint the system for extra safety.

4)Always carry a fire extinguisher during the test.

5)All systems should be checked before test.

6)Final re-check should be done.

7)Standing near STP during test is threat.

8)Tests should be done outdoor.