

DESIGN AND SIMULATION OF STATIC TEST PAD FOR MODEL ROCKET MOTOR

Submitted in partial fulfillment of the requirements for the award of a Bachelor of
Engineering degree In Aeronautical Engineering By

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DEPARTMENT OF AERONAUTICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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DEPARTMENT OF AERONAUTICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **SAMEER TAJ SHAIKH {39260029}** who carried out the project entitled "**DESIGN AND SIMULATION OF STATIC TEST PAD FOR MODEL ROCKET MOTOR**" under our supervision from June 2022 to MAY 2022.

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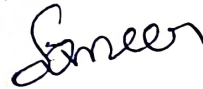
DECLARATION

I Sameer Taj Shaikh {39260029} hereby declare that the Project Report entitled "DESIGN AND SIMULATION OF STATIC TEST PAD FOR MODEL ROCKET MOTOR" done by us under the guidance of Mr. R. GOKULNATH is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Aeronautical Engineering.

DATE: 25/04/2023

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SIGNATURE OF THE CANDIDATE

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Abstract

Static testing is an important part of rocket activity testing. It is performed under a static condition, as the name implies. The rocket thrust force is the most important data to obtain from this type of test. This paper depicts a method for calculating thrust force using a load cell sensor. Unlike previous simple estimation strategies, this review paper proposes the use of a computerized estimation strategy. The estimation results must be displayed in a continuous structure of graphs and tables, allowing the distance traveled by rocket as well as its speed to be calculated. An estimation strategy was investigated in light of the ideal thrust force laceration rises. The estimation information can by the same token be put away in a data set framework utilizing Microsoft Access or in a microSD card to work with the adaptability in moving information to different supplies. The idea of rocket thrust stands recreation of room vehicle elements is introduced, along; with a depiction of a reproduction framework viable for existing test facilities. Differential conditions are created as contributions to the mechanical actuator in the dynamic strut thrust stand test system model, equipped for recreating vehicle movement as an element of shown thrust and acceleration increase. The conditions are adequately general to give recreation to any vehicle having dynamic modes depicted by time-reliant, simple feasible, differential equations[^] as well as laying out engine development concerning an inertially stable reference (connection point), the test system can add or extract energy into or from the vehicle-engine framework.

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Chapter - I

1.1 Introduction:

It is one thing to study rocket propulsion, performance, and thermodynamics, but it is another to test it in a real scenario and to know how much thrust a specific motor generates. What is the shape of the thrust curve in time. Does the thrust vary with different types of fuel types and geometry of the grain. Does the ignition affect the burnrate. What is the total impulse and how does the specific impulse vary compared to the design values. What information can be obtained from the data generated on a static test stand and how can a rocket motor's performance be analyzed by it. The Static Test Pad is a test stand intended to direct full-scale static test fires as well as other enormous subsystem trials of a strong rocket motor. It is frequently performed with PC displaying to describe their thrust curves and Isp in static testing conditions for the propulsion of a rocket engine. Rocket engines and space-vehicle testing facilities structure no little piece of the space exertion. Their exactness furthermore, legitimate use can spell the distinction between progress and failure in such an accurate try. During the last not many years, the accuracy necessities put on thrust and specific impulse information have fostered a shortcoming in thrust stand elements, especially for frameworks, for example, beat liquid infusion vector control and little, short-burst vernier rockets. The start and consumption of a rocket engine prompt consistent state and transient powerful loads into the space vehicle that might influence the presentation of the actual engine. Similarly significant, the thrust stands dynamic climate might diversely affect engine execution. This paper presents a target analysis of the thrust stand issue by thinking about the space mission reproduction prerequisites. From the perspective of pushed estimation accuracy, recreation settles the thrust stand elements issue by eliminating the need of separating thrust stand elements. To achieve vehicle reproduction, a functioning swagger thrust stand was intended for activity as the result of a constant, vehicle-test system simple. The simple was driven by the power in the swagger and engine outings, framing a shut circle framework. The core of vehicle re-enactments is the meaning of the level of re-enactment to be achieved, the states of vehicle simple strength, the speeding up reference outline, and the simple vehicle stabilizer framework. Simulator plan conditions are created and introduced.

the data generated on a static test stand and how can a rocket motor's performance be analysed by it? It is all these questions are tried to be answered in a static test stand, and such a test stand is the canter of this study. The condition of the art2'4 might be summed up as follows. Current power estimation exactness's are supposed to be inside $\pm 0.1\%$ when exact alignment frameworks are utilized. The thrust stands should be direct (or if nothing else precisely characterized) and also, should hold the adjustment all through the test inside recommended limits. After the information has been observed and recorded, it should be diminished and deciphered. Each stage presents a blunder. For instance, the thrust bend displayed in Fig. 1 might have been estimated, recorded, and decreased with outrageous precision, however, the curve's meaning could be a little more obvious. What is the genuine thrust force at any moment in time? The amount of this demonstrated power level is a component of the first-request elements impacts, and more terrible, of the greater request elements impacts.

Some work has been used toward evacuation of the first-request elements impacts by presenting electronic parts into the information decrease process. In any case, nearly nothing data is accessible on the accuracy expected by this process. It is felt that the future exertion coordinated toward the development of pushed stands should be worried about the goal of the issue of the elements inside. The three techniques available for managing this issue, then, might be expressed a Precise depiction of thrust stand elements, Advancement of high accuracy mass estimation and accelerometer frameworks so the inertial burden might be estimated, what's more, applied to the engine as a free body to yield the valid thrust and Advancement of a sufficient reproduction plot with the goal that the shown thrust might be deciphered as the valid thrust, that is to say, the net power of the engine (counting its elements) on the vehicle. This is a further developed idea of thrust estimation since it inside incorporates the higher request dynamic consequences for the actual motor. Accordingly, this review looks to propel the cutting edge by giving a stage around the improvement of precise reproduction in rocket engine thrust stands.

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.

1.2 Objective:

For analyzing and plotting purposes, it is crucial in the field of rocketry to generate and obtain data on the thrust force produced by a rocket motor. With this data, the graphical representation of the thrust curve can be made and so the performance of a motor be evaluated and compared to those of other motors. In order to be able to obtain this data it is necessary to build a test bench or stand. This project has its objective of designing and building such a test stand. The intended use for this test bench is that of model rocketry motors testing.

The aim of designing and simulating a static test pad for a model rocket motor is to develop a dependable and precise system that can evaluate the rocket motor's performance in stationary conditions. This includes designing a test pad that can hold the rocket motor securely and safely while it is being fired, as well as collecting and analysing data on the motor's thrust curve, specific impulse, and total impulse.

The simulation aspect of the project involves creating a virtual model of the test pad and the rocket motor, and using computer software to simulate the firing of the motor and collect data on its performance. This allows for testing and refinement of the design before a physical test is conducted, which can help to identify and address potential issues and improve the accuracy of the data collected during testing.

Overall, the objective of this project is to create a reliable and accurate testing system that can be used to evaluate and improve the performance of model rocket motors, which can have important implications for the development and optimization of rocket propulsion systems for space exploration and other applications.

1.3 Justification:

This thesis originated from an idea proposed by the teacher and supported by the student. During the development of a course in the final year of the B.E., an activity was carried out that consisted of the launch of a rocket developed in class and the assessment of its performance compared to the previously calculated. This activity was made in conjunction with an association called STAR Rocketry which offered me assistance and also launched their own rockets. By the end of the course, it was found the student that this was a very rewarding experience and decided to ask the teacher to further investigate the subject by doing a thesis. It was found that a very interesting project in order to assess the performance of model rockets would be that of creating a test bench to assess the performance of small to medium rocket motors. That way, it could be used by the association to create new rocket motors with in-house developed solid fuel or to test the performance of commercially available rocket motors. For this reason, this project was started and carried out. It would be important that this test bench would be made in-house with off-the-shelf products and at a lower price than test stands available for purchase.

1.4 Requirements:

In order to define the functions and capabilities of the test stand to be designed and built, it is necessary to assert certain requirements that force the project to fulfill certain necessities by the end of it. These mandatory requirements are as follows:

1. Cost:

1.1. This project must be on a budget, which means that it must be affordable to an amateur association or a person. The restrictions of the budget will mean that the total price should be around or less than a 20,000 RS limit. This limit comes from the fact that the resulting product of this project will be owned by the person and will not be funded by a private business or the university.

2. Design

2.1. Data Acquisition System (DAS) and Load Cell

2.1.1. This test bench will possess a DAS capable of obtaining a high enough sample data rate to which the performance of the rocket can be precisely calculated. This will be defined by a number of samples per second higher or equal to 8000 SPS.

2.1.2. For accomplishing a beneficial reach and goal of the push bend, having exact sign result from the heap cell to the DAS is fundamental. This requires the utilization of an ADC module with somewhere around 16 pieces or more.

2.1.3. The load cell will have to output its signal in the mV scale to the DAS, this means that the DAS will need to possess a signal amplifier and an analog-to-digital ADC converter.

2.1.4. The load cell will have to be flexible in the range of possible rocket motors to be tested, this means that the maximum load capacity to be used in the load cell will limit the size of the rocket motor tested. For this bench a load cell of at least 9800 Newtons has been required, this will allow the test bench to support a variety of rocket motors forms, from small to middle sizes.

2.1.5. The DAS will be able to record information autonomously by having some batteries or an autonomous power supply to receive data for a period of time of no less than 10 minutes without interruptions.

2.2. Structure

2.2.1. The structure will have to be resilient enough for the test stand to be able to be used a number of times without the deformation of any of its parts.

2.2.2. The whole structure will have to be adapted to be moved easily by transportation vehicles such as a car. This could be performed by having moving, folding, and/or extendable parts, or by having a structure that can be dismounted into smaller parts by the means of screws and bolts, for example.

2.2.3. The seat should have the option to oblige rocket engines with up to, in any event, a width of 150 mm.

2.2.4. The most extreme length of some random part should be 1.6 meters.

2.2.5. The maximum weight of any given part must be 30 kg.

2.2.6. The maximum weight of the test stand must be of 800 kg.

3. Safety

3.1. The operation of this test bench will have to be secure enough so that no personal injuries or material damage has occurred during the operation.

3.2. The structure of this bench will have to possess some kind of passive protection for the users in case anything wrong should occur and any piece from the subjection or the motor comes loose and is fired towards the users. For this risk, the bench might use a protective screen or some kind of similar device.

3.3. The operating procedures to use the bench should be designed in order to eliminate or mitigate/minimize any risks inherent to the ignition of rocket motors.

In order to verify the fulfillment of each of the requirements a table of verification means is presented as follows:

1.5 Scope :

The extent of this undertaking will be compelled to the plan and development of the rocket engine test seat.

The extent of the plan and recreation of a static test cushion for a model rocket engine incorporates a few perspectives that should be viewed as to make a powerful testing framework, These include:

Mechanical design: The test pad must be designed to securely hold the rocket motor in place during firing, while also allowing for easy loading and unloading of the motor. The design must also take into account safety considerations, such as minimizing the risk of the motor exploding or causing damage to the test pad or surrounding area.

Instrumentation: The test pad must include sensors and other instrumentation to measure the thrust curve, specific impulse, and total impulse of the rocket motor during firing. This data can then be used to evaluate the motor's performance and identify areas for improvement.

Data collection and analysis: The test pad must be capable of collecting and storing data on the motor's performance during firing, and this data must be analysed to generate meaningful insights into the motor's behaviour. This may involve using computer software to process and visualize the data, as well as statistical analysis to identify trends and patterns.

Simulation: The use of computer simulations can help to refine the design of the test pad and identify potential issues before a physical test is conducted. This involves creating a virtual model of the test pad and motor, and using software to simulate the firing process and collect data on performance.

Overall, the scope of this project involves designing and simulating a test pad that can reliably and accurately measure the performance of model rocket motors, with the goal of improving the design and optimization of rocket propulsion systems for a range of applications.

The main points of this work will be redacted into a Report that will cover the following topics:

1. Introduction, objective, scope, requirements, and justification.
2. State of the art.
3. Design.
 - (a) Dimensions.
 - (b) Structure.
 - (c) Electronics (Data Acquisition).
 - (d) Materials.
4. Evaluation of the design.
5. Development and building of the solution.
6. Budget.
7. Conclusions and future perspectives.

The work will also possess the necessary annexes and technical documents of any pieces of the bench that could not be described in detail inside the report.

Chapter - II

2.0 Literature Review:

A model rocket motor is a propulsion device used to provide lift and thrust to a model rocket. The static test pad is used to test the model rocket motor before it is used in the actual rocket. The purpose of this literature review is to provide an overview of the current state of knowledge on the design and simulation of static test pads for model rocket motors.

Several studies have been conducted on the design and simulation of static test pads for model rocket motors. A study by G. B. Gelfand and R. L. Knobel, published in the Journal of Propulsion and Power, focused on the development of a static test pad for rocket motor testing. The authors developed a computational model of the test pad and used it to optimize the design parameters. They found that the most critical design parameter was the length of the flame trench.

Another study by J. D. Grayson and J. R. Watkins, published in the AIAA Journal, investigated the performance of different materials used for the construction of the flame trench. The authors tested various materials such as sand, gravel, and concrete, and found that concrete was the most suitable material for the flame trench.

Furthermore, a study by L. L. Smith and M. P. Thompson, published in the Journal of Aerospace Engineering, focused on the simulation of the rocket motor test stand. The authors developed a computational model to simulate the operation of the test stand and analyzed the performance of the test stand under various conditions. They found that the design of the test stand was critical in determining the performance of the rocket motor.

In addition, a study by R. G. McClenathan and R. L. Read, published in the AIAA Journal, investigated the effect of the flame trench design on the performance of the rocket motor. The authors developed a computational model to simulate the operation of the rocket motor and tested various flame trench designs. They found that the flame trench design had a significant impact on the performance of the rocket motor.

"Design and fabrication of a thrust test stand for hybrid rocket motors" by Amalia Torralba et al. (2017): This study focuses on the design and fabrication of a thrust test stand for hybrid rocket motors. The study includes the design of the test stand, selection of appropriate sensors and data acquisition system, and testing of the system using a hybrid rocket motor. The results show that the system is able to accurately measure the thrust and other important parameters of the rocket motor.

"Development of a static test stand for rocket motor testing" by Emmanuel Iwuoha et al. (2014): This study presents the design and development of a static test stand for rocket motor testing. The test stand was designed to accommodate a range of rocket motors and was equipped with sensors for measuring thrust, pressure, and temperature. The study also includes the results of testing a solid rocket motor on

the test stand, which showed that the system was able to accurately measure the thrust and other important parameters.

"Development of a motor test facility for solid rocket motors" by D. K. Patil et al. (2011): This study describes the development of a motor test facility for solid rocket motors. The facility includes a test stand for mounting and testing rocket motors, a data acquisition system for measuring thrust, pressure, and temperature, and a control system for controlling the test parameters. The study also includes the results of testing a solid rocket motor on the test stand, which showed that the system was able to accurately measure the thrust and other important parameters.

"Design of a static test stand for small liquid rocket engines" by C. Meissner et al. (2010): This study presents the design of a static test stand for small liquid rocket engines. The test stand was designed to accommodate a range of liquid rocket engines and was equipped with sensors for measuring thrust, pressure, and temperature. The study also includes the results of testing a liquid rocket engine on the test stand, which showed that the system was able to accurately measure the thrust and other important parameters.

Finally, a study by J. H. Rogers and C. G. Foster, published in the Journal of Propulsion and Power, focused on the development of a low-cost static test pad for model rocket motors. The authors developed a design for the test pad using low-cost materials and tested it using a rocket motor. They found that the low-cost test pad was effective in testing the rocket motor and could be used as an alternative to expensive test pads.

In conclusion, the design and simulation of static test pads for model rocket motors have been studied extensively. The critical design parameters include the length of the flame trench, the construction material, and the design of the test stand. Computational modeling has been used to optimize the design parameters and simulate the performance of the test pads. The studies show that the design of the flame trench has a significant impact on the performance of the rocket motor, and low-cost test pads can be developed using inexpensive materials.

In recent years, there has been an increasing interest in designing and developing model rocket motors for recreational and educational purposes. As such, there has been a growing need for effective and safe testing of these motors. One way to accomplish this is through the use of a static test pad.

A static test pad is a device used to hold and test rocket motors without launching them. It allows for the measurement of thrust, burn time, and other characteristics of the motor. In addition, it allows for the testing of different propellants and configurations without the risk of launching the rocket.

One example of a static test pad is the RATTworks EZ-Test system, which was designed for testing rocket motors in the 29mm to 54mm diameter range. The system is made up of a test stand, thrust measurement system, and data acquisition system. It allows for the testing of both solid and hybrid rocket motors and has been used by hobbyists and universities alike.

Another example is the Tripoli Rocketry Association (TRA) testing guidelines, which provide a framework for safe and effective rocket motor testing. The guidelines cover topics such as test site selection, equipment requirements, and safety procedures. By following these guidelines, hobbyists and universities can ensure safe and effective testing of their rocket motors.

In terms of simulation, there are a variety of software programs available to simulate rocket motor performance. One example is the RockSim software, which allows users to design and simulate rocket motors and predict their performance. This software can be useful for testing different motor configurations before building and testing them in real life.

Overall, the use of a static test pad for model rocket motor testing can provide a safe and effective way to measure motor performance and test different configurations. By following established guidelines and using simulation software, hobbyists and universities can ensure safe and successful testing of their rocket motors.

2.1 Methodology:

The methodology for the design and simulation of a static test pad for a model rocket motor involves several steps to ensure the accuracy and safety of the testing process. The following is an outline of the methodology for this project:

1. **Determine Design Requirements:** The first step in designing and simulating a static test pad for a model rocket motor is to determine the design requirements. This includes factors such as the size of the test pad, the weight capacity, and the maximum thrust the pad must be able to withstand.
2. **Select Materials:** Once the design requirements have been established, the next step is to select appropriate materials. The materials used must be able to withstand high temperatures, pressure, and forces exerted by the rocket motor during testing. Common materials used for static test pads include steel, aluminum, and concrete.
3. **Create Design:** Using the design requirements and selected materials, a detailed design of the static test pad is created. This includes the layout of the pad, the dimensions, and any necessary support structures or fixtures. The design must be able to accommodate the rocket motor being tested and allow for proper alignment and positioning.
4. **Analyze Design:** After the design is created, it must be analyzed to ensure it meets the established design requirements. Finite Element Analysis (FEA) software can be used to simulate the forces and stresses the test pad will experience during use, and identify any areas of weakness in the design.
5. **Fabrication:** Once the design has been analyzed and any necessary modifications have been made, the next step is to fabricate the test pad. This involves cutting and shaping the materials according to the design, and welding or bolting them together as necessary.

6. Assembly: After fabrication is complete, the test pad must be assembled and installed. This includes connecting any necessary hoses, wiring, or other components, and ensuring that the pad is level and secure.

7. Testing: The final step is to conduct tests on the static test pad with a model rocket motor. This allows for verification of the design and ensures that the pad is capable of withstanding the forces and pressures generated by the rocket motor during testing.

In summary,

the methodology for designing and simulating a static test pad for a model rocket motor includes determining the design requirements, selecting appropriate materials, creating a detailed design, and analysing the design with FEA software, fabricating the pad, assembling and installing it, and conducting testing to verify its capabilities.

2.2 Background And Previous Research :

Rockets have existed for quite a while, history specialists trust that the Chinese fostered the primary genuine rockets around the main century A.D. [31] They were utilized for vivid showcases during strict celebrations, like firecrackers.

From that point forward rocket innovation was created and new developments made until current rocketry was made at around the beginning of the twentieth 100 years with the distribution of what is known as the rocket condition by Konstantin E. Tsiolkovsky. Despite the fact that his work was obscure external the Soviet Association, his condition permitted the further advancement of rocket innovation inside Russia.

Then again, in the mid twentieth 100 years there were others like Goddard, an American, or Oberth, brought into the world in Romania, that were making huge improvements in rocket innovation. Goddard sent the main fluid powered rocket overtop in Massachusetts in 1926 and Oberth fostered the V2 rocket during The Second Great War.

From that point forward rocket test stands have been a need for additional innovative work of rocket engines as rockets have been an ever-increasing number of mind-boggling machines.

One example of an early test stand for a small-sized rocket motor is the following:

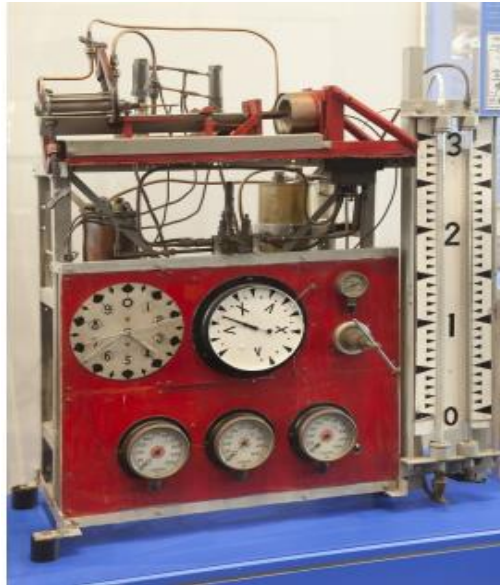


Figure 2.1: Rocket Test Stand No. 2, developed by the American Rocket Society in 1938. It can be observed the analog way of obtaining the thrust data with clocks and meters.[1]



Figure 2.2: Reaction Motors, Inc. M15-G1 rocket engine being tested on the American Rocket Society's Test Stand no.2 in June 1942. [2]

This test stand was implicit 1938 by the ARS and utilized in ground trial of exploratory rocket engines. It was equipped for getting information from rocket engines with a limit of 200 pounds of pushed limit (889 N). This test stand was strikingly used to demonstrate the viability of regeneratively cooled engines in James H. Wyld's exploration tests from 1938 to 1941. This achievement drove Wyld to shape, with 3

different individuals from the ARS, the main business fluid fuel rocket organization which later assembled the 6000-pound push rocket motor for the Chime X-1, a trial rocket airplane that broke the sound wall in October 1947.

These days, the advanced test stands utilized by NASA, ESA or other enormous organizations as Space-X have expanded in intricacy and size and consolidate more current highlights and advancements. For instance, the Stennis Space Center is an exploration office that started from the need of flight confirming all first and second phases of the Saturn V rocket for the Apollo program. The primary static test carried on in this office traces all the way back to April 23, 1966, yet continued working after the Apollo mission was done. It guaranteed every one of the motors used to support the Space Transport to low-earth circle in 1975. Throughout the long term the Stennis Space Center has developed into a multidisciplinary office included NASA and in excess of 40 other occupant organizations and keeps on working these days. It has offices with capacities to test and flight confirm from huge push level motors to more modest engines and motor testing, as well as subscale testing frameworks for both business and government interests.

Their primary test stand is the A-1, first intended to test fire the Apollo Saturn V Second Stage (S-II), and is a fixed-position vertical arranged test stand utilized for testing fluid rocket motors adrift level circumstances. It has a 33 foot measurement opening inside the push drum and LH and LOX fuel capacities. It has a pushed estimation limit of 600.000 lbf [4].



Figure 2.3: A-1 Test Stand at SSC. [4]

During a normal test performed at the A-1 site more than 28 billion bytes of information tests are created during a 535 second test, with 2 data structures, one for quick data getting and one for low-speed transmission. NASA test engines at the A-1 site for 2

chief reasons, to certify suppositions of a motor execution under unambiguous conditions and to develop the cognizance of how an engine will perform at explicit circumstances. For these objectives, the data getting systems ought to get whatever amount of data as could sensibly be anticipated and with precision. The A-1 test stand is given a fast data getting plan of 256 channels, each social event 102.400 models each second and a low-speed structure with 512 channels that produce 250 models each second. This large number of structures are expected through and through to measure each piece of engine action, for instance, pressures, temperatures, siphon cycles per second, and push and valve ability.

One more of the test stands being used in the Stennis Space Center, an even more minimal estimated one, is the E-2 Test Stand.



Figure 2.4: E-2 Test Stand at Stennis S.C. [5]

Here we can see the preliminary of the oxygen pre-burner part being made by SpaceX, in association with NASA, for its Raptor rocket engine, which is being attempted to control outings to Mars. The chief focuses of this preliminary of a pre-burner where to guarantee the unflinching nature of the beginning and the suitable temperature course for the siphon turbines. By and large, 76 hot fire tests were done on the part, amounting to 399.36 seconds [32]. This office was picked by Space-X for its little size and high-pressure capacities. Current patterns of creation and the progression of equipment have allowed the improvement of more unassuming and more affordable test stands that can be made and used by little affiliations or individual individuals, instead of being only reachable by gigantic organizations or authoritative affiliations.

One outline of a little and unassuming model is the going with [6], created by using simply an Arduino what's more, some fundamental off-the-rack materials.

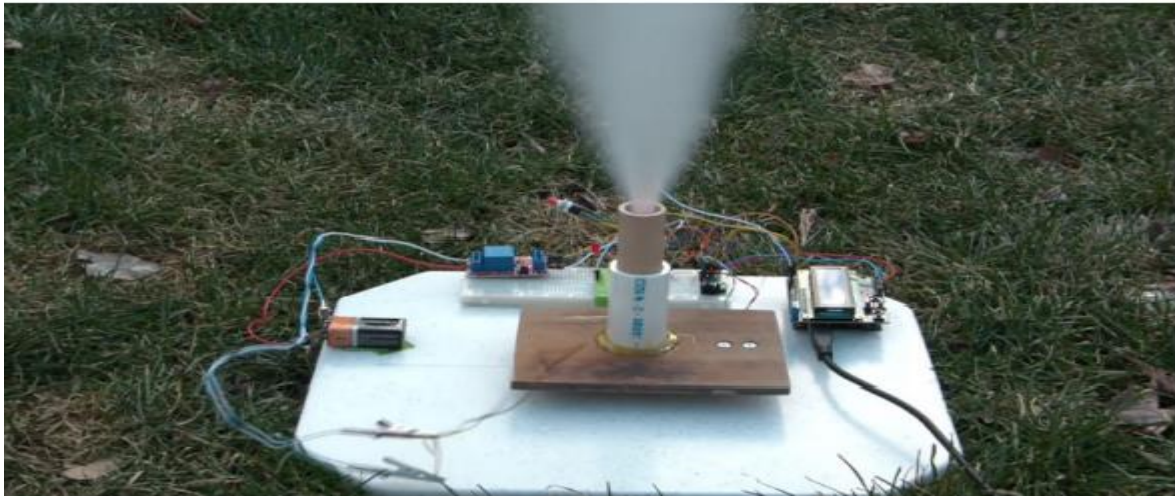


Figure 2.5: Arduino-powered rocket test stand. [6]

Here the most basic components of a test stand can be observed:

- Motor support structure
- Load cell
- Power supply for the electronics
- Electronics to process the signal for the DAS (Amplifier and A/D converter).
- DAS (Data Acquisition System), in this case, an Arduino that will send the data to a PC.

Although this is the most basic of configurations, it shows the more simple elements that a rocket stand will need in order to obtain the performance factors such as the specific impulse or the evolution of the thrust throughout time.

For bigger rockets, other inventors have developed bigger test stands that are more complex. For example Richard Nakka, an amateur creator has built some very interesting models such as the STS-5000 [7]

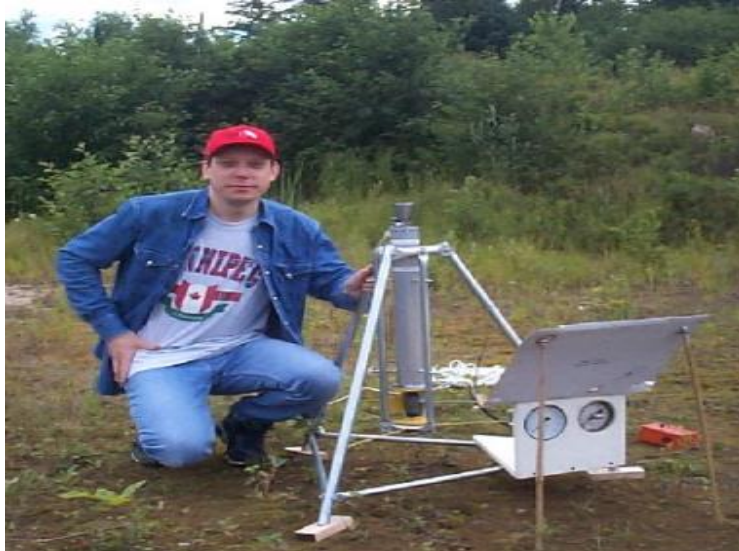


Figure 2.6: Richard Nakka's Statis Test Stand 5000. [7]

This is an upward downwards-situated test represents strong fuel rockets that have the ability to test M-class or on the other hand lower strong rocket engines with a push of up to 5000 Newtons. Noticing that all together is fascinating to test the underlying reasonability of this test stand, it was using pressurized water confirmation stacked to 105% of the plan limit (5300N). The benefit that this stand has contrasted with others is that as it is a mount it is self-evening out on any ground which implies that equivalent burden circulation will be accomplished at all legs and that it is foldable to be compact.

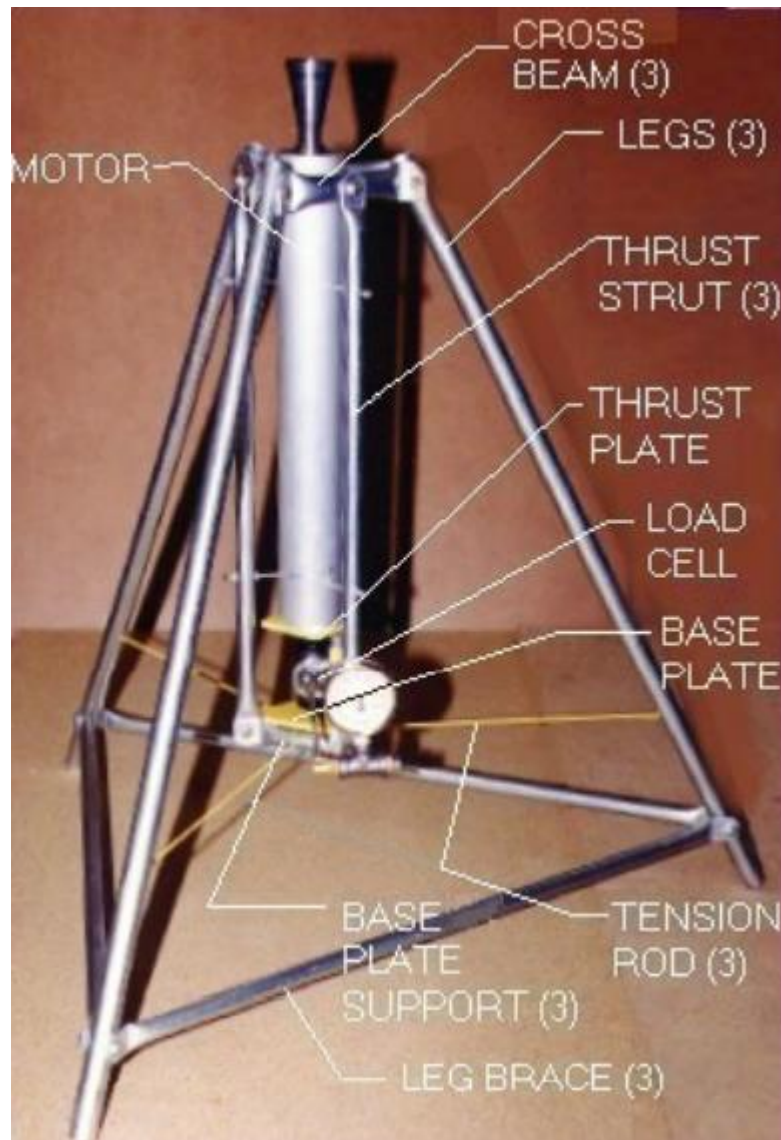


Figure 2.8: Richard Nakka's STS 5000 image illustrating the main components. [7]

This test stand was planned in view of effortlessness, utilizing EMT (Electrical Metallic Tubing) as the fundamental primary parts. The darterd plan takes into account simple dismantling for transportation and capacity reasons. Additionally, the effortlessness of development considers simple substitution and fixing of the construction in the event that that a devastating disappointment happens. primary parts. The darterd plan takes into account simple dismantling for transportation and capacity reasons. Additionally, the effortlessness of development considers simple substitution and fixing of the construction in the event that that a devastating disappointment happens.

Chapter - III

3.Design of The Test Stand:

In order to arrive to a suitable solution for our requirements, it is needed to study the different concepts and their advantages. In doing so, it will be judged the more suitable solution for our capacities. The different parameters to be analyzed in the design of a rocket test stand, before starting to develop it, are mainly the orientation of the bench and concept, the materials used in the construction, the electronics used and the methods of construction.

3.1 Conceptual Design:

3.1.1 Motor orientation

There are 3 essential kinds of rocket test remains with respect to motor course. These are level stands, vertical stands with the spout going up against upwards, and vertical stands with the spout defying downwards. All of these bearings partakes in its advantages and drawbacks. Nowadays the most used headings are the level for medium and gigantic estimated rockets and the vertical bearing with the spout standing up to downwards for tremendous offices, regardless of the way that as of late communicated in the top tier, an upward course with the spout defying upwards could exhibit supportive for more modest game plans.

1. Vertical orientation with the nozzle facing downwards :

(a) It is the most like a genuine situation as the rocket will be flying upwards when launched.

(b) It is the more exact approach to getting the exhibition of the engine, given that the weight has been considered. As it is in an upward direction, the weight of the rocket should be considered to get the total specific impulse created by the engine, which for fluid-powered motors would be simpler as the heaviness of the fuel isn't inside the burning chamber likewise with strong energizes.



Figure 3.1: Test of the Mk IV rocket from the Boston University Rocket Propulsion Group (BURPG).[8]

(c) Additionally, one of the primary drawbacks of utilizing this kind of direction is that as the thrust is projected upwards, which will intend that in the event that the construction of the test stand isn't as expected fixed or weighted down with stabilizer or stabilizers it could lift, tip aside or move causing a disastrous failure. This issue will imply that the general design of the test stand should weigh more than different arrangements.

2. Vertical orientation with the nozzle facing upwards:

(a) This geometry has the main advantage in the thrust direction. The fact that the thrust will push the structure of the test stand towards the floor will mean that no counterweights or fixing structures will be needed.



Figure 3.2: Vertical test stand with the nozzle facing upwards developed by Dewayne Doud in 2005[9]

(b) It is a calculation ideal for little lightweight compact arrangements.

(c) It definitely dislikes considering the weight of the rocket and fuel as in the past case as it is in an upward direction moreover.

(d) In spite of the fact that it makes the development of the construction more straightforward, it has issues with respect to the precision of the thrust estimations and the exhibition of the rocket engine. This issue is created by the way that the direction of the rocket is 180 degrees inverse to what the rocket would be in a genuine case situation.

(e) This may be reflected in the consuming time and following thrust produced by the fuels. It is demonstrated that the consuming time and advancement of the consuming region are impacted by the direction of the rocket in regard to gravity. This implies a distinction in the exhibition of the upward position confronting upwards contrasted with confronting downwards, which will show a greater season of consuming and thus less thrust created.

3. Horizontal orientation :

(a) The even direction is one of the most involved directions as it gives generally great estimations of the presentation contrasted with the genuine vertical direction however wipes out a portion of the issues present in an upward direction with the nozzle confronting downwards.



Figure 3.3: Horizontal test stand from Alexander Bruccoleri at Dartmouth College. [9]

(b) The even direction dispenses with the need of considering the weight of the engine and the force and in this way takes out the part of the load into the measurements of the delivered push. It will likewise make it more straightforward for adjustment purposes.

(c) This direction decreases the expense of development and complex weighting parts contrasted with the vertical downwards math as it tends to be fixed to the floor or upheld against a wall to fix it. This will decrease the general weight and intricacy of the construction and lessen the expense of materials.

(d) It should be noticed that this direction despite the fact that it wipes out factors while working out the thrust created, doesn't furnish a similar real exhibition as the genuine disposition that the rocket would have in a launch situation. Despite the fact that it is noted in the paper that the general exhibition of the engine in this direction is intently like the vertical direction. It is proven that the burning time and evolution of the burning area are affected by the orientation of the rocket with respect to gravity. This means a difference in the performance of the vertical position facing upwards compared to facing downwards, which will show a bigger time of burn and so less thrust generated.

Sl. No	Vertical (Top to bottom burning) (mm/s)	Inverted (Bottom to top Burning) (mm/s)	Horizontal burning (mm/s)
1	2.685	2.832	2.822
2	2.695	2.840	2.837
3	2.705	2.851	2.832
4	2.659	2.853	2.805
Average	2.690	2.840	2.820

Table 3.1: Experimental results obtained in [10].

Parameters	Horizontal	Vertical
Burn Time(sec)	76.97	75.86
Action Time (sec)	77.74	77.64
Pmax, MPaA	3.53	3.68
Burn Time Pavg, (MPaA)	2.82	2.97
Action Time Pavg (MPaA)	2.8	2.93

Table.3.2 Ballistic Parameters. []

3.2. Basic working principle of a Static Test Pad:

Static Test PAD:

The static test cushions are consistently used to test rocket motors and engines of various sizes or types to work in an efficient manner. A program runs both the motor turn over and data tying down systems to convey time-settled push data. It is laid out, to control any interesting powers or pseudo powers as gravity circling back to the body.

Presently, the grouping by which the static test cushion is started is given by -

1. Every one of the associations are made and checked. The heap cell is mounted onto the focal help shaft, and the engine onto the mounts. The I-formed base is laid on the ground if level or the legs are appended in any case.
2. Then, the heap cell is associated with the flying cove, and Arduino and speaker are associated alongside the Thermo coupler.
3. An order is given through Arduino to begin the start by a wi-fi module that permits us to remotely initiate the hand-off. At the point when the engine turns over, it applies the push along the even pivot equal; to the base, with fumes towards the side.
4. The engine is fixed, because of the engine mounts. Consequently, it will not dislodge, interpret or pivot, as the level of opportunity are locked. The ball moves permit hub development to slide onto the heap cell.
5. The heap cell gathering is mounted to a proper push estimation test stand getting the engine. As the engine is working, push is estimated with the heap cell.

6. The rocket motor test stand mount forestalls any side stacking on the phone, guaranteeing the heap cell is just getting pivotal burdens.

7. Because of this, it vibrates back and forth, similar to an oscillator. The vibrations create pressure in the heap cell, as it is straightforwardly associated with the engine mount. This pressure would be switched over completely to a computerized signal by the HX711 Board, which would be associated with the Arduino UNO by means of PCB as it is a power transducer, and stress is force per unit region.

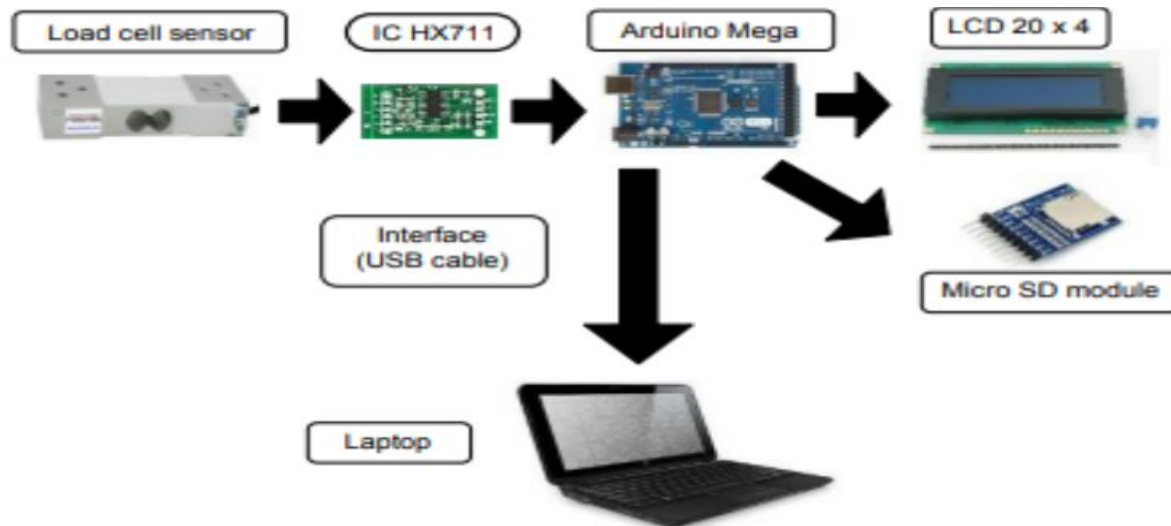


FIG. SYSTEM DESIGN

8. Mass flow and Drag are captured with load cells. Thrust data can be live streamed and logged for monitoring and later review and comparison against simulated models with external storage.

9. Throughout the test, the data is continuously converted from analog to digital information, and we determine the calibration factor, to see if there is any error in any of the sensors.

10. The testing automatically ends when the motor runs out of propellant. Hence, now our static testing of the rocket motor is done using the static test pad.

What is measured by STP?

By using STP we are going on measuring the below points:

- 1 Real-time thrust
- 2 Tank pressure
- 3 Specific Impulse
- 4 Vibrations
- 5 Burnout time

3.3The propellant used for different applications:

Rocket propellant is a well-combined mixture of fuel and oxidizer. The oxidizer provides oxygen for the fuel to burn. In some cases, a binder can be used for increasing the flexibility of the mixture in the casting process. The ratio of the fuel and oxidizer can be altered or the combustion chamber parameters can be changed to get different burn rates. The fuel and oxidizer are commercial grades and available from local suppliers. In this study, the appropriate ratio of fuel and oxidizer was obtained as follows:

2.1.1. Dark powder. Customarily, the dark powder is ready by dry blending 15% charcoal powder, 10% sulfur powder, and 75% potassium nitrate by weight, and 1 g of dextrin is added per 100 g of the blend. The fixings were combined as one for almost 2 min in a plastic compartment to forestall electrostatic release. The dark powder can be utilized as a wire ignitor, as it consumes quickly. The most extreme ignition temperature is around 1400 °C.

2.1.2. White blended powder. In this review, white powder comprised 65% potassium nitrate and 35% sugar powder by weight combined well as one. The last blended white powder can retain the dampness in the air; thus, it should be kept fixed in a hermetically sealed compartment whenever implied for some time in the future. The ignition temperature of the white blended powder was roughly 1200-1300 °C.

2.1.3. Rocket Sweets or R-Candy. This fuel utilized in our review contained a mix of sugar syrup, potassium nitrate, and sugar powder in the proportion of 65%, 18%, and 17% by weight, separately. In this exploration, the rocket candy was arranged to utilize an electric pot, as should be visible in figure 2 At first, the sugar syrup was warmed to a bubbling temperature. Yet again then, sugar powder and potassium nitrate were mixed in it and the syrup was warmed until it started rising, after which the electric pot was turned off likewise, and the hot mix filled the molds. The start temperature of R-Candy was about 1347 °C.

3.4Material Selection:

Preliminary research was done to select components having good characteristics as High strength-to-weight ratio, Ease of fabrication and affordability. An important parameter was decided to be specific strength, which is the ratio of Ultimate tensile strength of the material to the density of the material. Higher specific strength implies that the material is strong and lightweight.

Specific strength of a few components is given below:

<u>Material</u>	<u>Tensile strength (MPa)</u>	<u>Density (g/cm³)</u>	<u>Specific strength (kNm/kg)</u>	<u>Cost of 1kg raw material</u>	<u>Ease of fabrication</u>
<u>Aluminum alloy (6061-T6)</u>	<u>310</u>	<u>2.7</u>	<u>115</u>	<u>275</u>	<u>Medium</u>
<u>Aluminum alloy (7075-T6)</u>	<u>572</u>	<u>2.81</u>	<u>204</u>	<u>600</u>	<u>Low</u>
<u>Stainless steel (304)</u>	<u>505</u>	<u>8</u>	<u>63.1</u>	<u>135</u>	<u>High</u>

7075 aluminum (AA7075) is an aluminum amalgam, with zinc as the essential alloying component. It has great mechanical properties and displays great flexibility, high strength, sturdiness, and great protection from weakness. It is one of the most ordinarily utilized aluminum amalgams for exceptionally focused primary applications and has been broadly utilized in airplane underlying parts. In spite of the fact that Al-7075 has the most noteworthy explicit strength out of the three, it has high unambiguous cutting energy which makes it challenging to manufacture and significant expense of unrefined substance.

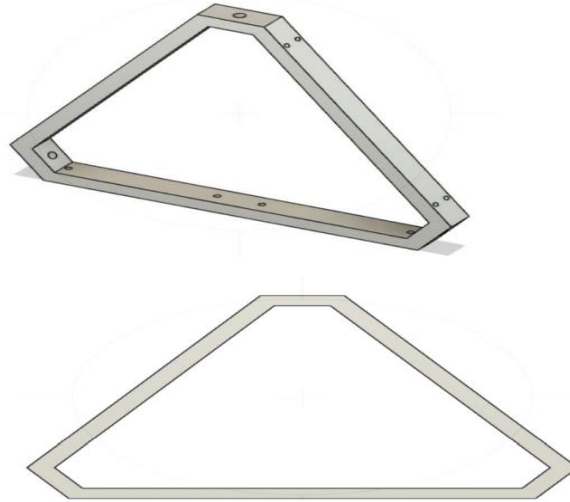
6061 Aluminum (A96061) is an aluminum amalgam containing magnesium and silicon as its major alloying components. It has great mechanical properties, shows great weldability, and is generally expelled. It is one of the most widely recognized composites of aluminum for universally useful use. Because of its high unambiguous strength, low unrefined substance cost and generally high simplicity of manufacture, Al-6061 was chosen to be utilized on the rocket mounts and three-sided casings of the plan.

Compared to other materials, **Stainless steel (SS-304)** has strong mechanical properties at ambient temperatures; it combines ductility, elasticity and hardness, enabling it to be flexible with any kind of fabrication methods while offering resistance to heavy wear. Due to its high specific strength, low raw material cost and high ease of fabrication, Stainless steel was selected to be used on the support plate onto which Load cell would be fixed. The support plate should be strong enough to withstand high localized sudden stresses imparted by the induced thrust of the rocket motor. In addition to that, Stainless steel would be used to make the motor centralizing rollers equipped with collars.

3.5 Components:

The main components of the static pad are the rocket mounts (Fixed and movable), Motor centering rollers, concentric aluminium pipes and the SS support plate.

Rocket Mounts (or) Triangular frames: Triangular frames constitutes the skeleton of the static pad. These are made of Al-6061 to reduce the entire weight of the product.

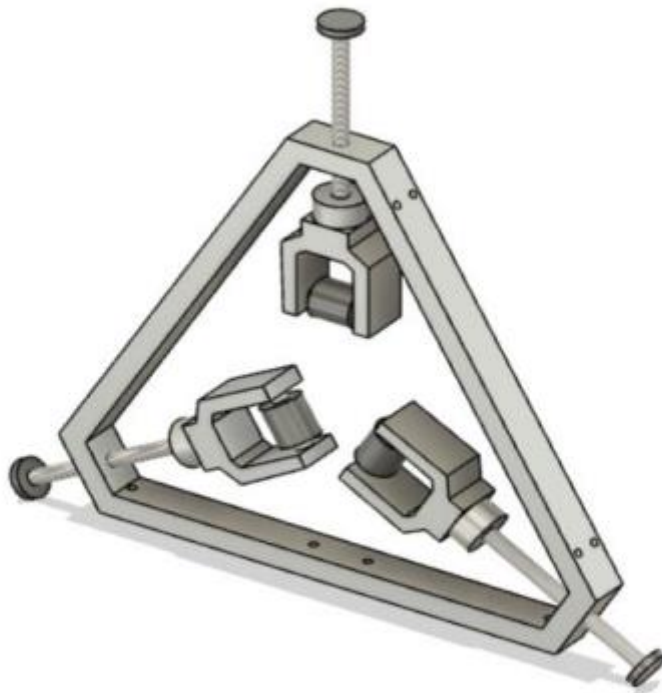


The frame is chamfered at the vertices so that the frames can be welded with one another with the help of stringers. Stringers are components whose purpose is to serve as structural components that transfer loads and stresses between components. The chamfered edges are also drilled and threaded with 20mm holes to fasten the collared rollers. Holes are made at the base to fasten the frames with the long ground supports.

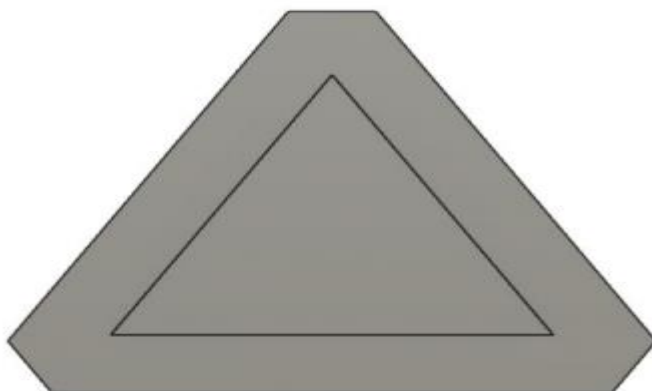
Motor centering collars with rollers: Collars were the perfect component for centering of rocket motors of various diameters. The relative motion of the screw on the collar and the threaded hole of the frame will not be transferred to the rollers which hold the rocket motor in place. Dependent relative motion of the screw will be translation and rotation along the axis, whereas the motion of the collar will be translational relative to the axis of screw.



And since the wear-out between the screw and the threaded hole of the frame is appreciable, Stainless steel is used in the making of the screw due to its superior wear resistance. The assembly of the triangular frame and the motor centering collar will give rise to the Rocket mount (Movable & fixed).



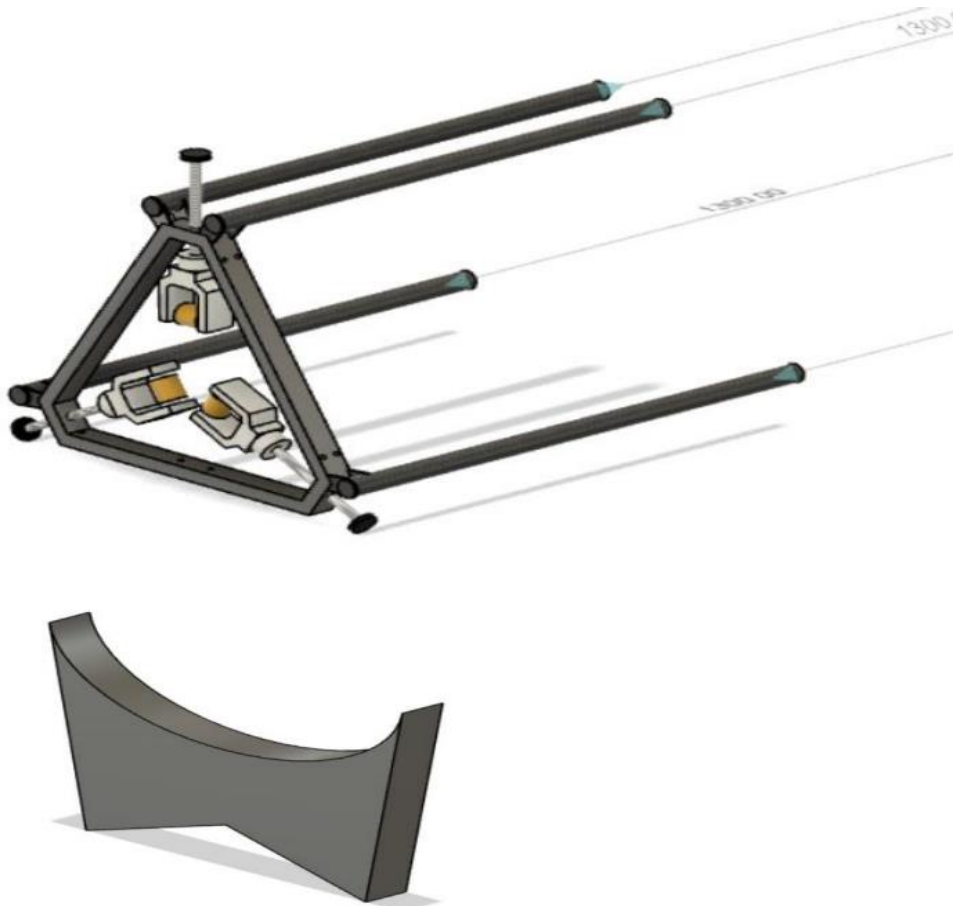
Stainless steel support plate: A support plate is welded to the fixed rocket mount with the help of stringers and is fixed firmly with the help of rigid ground supports. The dimensions of the support plate would be similar to that of the triangular frame albeit with a thickness of 1cm to withstand higher thrust forces from the motor.



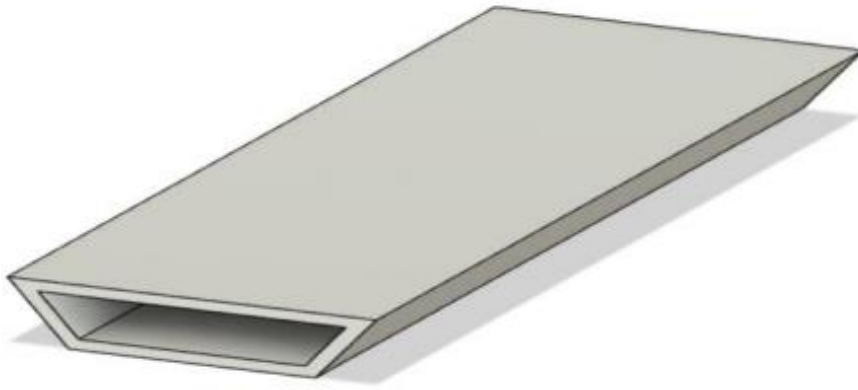
Stainless steel is preferred to Al-6061 due to its high yield strength, which is vital to withstand sudden stresses.

Concentric Aluminium pipes: An aluminium pipe with OD 46mm and ID 44 mm is fixed onto the triangular frames with the help of pipe mounting. Pipe mountings can be fabricated using any cutting process and ground to achieve a smooth finish. 4 Pipe mountings are welded to the frame as shown in the above-shown figure.

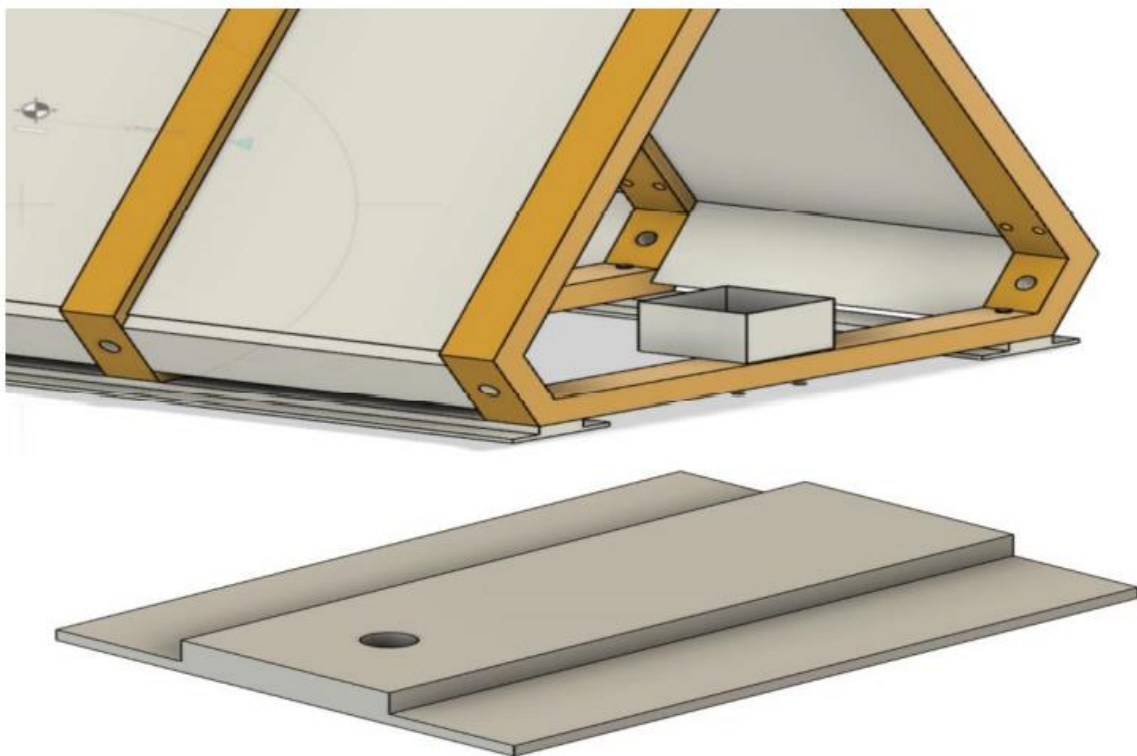
Another Aluminum pipe of OD 44mm and ID 42mm is fixed onto the movable rocket mount and this pipe is made to slide inside the pipe of a bigger size. This ingenious and simple mechanism would help adjust the size of the test pad to accommodate rocket motors which are longer than the default configuration of the test pad.



Stringers: As mentioned earlier, Stringers are parts whose purpose is to serve as structural components that transfer loads and stresses between components. A total of 9 stringers are used to attach 3 triangular frames and 1 support plate with one another.



Ground supports: They are attached to the test pad with M6 screws to fix the product firmly to the ground. They have a secondary function of distributing the forces evenly to the ground to restrict unnecessary moments due to thrust forces with the help of a larger cross section at the bottom. A ground support of longer length is fixed to the frame subassembly and a smaller length ground support is used on the movable rocket mount.



Doors: Doors are rectangular SS plates of 1mm which are placed in the frame to protect the avionics components that are present at the back of the test pad.

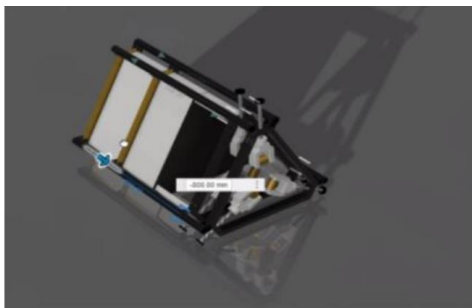
Avionics component box: It is an Aluminium box that is screwed to the triangular frame in which the avionics components are held.

3.6 DESIGN:

The design is just a simple triangular frame connected with beams to give it more strength. It is designed with parts that do not need high-end machining or processes to create. Also the design can be assembled or disassembled on site with very ease. Following are some

key points of our design:

- Simple design, with simple assembly.
- Every gram of steel and aluminium is used to provide strength to the frame, instead of only increase in weight.
- Very compatible design, it can accommodate any motors between [300mm to 1500mm], and of diameter [30mm to 250mm].
- User could change the length of STP according to the availability of space or length of motor, It could extend and contract up to 1060mm. FULLY EXTENDED FULLY EXTENDED
- Whole main frame is radially symmetric, due to which less complexity and good distribution of loads are observed.



FULLY EXTENDED



FULLY EXTENDED

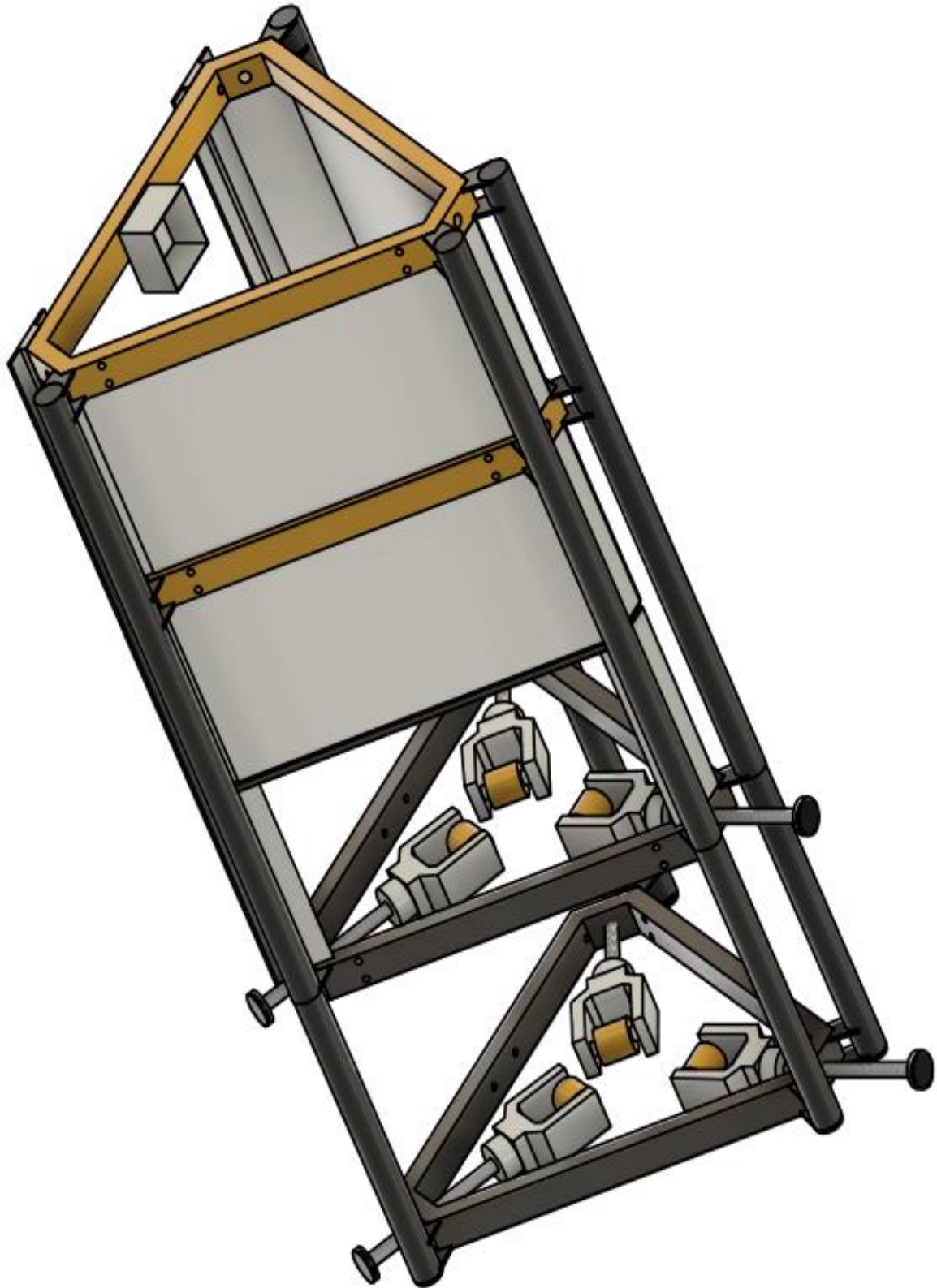
- The center of MOTOR MOUNTS and the centre of LOAD CELL MOUNT are in one line which is also the center line of the whole frame. It eliminates the tedious work of adjusting the load cell to the centre of the motor before every test of new motors.
- MOTOR MOUNTS contain rollers that give good hold on motor without restricting the lateral movement (movement along the line of the load cell) of the motor.
- This STP has 3 modes:
 1. HORIZONTAL MODE:- STP is placed horizontally with its GROUND SUPPORTS either pinned to the ground if needed, or it can be simply placed on the ground as its rubber pads will provide grip with the ground. In this mode the motor can be tested horizontally.
 2. VERTICAL MODE:- STP is placed vertically, the motor mount face up to the sky , which is supported by rear part (Avionics bay) of the frame. CoG (center of gravity) is

very near to the avionics bay, which is very near to the ground in vertical mode, hence will not topple. In this mode, motor can be tested vertically (that is nozzle facing up to the sky) with very ease.

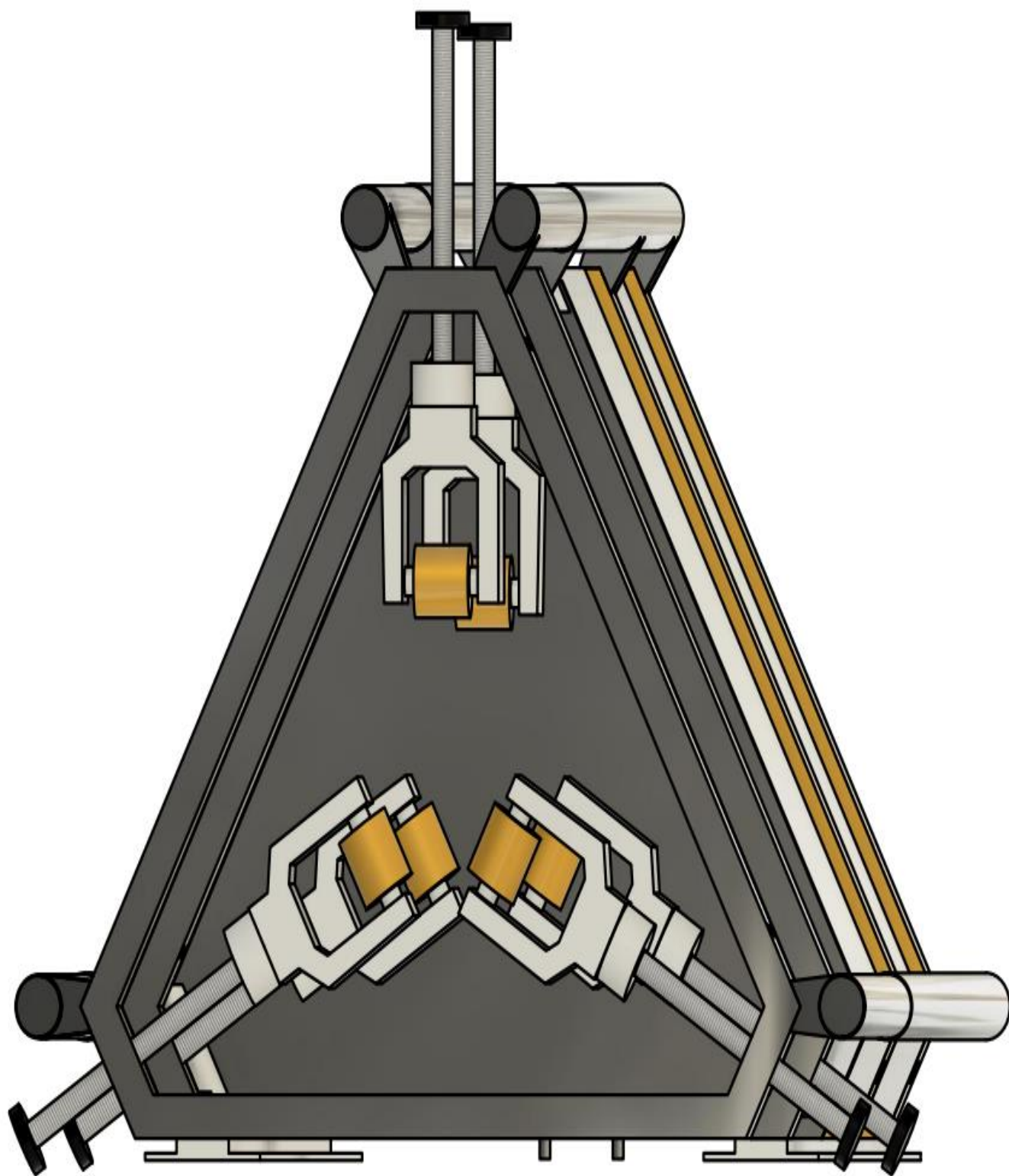
3. TRANSPORT MODE:- STP contains wheels on one of the adjacent lateral faces of the triangular frame. We can easily topple the frame by 60° so that from the GROUND SUPPORTS it comes on the support of WHEELS and then can be transported easily.

3.7 MODELS:









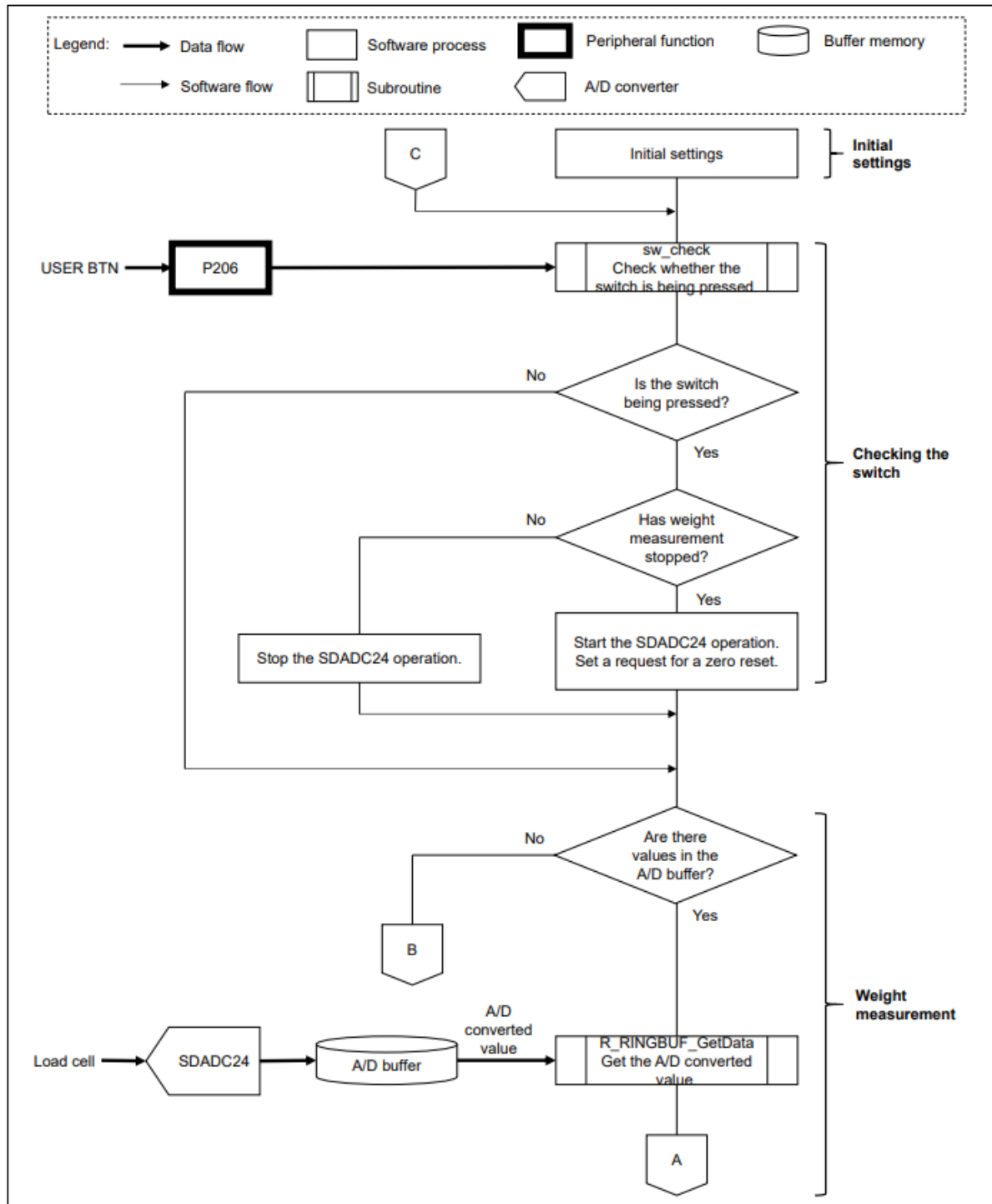


Fig- Flowchart of Sample Program Processing (1/2)

Chapter - IV

4.0 Electronics:

4.1 Objective:

The goal of the hardware in this framework will be of gathering the information produced during the trial of the strong fuel engine. Without the gadgets, the seat ought to have the option to be utilized independently what's more, securely with a rocket engine. The capability of the electronic framework will be that of detecting and recording the thrust created by the engine in the seat. Hence it is required the accompanying originations:

- Detecting device that precisely gets measures from the applied power.
- Gadgets to process and change over this simple sign into a computerized stream of information to be utilized in a

PC.

- Battery or power supply for all the hardware.
- PC to break down and post-process the produced information.

4.2 Electronics selection:

The choice of the hardware is vital as it will choose the grade of exactness and number of information produced in our plan. It is likewise vital as the cost is a boundary extremely dependent on it, contingent upon the goal and exactness wanted by our necessities, the gadgets' cost can change from under 3000RS to more than a great many RS. This will likewise decide the scope of engines that the stand will actually want to test.

4.2.1 Load Cell:

The principal part and most significant electronic piece of hardware in the seat is the detecting part, it might be said it is the "heart" of the test stand. It will change over the heap (push created by the engine) into electrical signs to be handled later. It will decide the scope of engines that the stand acknowledges and the precision with which the examples are taken.

There are various strategies for getting the pushed force from a test stand, as found in the cutting edge the first procedures utilized in quite a while of rocket history were more simple techniques, developed with springs, switches, and simple dials. Later different strategies were imagined, for example, "push meters" and "push diagrams", which through a sled on rails plotted the thrust development on a moving piece of paper provided by a taking care of component.

With the development of gadgets and transducers, these more mechanical and antiquated strategies were quit utilizing and load cells turned into the for the most part utilized technique for estimating the push. In unambiguous Strain Check Burden Cells.

Strain Check load cells are equipped for changing over into an electrical sign the power applied to a surface, are little in size, and modest in cost. With the reasonableness of gadgets, strain measure load cells have become entirely available.

A strain measure load cell is generally a metallic construction that has at least one strain checks on body misshape as a power follows up on the design. This misshapening will prompt a disfigurement of the strain measure, which thus will change the opposition esteem that the strain check presents to an electrical flow. The adjustment of result voltage will be corresponding to the power applied, hence making it conceivable to decide the power esteem given that the reasonableness is known.

In the accompanying figure, it very well may be seen that a solitary strain measure is twisted when pressure or tensional burden is applied to a heap cell. This deformity will change the obstruction of the measure to the ongoing going through its wires as the wires of the check are made longer and more slender with the tensional pressure or more limited and thicker with pressure of the cell. Since estimating the adjustment of a solitary strain check is undeniably challenging as the opposition change is tiny, expanding the quantity of checks applied related into a heap cell permits getting a more quantifiable change. Thus, a bunch of 4 measures are applied in a Wheatstone Extension circuit.

RTC uses strain gauge based, canister type load cells to measure thrust data during the static firing of rocket motors. This is because L-blocks have inherent clearance and accessibility issues, and canister type load cells have a long lifecycle and can deliver reliable use for decades, as long as there is no catastrophic motor failure that compromises their integrity. Thrust is defined as the forward-directed force developed in a jet or rocket engine as a reaction to the rearward ejection of fuel gases at high velocities. A load cell is a transducer that converts thrust to an electrical signal that can be acquired, stored, and analyzed. The electrical signal generated by a load cell is proportional to the amount of thrust applied to its measurement element. The load cell measurement element comprises a load path, an elastic body, and a strain gauge. The electrical output of a load cell is based on the phenomenon of resistance variation due to the elongation of a wire, which is the strain gauge. When thrust is applied to the measurement element, the elastic body is compressed, and its diameter slightly increases. This increase in diameter induces a measurable change in resistance due to the elongation effect of the strain gauge, which is bonded to the elastic body, and subsequently acquired and analyzed. graphically represents the thrust data generated by a load cell, and all data used in this research has been normalized to ensure its sensitivity.

The basic operation of a Wheatstone circuit is to amplify and make visible a change into one or more of the resistances. Using Ohm's law, it is possible to determine the change in the output voltage in the function of the resistances.

$V_o = [R_3/(R_3 + R_4) - R_2/(R_1 + R_2)]V_e$ x Where V_o is the output voltage, R_1 to R_4 are the resistance of the four strain gauges and V_e x is the excitation voltage that will be of known value.

*YZC – 526:

The picked load cell for this test stand has been the YZC-526, which is a s-type load cell with a most extreme burden limit of 1 ton (9810 N). It has been picked this one for its cheapness and high burden limit. It very well may be seen in the YZC-526 burden cell the various wires emerging from it and how they relate to the data sources and results of the Wheatstone span. It tends to be seen that there are 4 wires associated with the cell, they are: white, red, green and dark.



Figure 4.1: YZC-526 Load Cell. [13]

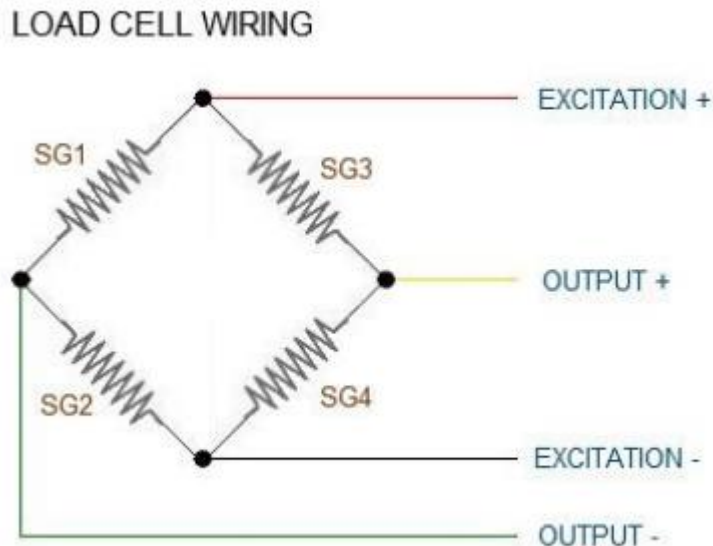


Figure 4.2: Wheatstone Bridge circuit wire diagram. [14]

Wheatstone bridge node	Typical color code
$V_{ex} (+)$	red
$V_{ex} (-)$ or GND	black
$V_o (+)$	white
$V_o (-)$	green

Table 4.1: Wire color-coding

Parameter	Value
Manufacturer	Guang CE
Model	YZC-526
Load cell material	Alloy steel
Maximum load capacity	1000 kg
Sensitivity	2 +/- 0.05 mV/V
Combined error (%RO)	< +/- 0.030
Creep (%RO/30 min)	0.02
Temperature effect on sensitivity (%RO/°C)	0.0016
Recommended excitation voltage	10-15 V

Table 4.2: Specifications

4.2.2 Amplifier:

When the heap cell is arrangement it is expected to enhance the sign that will be produced in the request for mV to a reasonable greatness to be utilized.

In the event that the 5V result from Arduino is utilized as the excitation voltage for the heap cell, which has a responsiveness of 2mv/V, then the total scope of voltage result would be of 10mV. Which is too little to possibly be utilized for an Arduino without enhancing it first.

Thus, it has been picked the accompanying speaker board: the Differential Intensifier safeguard for Arduino Uno (DAAU) from Upsilon Designing.

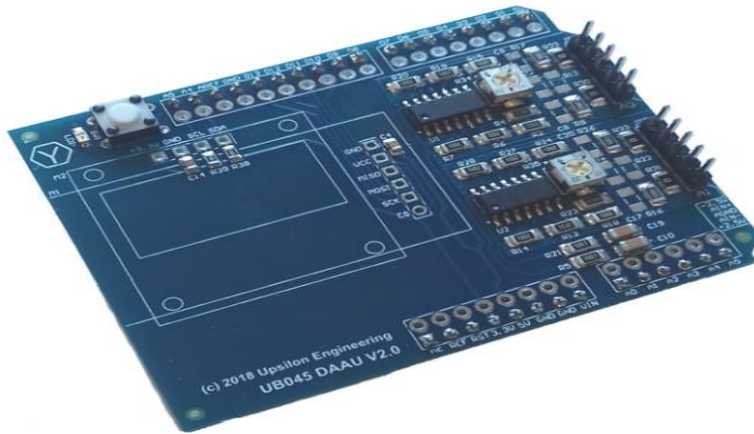


Figure 4.5: Upsilon's DAAU amplifier. [15]

This amplifier has a 2 channels and each has a gain k than can be set from 9 to 43. Thus the 10 mV would become a difference in 430 mV which can be used by the ADC. A basic example of the operation of this amplifier is presented in the following scheme:

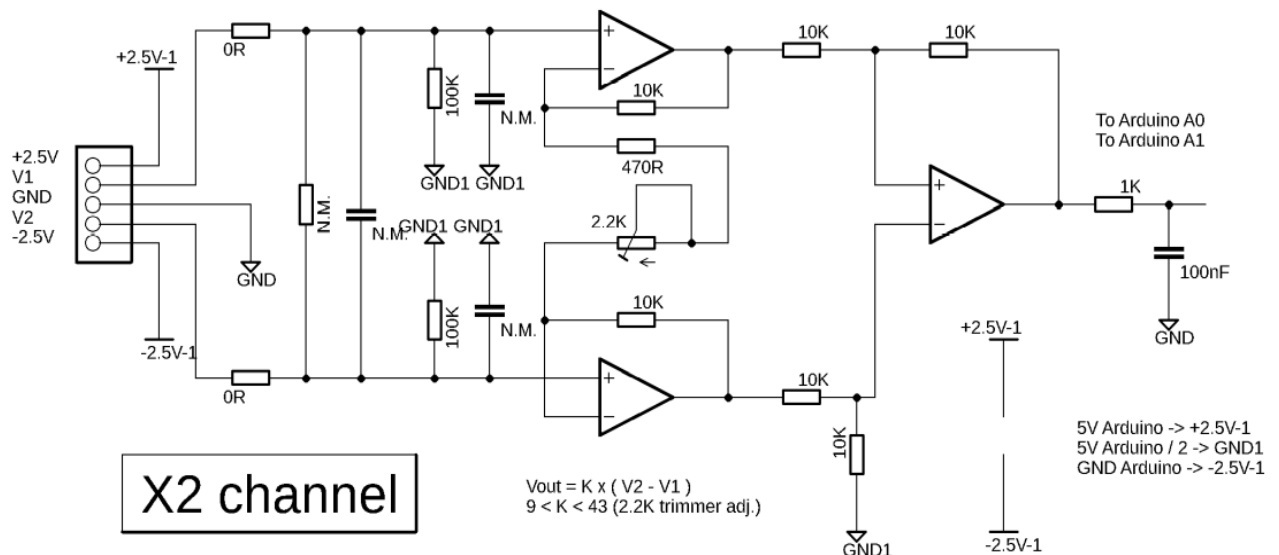


Figure 4.6: Schematics of the inward parts of the intensifier. [15]

The selection criteria for this amplifier was primarily based on availability and Arduino compatibility as there are not many amplifiers for this type of operation as usually these type of systems come together with the load cell and the data acquisition in conjunction. For this reason not many alternatives were found to be bought for a moderate price separately.

Another alternative that was contemplated was to use an INA125 amplifier in a breadboard or integrated circuit, but the realization of such a project would be far more complicated than using the DAAU found, which has the ability to be integrated seamlessly into an Arduino Uno Mega.

4.2.3 Analog to Digital Converter:

When the sign is intensified it actually should be converted into a computerized signal so Arduino can handle it. A simple to-computerized converter will interpret the voltage of an electric flow into a computerized number that will be relative to that voltage. For instance in a 3 cycle ADC converter there are $2^3 = 8$ levels, so a signal with a reach from 0 V to 1 V, will have a voltage goal of $1V/8 = 0.125V$. Thus, it is vital on an ADC the goal in number of pieces.



Figure 4.7: ADC ad7606. [16]

The second most important parameter to take into account for an ADC converter to be used in a test stand is the Sampling Rate. This parameter indicates the number of samples that the converter is able to process per second, so if the sampling rate is high the more samples that will be measured in a second and the more precise the measurement of the thrust vs the time will be. Thus, creating a smooth graph without big discrete steps.

The chosen converter has been the AD7606 because of a good performance in resolution and sampling rate, which are above those in the requirements. It is an ADC capable of receiving 8 different analog signals, with a 16 bit resolution ($2^{16} = 65536$ levels) and a sampling rate of 200 kSPS.

This means that the minimum value detected will be of: $5/2^{16} = 0.0763$ mV Which is far lesser than the amplified signal from the differential amplifier.

The selection criteria to choosing this ADC instead of others was a combination of availability to be purchased on the web, performance adequate to that in the requirements as the 200 kSPS is high enough to have enough samples in time to obtain a good enough plot of the thrust vs time, the 16-bit resolution which will make precise enough measurements to plot, the low price and the Arduino compatibility. Other candidates and possibilities were studied, as the use of the ADS1115 or the HX711 or more expensive DAQ systems. As it can be observed the only performance that fulfills the requirements between these candidates is the one selected. Other suitable options (not included in the table) involved a higher price.

4.2.4 Arduino Mega:

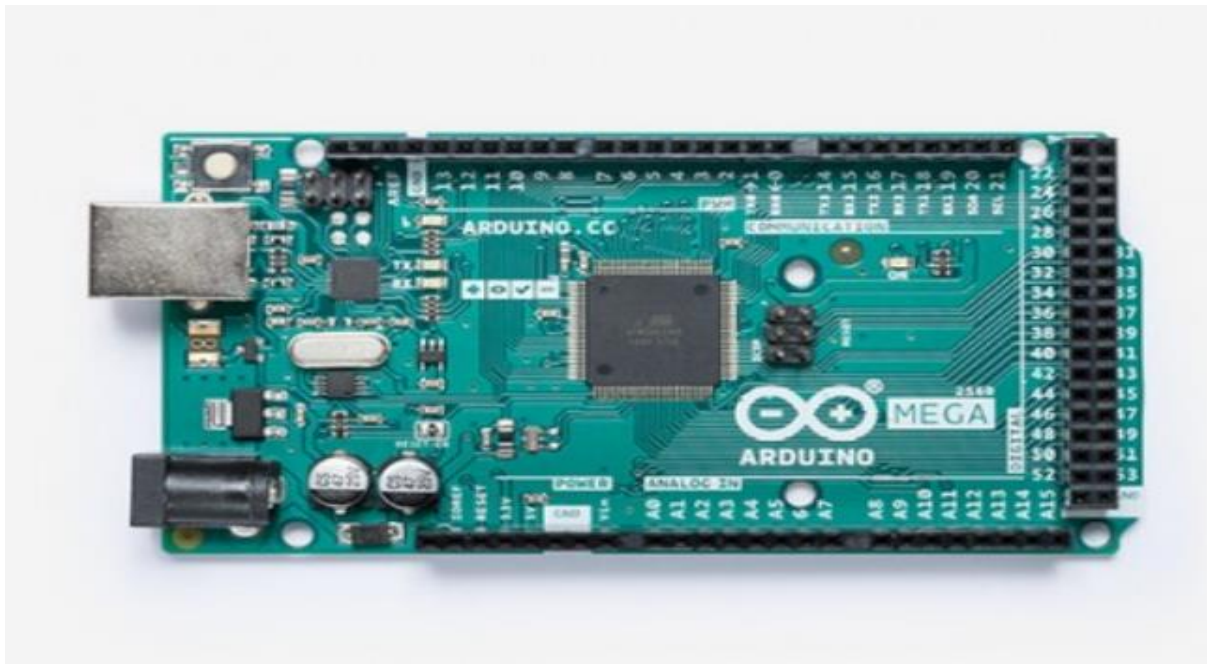


Figure 4.7: Arduino Mega Rev.3. [17]

Once the signal has been processed into a digital form, then it can be used by a microcontroller for storing the data, processing the data or taking any actions. In this case the data obtained is only received by the Arduino and then sent to the computer for plotting.

The chosen solution was at first the Arduino Uno, which is the basic Arduino model, an inexpensive one, that is provided with an ATmega328P microcontroller. It was chosen instead of other Arduino as it was compatible with the amplifier DAAU shield. Later it was found that when combined with the shield more ports were needed in order to connect it with the ADC converter at the same time, so another solution had to be found. This other solution was the Arduino Mega, and provided with a better micro-controller, the ATmega2560, and more pins, was suitable for all the connections that were needed.

Parameter	Arduino Uno	Arduino Mega	Arduino Micro
Price	14-25 €	16-35 €	12-18 €
Dimensions	68 x 53 mm	101 x 53 mm	48 x 18 mm
Micro-controller	ATmega328P	ATmega2560	ATmega32U4
Clock Speed	16 MHz	16 MHz	16 MHz
Flash memory	32 KB	256 KB	32 KB
Voltage Level	5V	5V	5V
Digital I/O Pins	14	54	20
Analog pins	6	16	12
USB Connectivity	Standard A/B USB	Standard A/B USB	Micro-USB
Shield Compatibility	YES	YES	NO

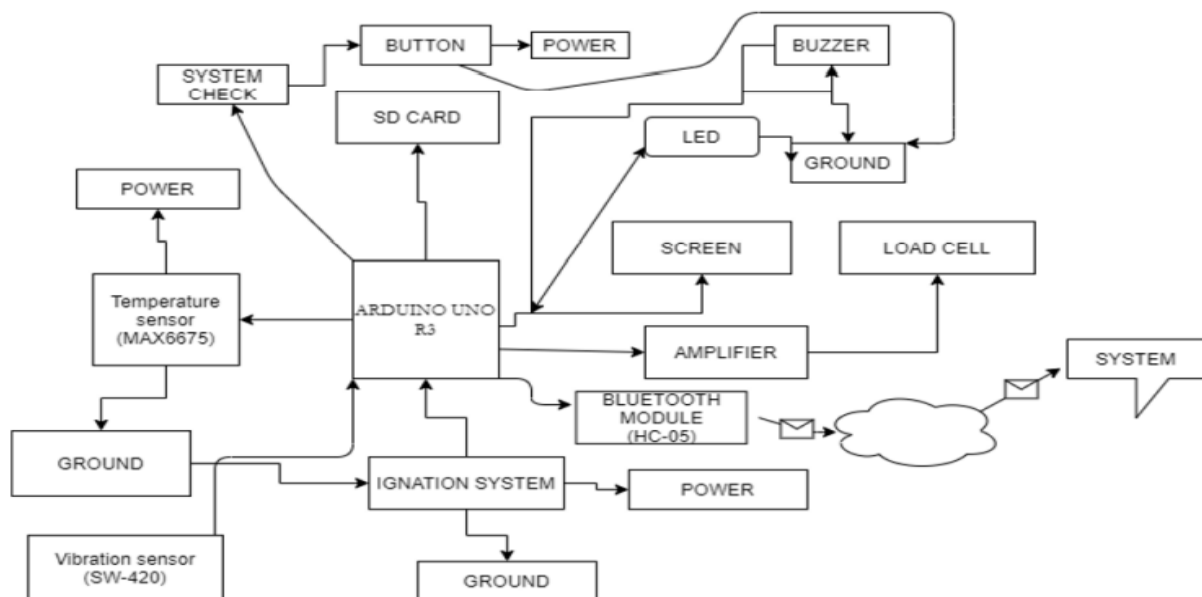
Table 4.3: Technical comparison between Arduino models. [17] [29]

4.3 Testing:

Once all the components have been selected and they are connected from the load cell which receives the thrust force as a strain on the gauge, to the computer which is able to process the signal, a simple test was done to guarantee that all the parts functioned.

The test consisted of applying a force on the cell with different weights above it or by applying pressure with the hand and observing the change and recording the data on the computer. It was observed that the load cell without a load returned to zero and that applying a variable load on the cell the recorded values varied also.

The connection between all the parts and the whole system hooked up can be observed in the following image:



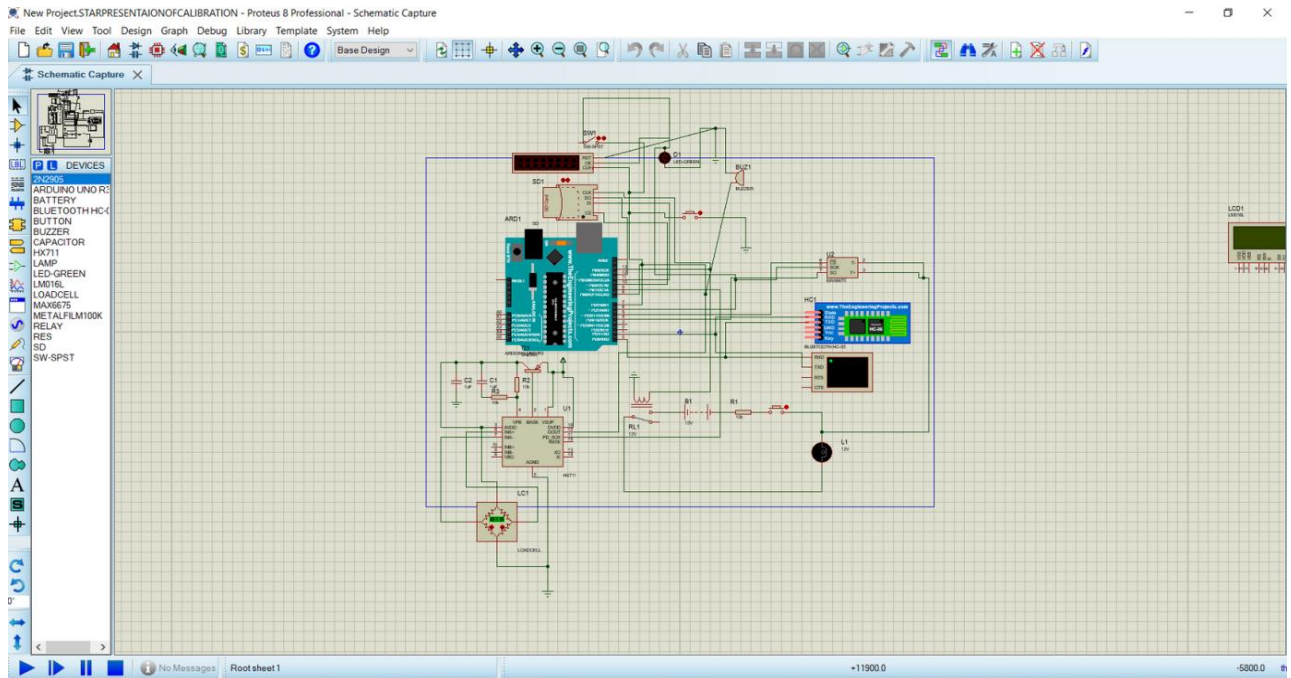


Figure 4.8: Test of the electronics.

4.4Data Acquired By:

We thought of making a system (app) to acquire, control and graph the data using the Bluetooth module Graphical User Interface In Test pad we required a graphical user interface (GUI) which can help for wireless Data acquisition, provide live data with graph as well as basic command system so it can be operated at some distance. We come up with a Bluetooth module (HC 05) which will be connected with a physical circuit and work as a transmitter for GUI.

So basically, idea of transmitter was clear but for GUI which will work as a wireless Bluetooth receiver, there are various platforms to develop GUI and after looking at few of the options we finally agree to work on “MIT App Inventor”. Well mit app Inventor is a website-based platform where anyone can develop their basic app with help of generating layouts as well as block commands, it is flexible and easy to learn also makes changes if any are required it consumes less time than any other complex app developer. Once the app layout is ready and the invisible block command structure we can transfer and install app on our Android cell phone (as currently apps that are developed in MIT App Inventor is only supported on Android).

4.5 PCB:

A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. Components (e.g. capacitors, resistors or active devices) are generally soldered on the PCB. Advanced PCBs may contain components embedded in the substrate. Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part.

4.5.1 Types of PCB:

Single sided Double sided PTH Multilayer PTH Metal clad PCB

TYPES OF PCB Single-Sided A printed circuit board with a conductive circuit pattern one side only. Holes in the board are usually not plated through. These single sided printed circuit boards are widely used in various electronics applications. Being single sided circuit board, it connects various electronic components electrically. We can provide customization to our range of single-sided printed circuit boards. In single side PCB there is a solder side where soldering is done and other is the component side where components are fixed. The printing in single sided PCB is through screen printing. There are two sides in the single-sided one is the component side and other is solder side. The component side is called top legend or top side and solder side is called bottom side. SMD components are the components which are fixed on PCB through pasting. In single sided when there are SMD components then there will be bottom legend in the single side PCB.

Double-sided PCB's having circuits or copper on both sides are called double-sided PCB's. They have benefit to decrease the complexity of wires of circuit far better than single side PCB's. Double sided consist of both top and bottom legend. They comprise of soldering from both sides. Photo printing is used to print double sided PCB. The best part of double side PCB is that there is circuit on both sides. Introduction of PCB design software PCB is a thin (usually 0.5-3 mm) board made of fiberglass, composite epoxy, or other laminate material. Conductive pathways are etched or printed onto board, connecting different electronic components on the PCB. There are single sided (one copper layer), double sided (two copper layers) or multi-layer up to 10+ layers PCBs. Beside the conductive layer most PCBs contain solder mask layers (a thin lacquer-like layer of polymer that is usually applied to prevent solder bridges between closely spaced solder pads) and silk screen layers (displaying text information for soldering or application).

Different tools used for PCB designing:

Schematic design creation, Schematic design capture, Determination of PCB template, card dimensions, heat sinks, and fixed components, Deciding on PCB stack layers, Line impedance determination, Component placement, Signal traces routing, Gerber file generation, Circuit design using software tools.

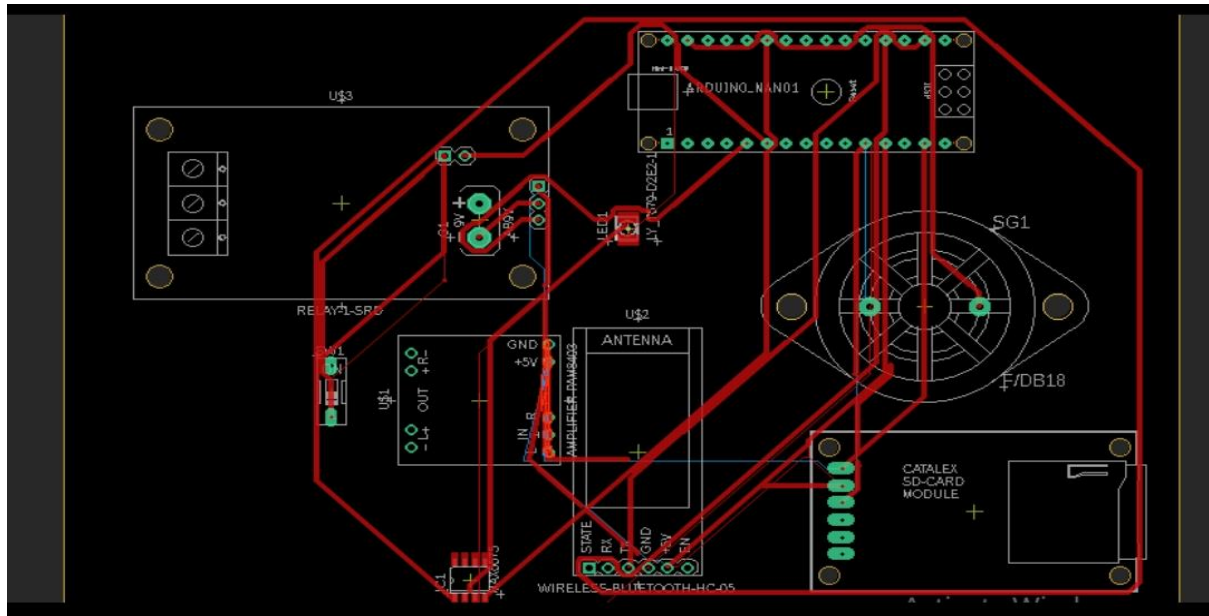


Fig.4.9 PCB Layout

4.6 Economic viability:

There are not many available test stands for middle-sized rockets in the market to be bought by particulars or being commercially distributed, almost all of the solutions observed in the state of the art chapter were developed by individuals or organizations to be used within said organizations and not for mass production and distribution to the public. What makes it so is the fact that for many rockets, once they are above a certain size, need a particular stand that is customized to work with such rocket. It is difficult to find a test stand that as the one built and described by the author, can adapt to different length and sizes of motors. Also another big reason is that there is not a big demand on this type of solutions, thus making it almost impossible to mass produce. Usually what it is done is that a certain organization with enough funds designs a bench to test a certain rocket motor or to test a certain type of motors (solid, liquid or hybrid) and then other smaller companies or organizations rent such stand in order to test their own motors.

Despite the fact that it has been found an intently comparative item accessible on the web to which looks at the price tag of the created arrangement. It is a rocket test stand made by Aerocon Systems, an association arranged in San José, California (US). Despite the fact that Aerocon Frameworks works in a joint effort with large organizations like Boeing, SpaceX, or Airbus, an organization started from novice rocketry that actually offers items and answers for the beginner rocket local area.

4.7 Software that we utilized to develop our Static Test Pad –

1. ArduinoIDE—This is the software with which we did all of our programmings with the electronics systems. It was the main system through which we would command the static test pad.
2. Proteus Professional – Proteus was used in simulating the working of the electronics part of our project. We built circuits and connections, for relay through the wifi module, and for calibration factor, and for storing data in SD Card.
3. Solidworks – Solidworks was used for designing the final computer-aided designing (CAD) model of our project. All of our components were built again on Solidworks. Most of our simulations were done on Solidworks, while few on Fusion 360. We ran the linear static stress simulation on Solidworks.
4. Fusion 360 – Another CAD software that we used in our design is Fusion 360. I designed all of the initial concept components and prototypes on Fusion 360.
5. EAGLE EDA - Basically we used eagle software for PCB designing all our PCBs is done by eagle software.

4.8 Precautions:

1. Make sure that the static test pad is able to take a wide range of motor thrusts than the maximum thrust you intend to use. Adequate Safety factors are really essential in such cases.
2. Double check on the placement of the static test stand you erect by using a spirit level and clear the ground off any combustible materials.
3. Place the Static test pad on a rooted object of greater mass than the thrust of the rocket motor you are testing plus also keep in mind the center of mass must be closer to the ground.
4. Ensure to check all the electronic connections on the PCB, and the nuts and bolts are before initiating the command to fire the ignition.
5. Keep an eye on the environment and local weather to avoid any damage in case of any inhibitors.
6. In the unfortunate case of fumes, exhaust and sparks being uncontrollable have a fire extinguisher at close proximity.
7. Always maintain a safe distance from the static test pad during operation.

Chapter-V

5.0 Results

5.1 SIMULATION:

All simulation are done on FUSION 360. Design is simulated by giving real life constraints with static load applied at the centre of the LOAD CELL mount.

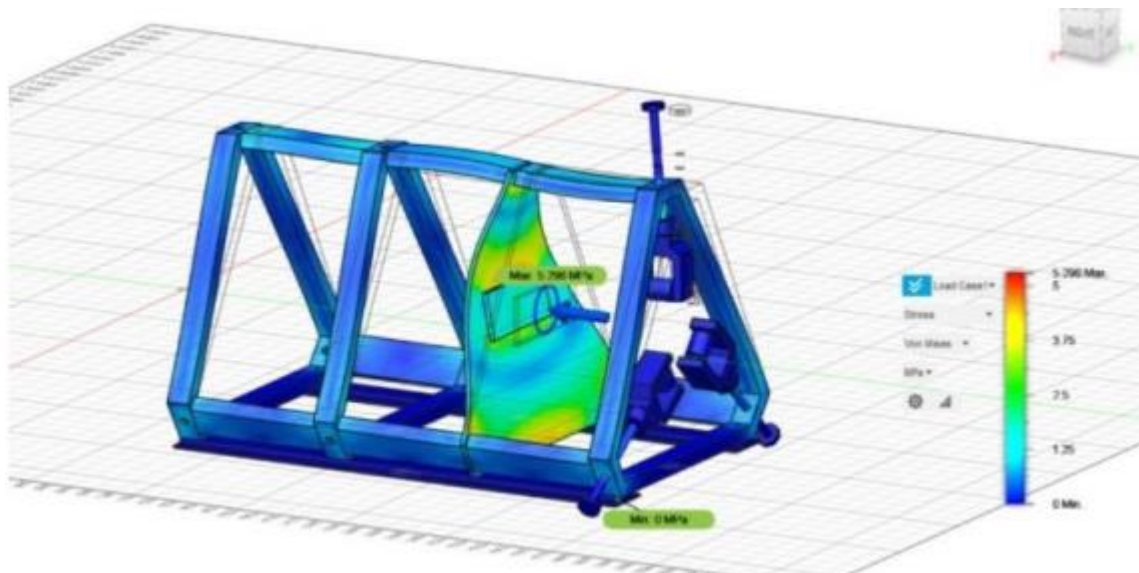
The following are the constraints taken into consideration while simulating in FUSION 360.

- GROUND SUPPORTS are fixed (for horizontal test mode).
- Static Load of 500 N and 1000 N are applied respectively at the centre of the strong plate.
- All joints are fixed except the sliding joints between 46mm dia and 44mm dia pipe which holds the last MOTOR MOUNT.

ALL THE SIMULATION ARE DONE WITHOUT INCLUDING THE TRUSSES WHICH SUPPORTS THE STEEL PLATE ON WHICH THE LOAD CELL WILL GET MOUNT INTO CONSIDERATION.

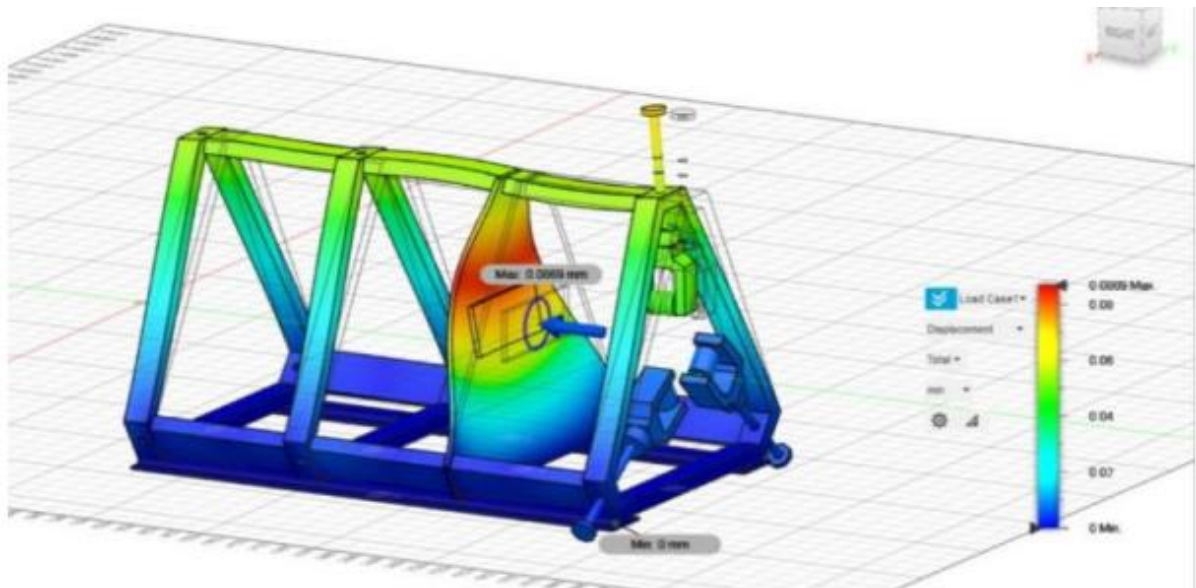
*FUSION 360 SHOWS DEFORMATON OF COMPONENT IN EXXAGERATED FORM STATIC LOAD OF 500 N

1] STRESS



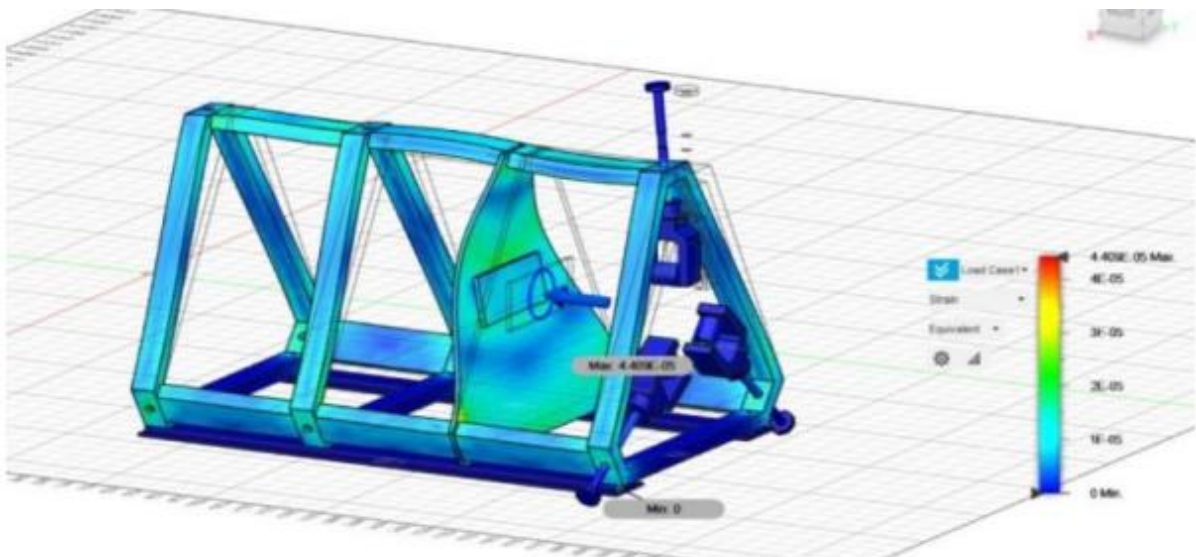
MAX STRESS- 5.296 MPa (At the middle of the steel plate when the load will get mount) YEILD STRENGTH OF STEEL = 350MPa

2] DISPLACEMENT:



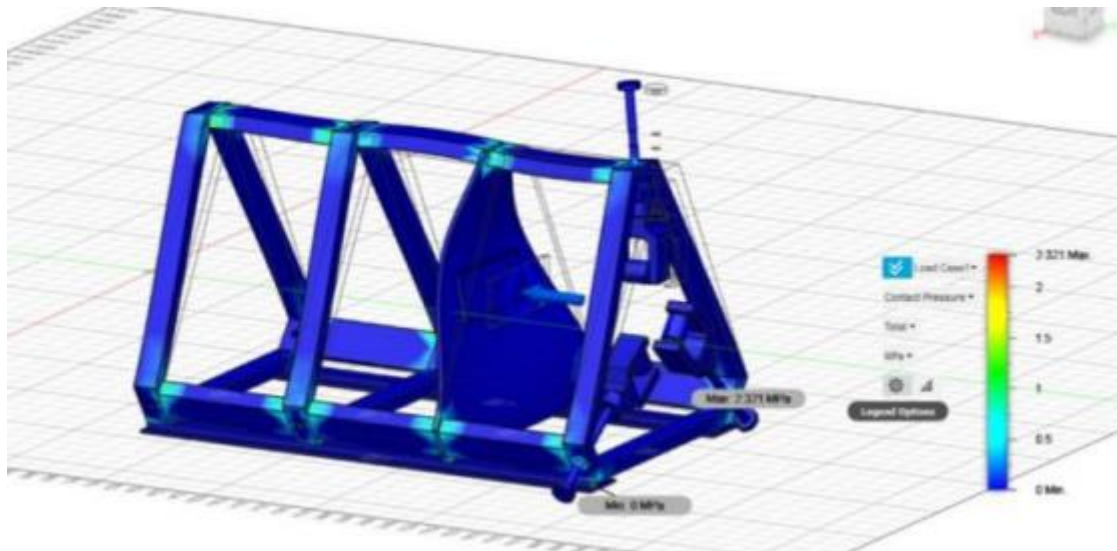
MAX DISPLACEMENT= 0.0869mm (At the point of loading)

3] STRAIN:



MAX STRAIN= 4.409×10^{-5}

4] CONTACT PRESSURE:

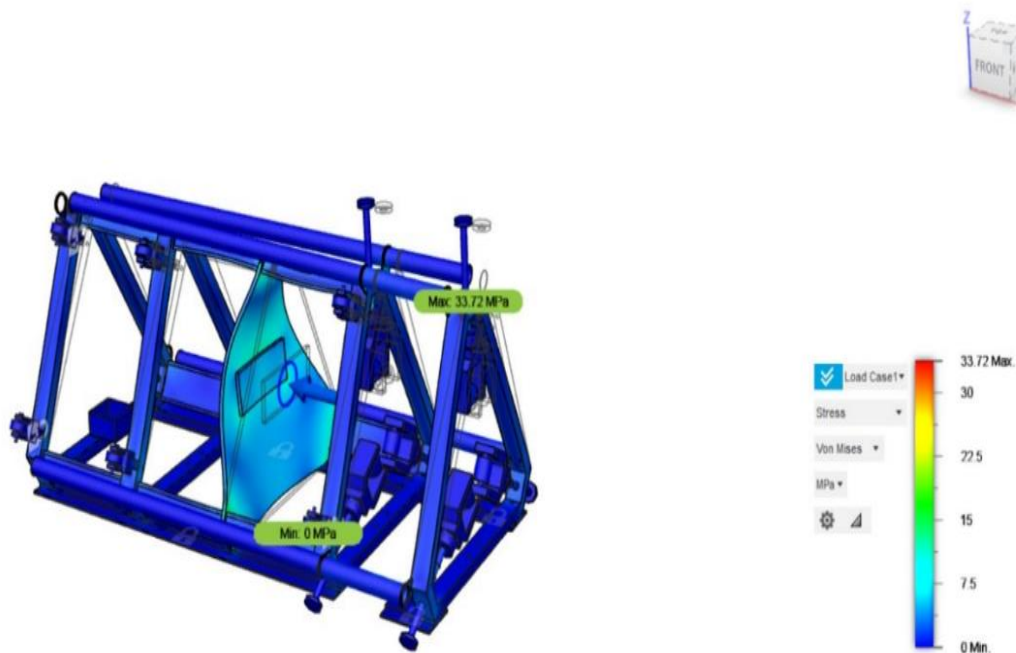


CONTACT PRESSURE 2.321MPa

STATIC LOAD OF 1000N

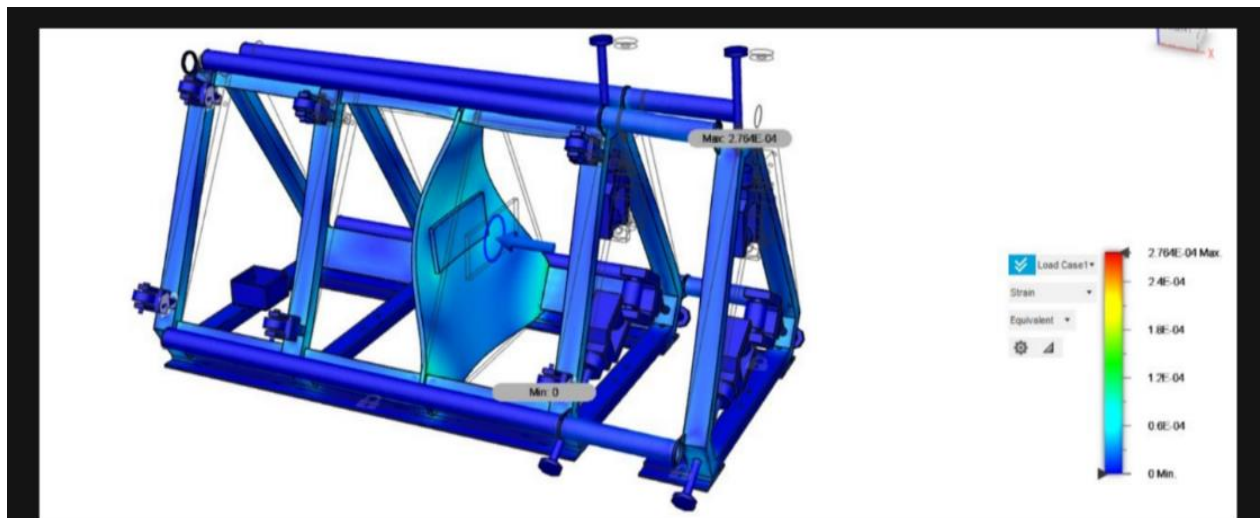
1]

STRESS



MAX STRESS= 33.72MPa (At the middle of the steel plate when the load will get mount) YEILD STRENGTH OF STEEL = 350MPa

2] STRAIN:



MAX STRAIN=2.764E04

3] CONTACT PRESSURE:



CONTACT PRESSURE=25.69MPa

We can increase the ability of the frame by adding the trusses behind the strong steel plate to make it more sturdy. All these simulations are done without trusses. The current simulation of static load of 500 N and 1000 N shows good result. The max stress in both cases are way less than the yield strength of steel and aluminium too. Also the distortion was also in the range of 10^{-5} and displacement was less than 0.2mm . Hence it shows that STP can test and read the thrust of various solid motor rocket very precisely. With little to no error.

5.2 Cost of the Static test pad:

The cost of the test pad with the dimensions and the materials used for the components are as follows:

<u>S.No</u>	<u>Name</u>	<u>Qty</u>	<u>Final cost</u>	<u>Material Used</u>
<u>1</u>	<u>Long support</u>	<u>2</u>	<u>796.5</u>	<u>SS</u>
<u>2</u>	<u>Triangular mount</u>	<u>4</u>	<u>8662.5</u>	<u>Al-6061</u>
<u>3</u>	<u>Plate</u>	<u>1</u>	<u>2875.5</u>	<u>SS</u>
<u>4</u>	<u>Stringers</u>	<u>9</u>	<u>2211</u>	<u>Al-6061</u>
<u>5</u>	<u>Screws</u>	<u>10</u>	<u>31.05</u>	<u>SS</u>
<u>6</u>	<u>Pipe mounting</u>	<u>8</u>	<u>43.2</u>	<u>SS</u>
<u>7</u>	<u>Pipe</u>	<u>8</u>	<u>440</u>	<u>Al-6061</u>
<u>8</u>	<u>Small supports</u>	<u>2</u>	<u>113.4</u>	<u>SS</u>
<u>9</u>	<u>Roller & collar</u>	<u>6</u>	<u>1617.6</u>	<u>SS</u>
<u>10</u>	<u>Screw for Roller & collar</u>	<u>6</u>	<u>738.45</u>	<u>SS</u>
<u>11</u>	<u>Component Box</u>	<u>1</u>	<u>36.45</u>	<u>SS</u>
<u>12</u>	<u>Doors</u>	<u>4</u>	<u>1500</u>	<u>SS</u>
		<u>TOTAL COST</u>	<u>19065.65</u>	

Chapter – VI

6.1 Future work and perspectives:

The future work that was left approaching around the completion of this adventure is the going with, this section is significant to show and portray delicately the going with fundamental and important activities to be conveyed out:

- Change of the sensors: the heap cell is utilitarian after this endeavor anyway when mounted to the test stand ought to be changed. There are two methods for managing change, a genuine arrangement which is ensuring that the phone isn't presented to any offset loads like weight or fundamental tensional pressure, furthermore guarantees that there are no gratings or parts that can change the readings; then, at that point, there is the item approach which is the assessment of the results and from the testing with various known loads or loads, the deduction of the powers that don't come from the rocket motor, as offsets upheaval.
- Warm survey and warm affirmation of the parts and scene that are presented to the fumes of the rocket motor. It is vital to adjust to the prosperity regularizing and to work safely that no flammable materials are on the area or in the stand, and accepting this is the situation that they are fittingly defended.
- Affirmation protect or plate, this was commentated in this assignment anyway not yet arranged and worked for a shortfall of resources. It is essential that security penetrated the plate to protect it from shrapnel.
- The sensible rocket ought to be created or bought and a pre-flight assessment of the speculative execution and direct considered, static examination and dynamic assessment.
- Begin structures ought to be considered and applied to the rocket motor.
- Testing of the test remains under veritable conditions with the crucial security wellbeing measures. In light of everything, it could be said that this is a very multifaceted endeavor with a ton of improvements that ought to be conceivable moreover, with a splendid future and extraordinary potential outcomes arranged in the results got in this survey. For this, it is contemplated that this has been an incredibly repaying experience, which made the maker gain some critical information and expand his knowledge into different enchanting rocketry-related districts.

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ANNEX

https://drive.google.com/file/d/1EDsbtDwCSuDAOmN4_IYr9AHILXZMMtPJ/view?usp=share_link

Report of Design and Simulation of static test pad for model rocket motor

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