Internship Report on

Static Test Pad for Rocket Motor

At STAR – Space Technology and Aeronautical Rocketry

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Acknowledgements:

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My heartfelt thanks go to my team members who worked diligently and collaboratively, bringing their skills, dedication, and creativity to every stage of the project. Their relentless efforts and teamwork were instrumental in overcoming challenges and achieving our goals.

I am thankful to Avionics team member for providing with the necessary resources, support to carry out the research and development for the Static Test Pad.

The successful completion of the Static Test Pad for Solid Rocket Motors would not have been possible without the collective effort, encouragement, and support from all these individuals. Thank you for being an integral part of this project and for contributing to its success.

Shingala Vaidik

Abstract:

Static Test Pads (STPs) play a crucial role in calibrating solid rocket motors before launch. This paper outlines the design of a specific STP capable of testing high-powered rocket motors. The focus was on creating a portable and cost-effective mechanism to benefit small-scale rocket developers with limited resources.

The STP features an ergonomic design with curved surfaces and stability in mind. Its delicately engineered façade ensures accurate axial calibration of thrust. Simulations using Fusion 360 resulted in promising safety factors of 2 and limited stress. A specially designed PCB facilitated data collection with visual outputs and virtual terminals for various parameters.

To enhance accessibility, an auditory interface was implemented for wide-scale use. Emphasizing the vertical orientation for maximum thrust accuracy and a stable base to prevent micromovements, this STP is an ideal option for students and professionals building high-powered rockets.

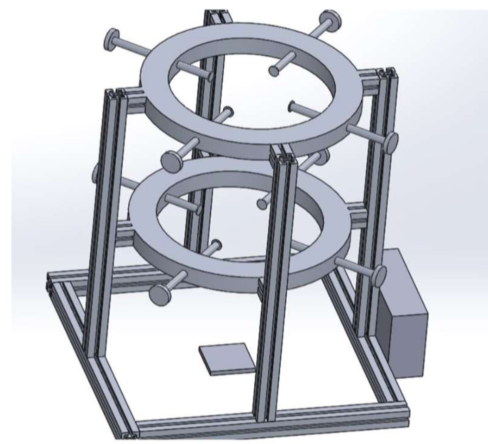
With its affordability, portability, accuracy, and versatility, this vertical STP offers a valuable solution to meet the needs of the growing market of aviation enthusiasts and rocket developers.

Table of content: (Index)

Rocket Motor Static Test Pad

1. What is a Rocket Motor Static Test Pad?

A Rocket Motor Static Test Pad is a specialized facility for testing high-powered rocket motors in a controlled environment. It allows engineers and researchers to evaluate the performance, safety, and reliability of rocket motors before integrating them into actual launch vehicles. The test pad subjects the rocket motor to static testing, where the rocket remains stationary while the engine fires. It is equipped with sensors, avionics systems, and data acquisition equipment to measure critical parameters such as thrust, pressure, temperature, and vibrations in real-time during testing.



Our STP

Other STP

2. Basic working principle of Rocket Motor Static Test Pad:

A STP is used to test rocket motors of varying sizes and lengths. It is supposed to ensure stability and safety along with efficient data collection. A computer program is used to ignite the motor and then the data acquisition process is triggered. The following points give a brief idea of the working principle.

- **Body:** The body consists of two clamps which together form a motor mount to hold the rocket motor in place, vertically. These clamps are mounted on a 4-support rod and one of which also holds the avionics bay, load cell mount middle of the base frame. After ignition, the motor exerts force on the load cell.
- **Avionics:** The avionics, i.e., the electronic circuit is responsible for igniting the motor and collecting data from the load cell. In addition to it, the avionics collects temperature and other data and send signal in case of emergencies. The data collected is then used to analyse the performance of the rocket motor under various conditions

3. Why to make Rocket Motor Static Test Pad?

A Rocket Motor Static Test Pad is an essential facility used for conducting static testing of rocket motors before they are integrated into an actual rocket or launch vehicle. These test pads serve several important purposes:

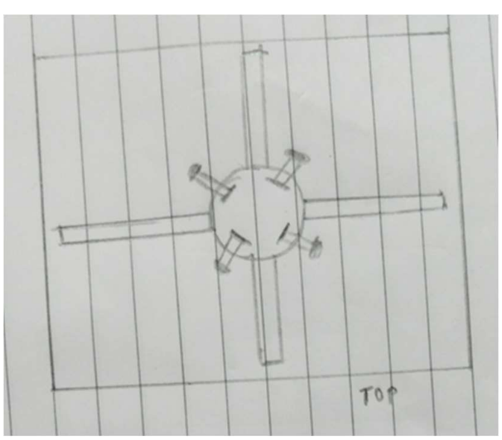
1. **Performance Verification:** Static testing allows engineers to verify the performance of the rocket motor under controlled conditions on the ground. It provides critical data on thrust, pressure, temperature, and other parameters, helping engineers understand how the motor behaves and ensuring it meets performance requirements.
2. **Safety Testing:** Static tests are conducted in a controlled environment, enabling engineers to assess the safety of the rocket motor's design and operation. It helps identify potential issues or anomalies that may arise during actual flight, ensuring the motor's reliability and safety.
3. **Validation of Design and Manufacturing Processes:** Static testing validates the design and manufacturing processes of the rocket motor. It helps identify any design flaws or manufacturing defects early in the development phase, allowing for improvements before the rocket motor is used in an actual launch.
4. **Reducing Flight Risks:** Conducting static tests before flight significantly reduces the risks associated with launching untested rocket motors. It minimizes the chances of failures during actual missions, ensuring a higher level of success and reliability for space missions.
5. **Calibration of Thrust Vector Control (TVC) Systems:** Many rockets use Thrust Vector Control systems to steer and control their trajectory during flight. Static testing helps calibrate and verify the TVC systems, ensuring precise control and stability during the rocket's ascent.

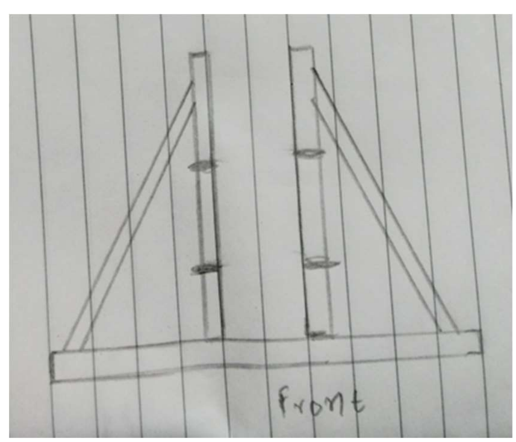
6. **Iterative Development:** Static testing allows for iterative development of rocket motors. After each test, engineers can analyse the data, make necessary improvements, and conduct further tests to refine the design and optimize performance.
7. **Cost Savings:** By detecting issues during static tests, potential expensive failures during actual launches can be avoided. Early identification of problems leads to cost savings in the long run.
8. **Training and Familiarization:** Static tests provide an opportunity for engineers and technicians to gain experience and become familiar with the rocket motor, its behaviour, and the testing process. This experience enhances the team's expertise and readiness for future missions.

4. Architecture:

- **Design:** As Aerospace Engineer I was mainly involve in design part of project although I also contribute little bit in avionics part. **In design team Drish dedhia and my self-working and little bit contributed in phase 2 by Ninaad Gambhir**. The design was carried out in three different phases

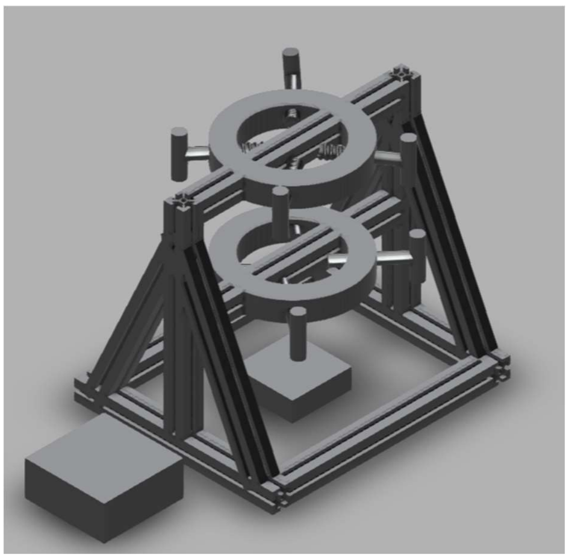
  Phase 1: In Phase 1, extensive research was carryout to study various types of Static Test Pads already in use and a conceptual idea was formed. While formulating the conceptual design, it was decided to keep the motor in vertical position to avoid Force vector come in one direction for that we have to develop same force in different direction and because of that force we have to specify soil condition where test will carried out so because of this constrain we have decided choose vertical design.
  Also, we have drawn the rough sketch of STP. Here you can see we have decided to use base square frame and two vertical support rods, 2 clamp and 4 rod to support vertical rod.





Phase 2: In Phase 2, the conceptual design was converted in to an actual design using Fusion 360. One team member made the Fusion 360 model although we change design little bit. Also, this model is rough model here you can spot some mistakes because team member doesn't able to make some part so I take lead to make model in phase 3. Although you can see what we are thinking to make.

Also, I am researching about material. We have to choose material which has lightweight, strong and economically beneficial during research I come up with Aluminium T-slot extrusion.



Fusion 360 model

Aluminium T-slot extrusion

Here the benefit of using Aluminium 6061 T6 T-slot extrusion profiles.

Versatility: T-slot extrusion profiles provide a versatile framework that allows for easy attachment of various components, accessories, and fasteners. The T-slot design enables the construction of complex structures and the integration of different elements without the need for complex welding or fabrication.

Modular Design: T-slot extrusion profiles are designed to be modular, meaning they can be easily connected and reconfigured. This modularity allows for flexibility in adjusting and modifying the structure as needed, making it ideal for prototyping, rapid iterations, and future expansion.

Easy Assembly: With T-slot extrusion profiles, assembly is simplified compared to working with solid aluminium rods. The T-slot design provides pre-defined slots or channels where components can be slid into place and secured using nuts, bolts, or other fasteners. This simplifies the assembly process and saves time.

Customization: T-slot extrusion profiles can be cut, drilled, and machined to suit specific requirements. This allows for customization and precise sizing according to the project's needs. Additionally, accessories such as brackets, connectors, and hinges are readily available to enhance functionality and enable further customization.

Lightweight: Aluminium 6061 T6 is known for its lightweight properties. By using extrusion profiles instead of solid rods, the overall weight of the structure can be reduced while maintaining strength and structural integrity. This is particularly beneficial when weight is a concern, such as in applications where portability or energy efficiency is important.

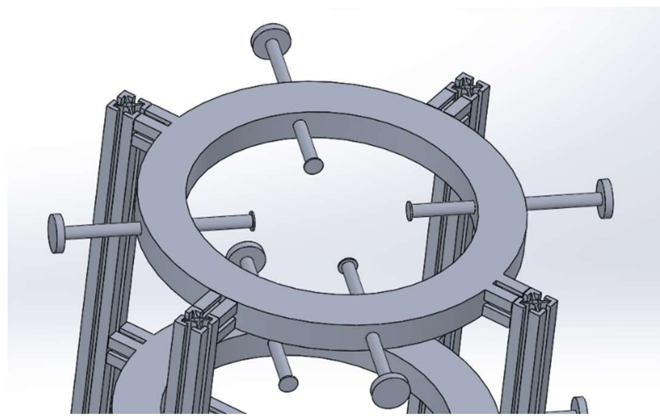
Cost-Effective: T-slot extrusion profiles can be cost-effective compared to solid aluminium rods, especially for complex structures. They eliminate the need for additional fabrication processes and reduce material waste. The modular design also allows for reusability and adaptability, reducing the cost of future modifications or reconfigurations.

Phase 3: In Phase 3, major design was carried out. I take lead to make model and modify what are the mistake in phase 2. Also, I was researching about fasteners. There are many fasteners available in the market for T-slot extrusion but I choose INNER CONNECTOR-For 90-degree connection in the structure because this fastener is easy to use, simple to install and creates strong 90-degree connection the fastener has two built-in set screws that fasten to the bottom of the t-slot channel with an Allen wrench so **no additional Machining or components are required to attach this item.** When installed into the Extrusion the Fastener will sit flush with the profile slot making this a **good option for our project because we are also focusing on cosmetic looks**.

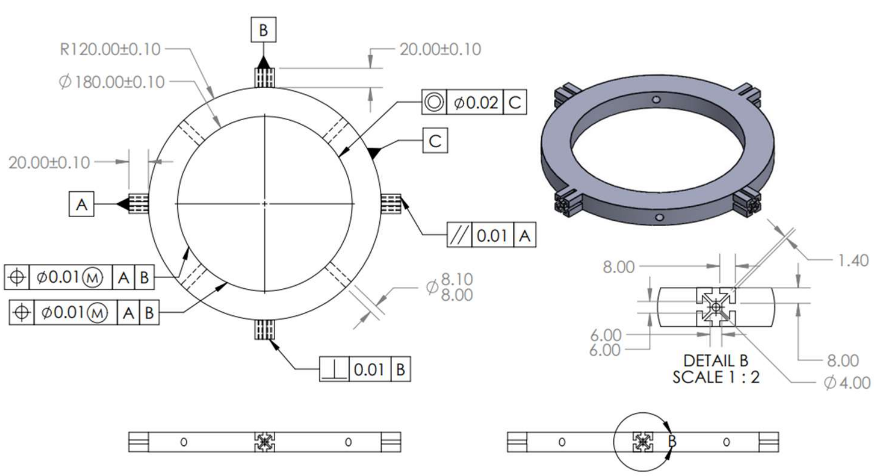
Inner Connector

Also, while researching about fastener that can use to connect rod at certain angle, the pricing of that fastener was too high because that we change our design and make it 4 vertical rod and connect the clamp to this rod so that it can be more stable and **INNER CONNECTOR way cheaper than angle fastener**.

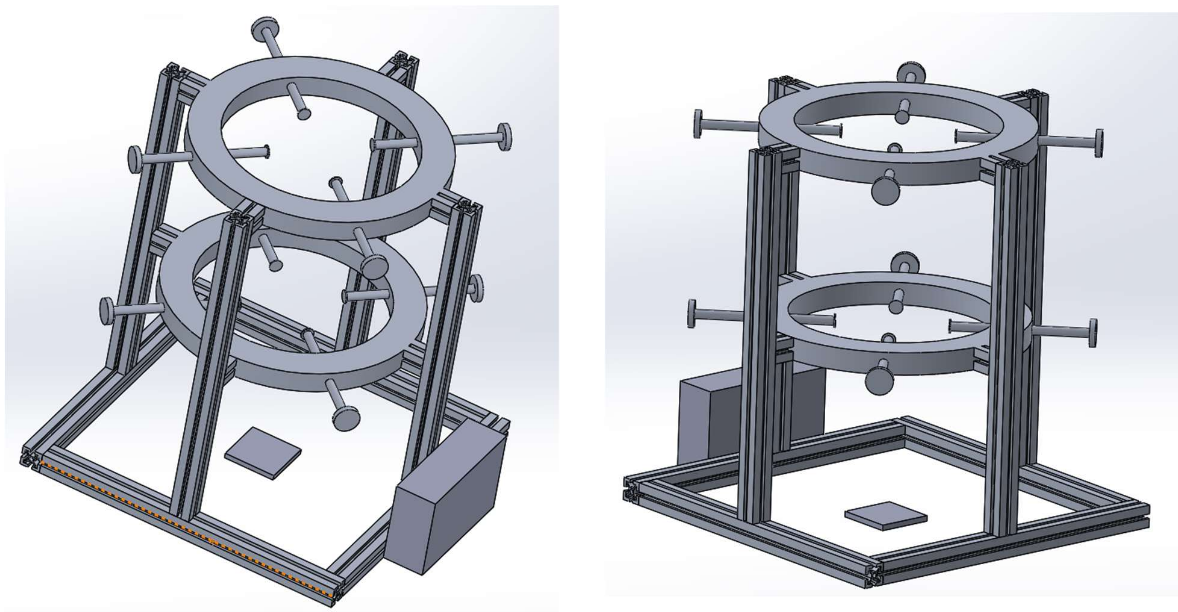
Also, we decided to use 4 circular rods instead of clamp (because clamp will hold Rocket motor way tighter because of that it can't exert actual force on the load cell) and **mount the spring on that rod** so if rocket motor has different diameter so we can pull that screw type rod and put in-between motor and that automatically adjust to required diameter of the Rocket motor.



Also, we have to focus on total prizing of STP. Because of that we have to choose all the component that readily available in the market so we have chosen max. component that readily available market but we have to make middle 2 ring (clamp like structure) **so for manufacturing we have to give a drawing with all tolerance and raw material so I make the drawing of middle 2 ring and we decided to give around 4 kg of aluminium 6061 for 1 STP**.

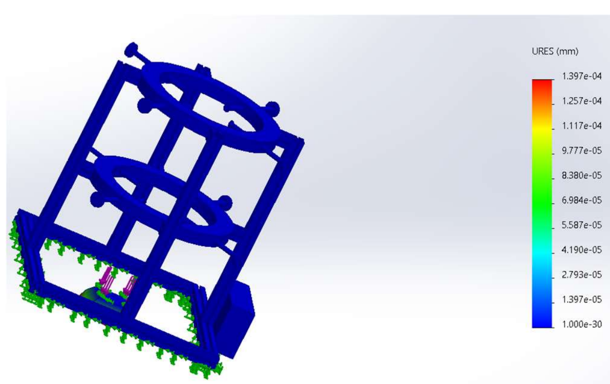


So, for final design we have 4 rod of 30 cm that make base square frame and 4 vertical rod of 33 cm and 2 middle rings (clamp like structure with 8 screw like structure and spring mounted on it), these 2 rings are 15 cm apart because minimum height of the rocket motor is around 38 cm. Avionic Bay will connect to one of the vertical rods and load cell will be in the centre of the square frame.



Final STP

Also, we run the couple of simulation but in our STP there is not much load because max. load apply to ground because of vertical design and little bit vibration in any direction will be adjust by spring mounted on 8 screw like structure. Also, rocker motor flame will be upward so temperature will not affect much on the structure.



- **Avionics:** I contribute little bit in the avionic part basically I know what are the components will be useful and basic flowchart and most of work done by avionics team.

  Components in the Avionics Bay:

  1. **Microcontroller Board - Arduino Uno R3:**

  The heart of our avionics system is the Arduino Uno R3 microcontroller board. it offers a versatile platform for programming and interfacing with different sensors, ensuring accurate data acquisition.

  2. **Amplifier - AD595:**

  To amplify the digital signal from the load cell, we use the reliable AD595 Amplifier. It enhances the precision of data collected during the test, enabling us to analyse thrust and other factor variations with greater accuracy.

  3. **Temperature Sensor K-type:**

  The K-type Temperature Sensor is an essential component for determining flame temperature, specific impulse, and chamber pressure. Paired with the AD595 thermocouple amplifier, it accurately measures temperature changes within the rocket motor.

  4. **Alternative Data Storage - SD Card:**

  For seamless data storage and processing, we have incorporated an SD Card and SD Card holder. This ensures data integrity and provides a reliable backup in case of any unforeseen data loss.

  5. **Wi-Fi Module:**

  To enhance flexibility and remote-control capabilities, this module allows us to calibrate sensors and activate relays wirelessly, adding convenience to our testing procedures.

  6. **Printed Circuit Board (PCB):**

  The integration of all electrical subsystems onto a Printed Circuit Board (PCB) streamlines the avionics setup. This eliminates the need for excessive connecting wires, ensuring a clean and efficient design.

  7. **Arduino Circuit Breaker:**

  Safety is paramount in our avionics system. The Arduino Circuit Breaker safeguards the circuit against high voltage surges or malfunctions, preventing any potential damage to sensitive components.

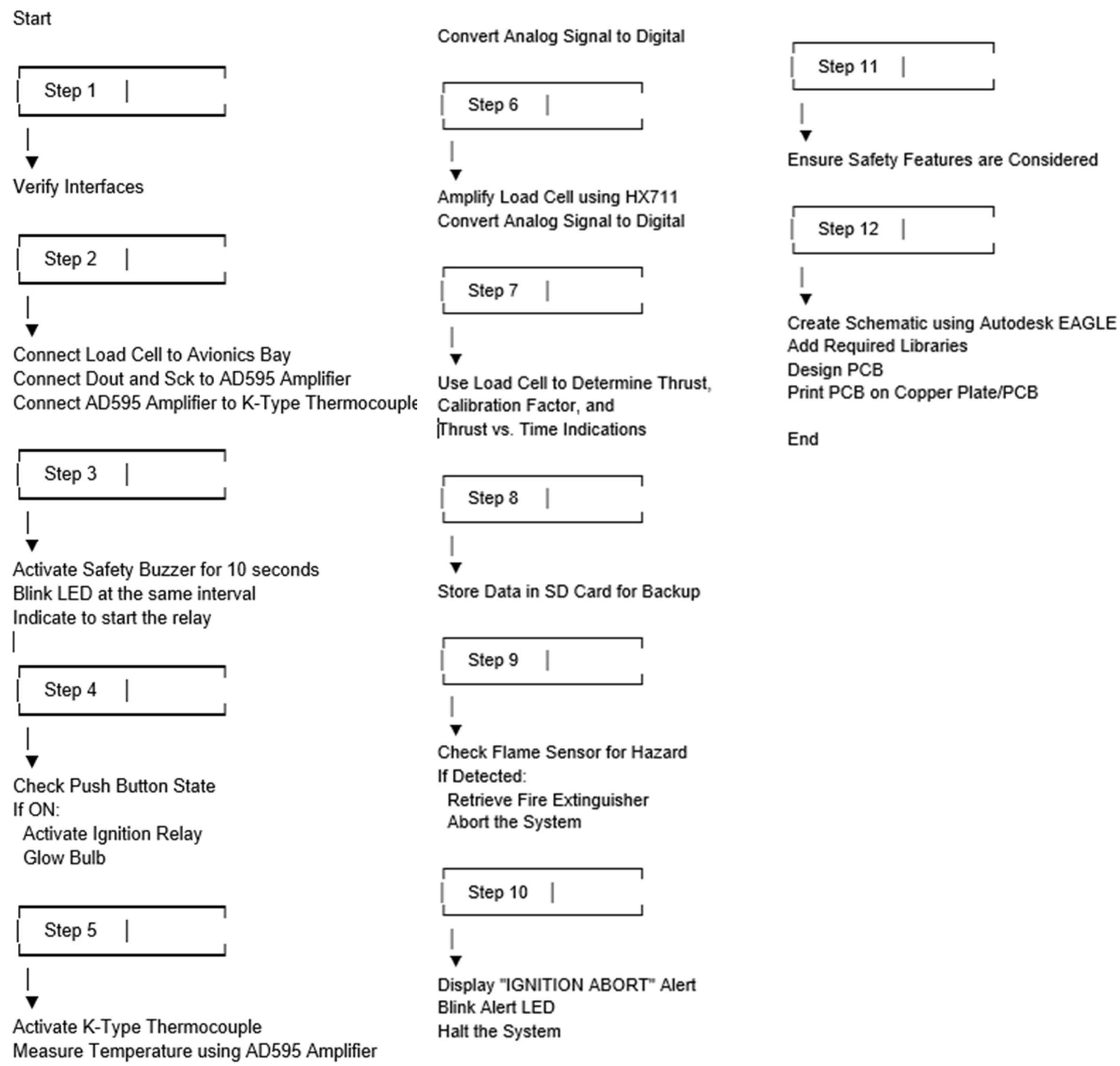
  8. **LED, Load Cell, and Buzzer:**

  We've included essential indicators like LEDs to display key statuses, Load Cells for thrust measurement, and a Buzzer for alerting operators during crucial stages of the test.

  9. **Systems Check & Ignition Controls:**

  To facilitate thorough systems checks, we have implemented controls that allow operators to verify the readiness of the avionics system before ignition.

Flow chart:



5. Software required to Rocket Motor Static Test Pad:

In our quest to create an efficient and reliable Rocket Motor Static Test Pad, we harnessed the power of various software tools that played pivotal roles in different stages of the project. These software tools were instrumental in programming, simulating, and designing our avionics and mechanical systems. Let's explore each of them:

1. Arduino IDE: Central to our electronics systems, the Arduino IDE was the backbone of our programming endeavours. This user-friendly software served as the main interface for

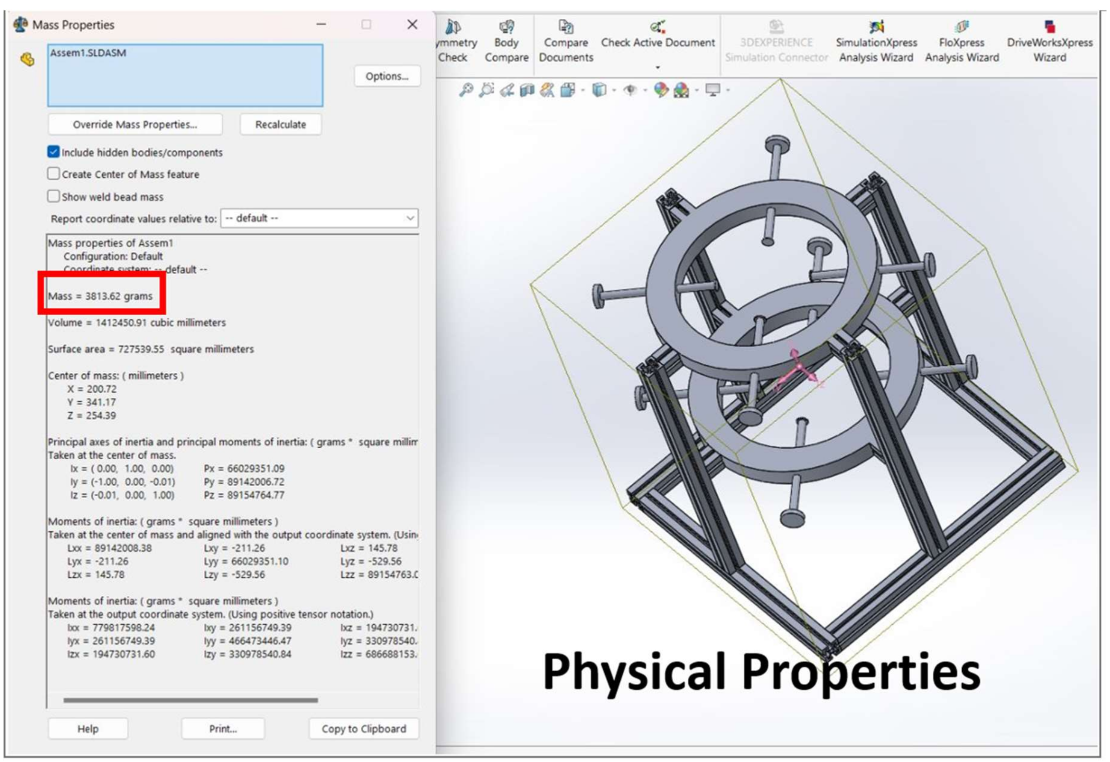
commanding and controlling the static test pad. We programmed our microcontroller boards using Arduino IDE, ensuring seamless communication and precise data acquisition.

2. Proteus Professional: In our pursuit of perfection, Proteus Professional proved to be an invaluable tool for simulating the intricate workings of our electronics. With Proteus, we constructed comprehensive circuits and connections, enabling relay control through the wife module and calibration factor adjustments. Additionally, it facilitated data storage in the SD Card, providing us with an advanced and reliable virtual environment for testing and refinement.

3. SolidWorks: Stepping into the realm of computer-aided design (CAD), SolidWorks was our go-to software for creating the final CAD model of our project. This powerful tool allowed us to meticulously design and visualize every component with precision.

4. Fusion 360: Empowering our initial concept and prototype designs, Fusion 360 was an integral part of our CAD endeavours. With its user-friendly interface.

6. **Total weight: 4 kg** (including fasteners weight)



7. Prizing:

Element	Price
Custom Aluminium T Slot extrusion profile-3500mm	Rs.379/1000mm-379x3.5-Rs.**1326.5**
Aluminium 6061 Rings and Clamping screws	Aluminium 6061- 250/kg - 250x3.6kg – Rs.**900**
Inner connector for rods	Rs.100/piece – 16x 100 – Rs. **1600**
Machining cost	Approximately Rs. **800**
Springs for clamps	Rs 10/ piece – 10x8 – rs**. 80**
TOTAL PRICE	**RS. 4706/-**

8. Procedure to build a Rocket Motor Static Test Pad:

To construct a robust and reliable Rocket Motor Static Test Pad, follow these step-by-step instructions:

Step 1: Assemble the Base Frame

- Take four T-slot extrusions of 30 cm length each.
- Connect these extrusions using INNER CONNECTORS to form a square base frame. Ensure a secure and stable connection.

Step 2: Build the Vertical Support

- Take four T-slot vertical extrusions of 33 cm length each.
- Attach these vertical extrusions to the exact centre of the base frame using INNER CONNECTORS. This will form the vertical support structure for the test pad.

Step 3: Add Middle Rings (Clamp-like Structure)

- Obtain two middle rings that resemble clamp-like structures.
- Connect these middle rings to the four vertical rods using INNER CONNECTORS. Position them at the center of the vertical rods, ensuring an equal distance between the rings.
- The gap between the upper and lower rings should be 15 cm.

Step 4: Insert Screw Type Rods

- Take eight screw type rods mentioned earlier.
- Insert these rods into the holes of the middle rings. These rods will act as mounting points for the springs.

Step 5: Mount the Springs

- Place the springs on the screw type rods, securing them in place. The springs will provide the necessary flexibility and cushioning during rocket motor testing.

With these steps completed, your Rocket Motor Static Test Pad is now ready for testing rocket motors. The sturdy base frame and vertical support ensure stability and accurate positioning of the rocket motor. The middle rings and springs add an essential component to accommodate and dampen the thrust generated during testing. Always ensure safety protocols are followed, and all personnel are positioned at a safe distance during tests.

By following this guide, you have successfully built a functional and efficient Rocket Motor Static Test Pad, providing a reliable platform for performance analysis of rocket motors. Happy testing and best of luck in your endeavours!

9. Observation:

Conclusions from the Design Procedure:

1. Comprehensive Design: The Rocket Motor Static Test Pad design is a culmination of various considerations, making it lightweight, strong, durable, and cost-efficient. Its versatility allows it to accommodate rocket motors of different diameters and lengths.

2. Thrust and Stress Capability: The design has been analysed and found to withstand thrust, making it suitable for testing a wide range of rocket motors with varying power levels.

3. Future-Ready Design: Taking future needs into account during the design process ensures that the test pad remains relevant and adaptable to evolving requirements. Its manageable weight of 3.8kg makes it easily transportable and deployable in diverse testing environments.

4. Efficient Assembly with T-Slot Aluminium: The incorporation of Al6061 20x20 T-Slot extrusions significantly simplifies the assembly and disassembly process, enabling rapid setup and breakdown of the entire test pad system.

5. Remote Activation and Real-Time Data Transfer: The integration of a Wi-Fi Module enables remote activation of relays, minimizing risks associated with proximity to the test stand. It also facilitates real-time data transfer, enhancing data collection efficiency.

6. Data Storage and Backup: The inclusion of an SD Card for data storage serves a dual purpose by providing a convenient means of data collection and acting as a reliable backup for future analysis and reference.

10. Key Learnings from the Rocket Motor Static Test Pad Project

Throughout my journey in the Rocket Motor Static Test Pad (STP) project, I have gained valuable insights and skills across various domains. The experience has been both enriching and rewarding, and I am delighted to share my learnings:

1. Understanding the Purpose of STP:
At the project's outset, I acquired a comprehensive understanding of STPs, their significance, and the data parameters collected during static tests. This foundational knowledge allowed me to grasp the project's goals and objectives effectively.

2. Design Thinking and CAD Mastery:
As a design intern, I dived into the world of design thinking and honed my skills in Computer-Aided Design (CAD). I gained proficiency in Creo and Fusion 360, learning how to consider multiple factors while crafting efficient and robust designs. Simulations in Fusion 360 enabled me to optimize designs for performance and reliability.

3. Avionics and Electronics:

Venturing into avionics and electronics, I familiarized myself with Arduino IDE for coding, created schematics using Proteus, and designed PCBs using Eagle. This exposure at a beginner's level laid a solid foundation for understanding the intricate interplay between avionics and design elements.

4. Real-World Application of Theory:
This project served as an invaluable platform to apply theoretical knowledge into practical implementations. I learned how to adapt theoretical concepts to real-world challenges and find innovative solutions. Cost analysis and resource management were also essential skills I honed during this process.

5. Embracing Challenges and Growth:
Navigating the complexities of rocket motor testing and STP development taught me to embrace challenges with enthusiasm. Every hurdle presented an opportunity for growth and learning, leading to a sense of accomplishment at each milestone achieved.

11. Results:

This report outlines the profound significance of each component integrated into the assembly of the Rocket Motor Static Test Pad (STP) and the extensive simulations performed. The culmination of brainstorming, designing, and rigorous testing led to the successful development of an ergonomic and high-performance STP, meeting all intended characteristics.

The culmination of the design process, extensive simulations, and testing efforts led to the successful realization of an efficient and high-performance Rocket Motor Static Test Pad. It demonstrated the intended characteristics, fulfilling the project's objectives and paving the way for reliable and accurate rocket motor testing.

12. Conclusion:

Through dedication, ingenuity, and a collaborative approach, the Rocket Motor Static Test Pad was designed, tested, and brought to fruition. Its seamless assembly, robust performance, and safety measures offer an invaluable platform for future rocket motor testing endeavours. This accomplishment is a testament to the team's expertise, commitment, and ability to overcome challenges, delivering a state-of-the-art STP that advances the field of rocket motor testing.

13. Precautions:

To ensure the safe and accurate testing of rocket motors on the Static Test Pad (STP), we have implemented a series of critical safety precautions. These precautions are designed to protect personnel, equipment, and the surrounding environment during the testing process. Let's delve into these safety measures:

1. **Motor Placement and Clamping:** Proper motor placement and secure clamping are paramount. The rocket motor must be positioned in the correct orientation to ensure accurate load application. Sturdy clamps are tightly attached to maintain the correct angle, preventing any slanted positioning that could compromise the test results.
2. **Ablative Coating for Enhanced Safety:** To provide an additional layer of safety and limit potential damage, all components, including the rocket motor and test stand, are coated with an ablative material. This coating helps dissipate heat and minimizes the risk of thermal damage during testing.
3. **Safe Operator Distance:** We prioritize the safety of our operators, ensuring they maintain a minimum distance of 10 meters from the STP during testing. This distance safeguards personnel from potential risks associated with ignition and exhaust gases.
4. **Emergency Preparedness:** In the event of an emergency, we have implemented a clear LED signal system. This signal indicates any discrepancies or issues during testing. We emphasize the importance of maintaining the maximum distance from the STP during such situations to guarantee the safety of all personnel.
5. **Thorough Ignition Checks:** Before initiating any tests, we perform repeated and rigorous checks on the ignition system. Verifying the operational status of the relay ensures that ignition will not occur instantaneously, reducing the potential for accidental and unplanned firings.

14. References:

1. https://youtu.be/igtcGMTDUIs
2. https://www.youtube.com/playlist?list=PL6wv_7qUh1Ram1QN48aVeN7YBy2S7_kcD
3. Previous internship reports
4. https://www.indiamart.com/?back=1
5. https://robu.in/product/easymech-20x20-t-slot-aluminium-extrusion-profile-1000-mm/
6. https://www.tslots.com/