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A Novel Approach to Two-Stage Model Rocket Design: Integrating Sensors, Cameras, Electrical Ignition, and Electrical Separation

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Abstract
Model rocketry is a unique and effective way to teach engineering students about problem-solving and design, and it has potential applications in the emerging research and development of aerospace systems. This paper focuses on designing a two-stage model rocket with three parallel stagings and a recovery system for both stages, with a target altitude of around 1000 feet. The rocket is 48 cm long, 5 cm wide, and weighs approximately 500 g. It also includes various sensors to validate simulations and calculation results, such as altitude, gyro, acceleration, and location, as well as a camera that transmits live footage to the ground using telemetry. The second stage is ignited wirelessly. The paper also discusses the design of the electrical ignition system, launch pad and potential future advancements.

Keywords: Model Rocketry, Two-Stage Rocket, Parallel Staging, Recovery System, Altitude Sensor, Gyro Sensor, Acceleration Sensor, Location Sensor, Camera, Telemetry, Wireless Ignition, Electrical Ignition System, Launch Pad, Future Advancements, Aerospace Engineering and Electronics Engineering

Introduction
A solid-state rocket, also known as a model rocket with solid engines, is a prototype of an actual launch vehicle used for a variety of applications, including launching satellites into space and missiles for air-to-air and air-to-ground combat. Solid-state rockets can consist of one or more stages, each with its own propellant and engines. Figure 1 illustrates the structure of a two-stage model rocket [1].

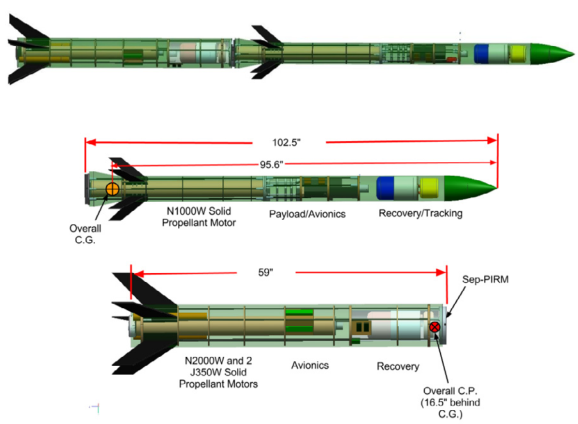


Figure 1: Structure of a Two-Stage Model Rocket [2]

The above figure illustrates the structure of a typical model rocket, with the structure of both stages shown separately. The upper stage consists of the following components:

- Nose Cone: Protects the rocket's payload from aerodynamic forces during launch and ascent.
- Recovery System: Includes a parachute to slow the rocket's descent and prevent it from crashing.
- Payload/Avionics: Electronics, including sensors and controllers.

- Solid Motor: The main engine that generates thrust to propel the rocket.
- Fins: Provide stability and control during flight.
- The lower stage consists of the following components:
- Recovery System: Includes a parachute to slow the rocket's descent and prevent it from crashing.
- Solid Motor (S): Generates thrust to propel the lower stage.
- Fins: Provide stability and control during flight.

This paper focuses on designing a two-stage model rocket using solid engines with three parallel stages and a recovery system for both stages. The rocket is aimed to achieve an altitude of around 1000 feet, with a length of 48 cm, a width of 5 cm, and a weight of approximately 500 g. The rocket also includes various sensors to validate simulations and calculation results, such as altitude, gyro, acceleration, and location. A camera transmits live footage to the ground using telemetry. The second stage is ignited wirelessly. The paper also discusses the design of the electrical ignition system and launch pad and potential future advancements.

The model rocket is subjected to four forces during flight: weight, thrust, lift, and drag. The relative magnitude and direction of these forces determine the rocket's flight trajectory.

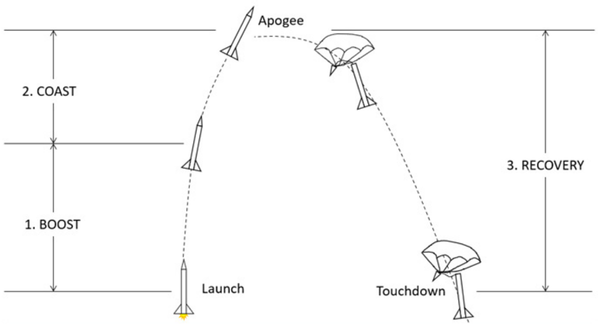


Figure 2: Flight Profile of a Typical Single-Stage Model Rocket [3]

The above figure illustrates the events in the flight of a single-stage model rocket [4].

- A launch pad is used to ensure sufficient stability for the rocket, since during launch, the speed of the rocket is too high to ensure stability.
- The rocket leaves the pad and begins a powered ascent. Thrust is still greater than weight, and the aerodynamic forces of lift and drag now act on the rocket.
- When the rocket runs out of fuel, it enters coasting flight. The vehicle slows down due to weight and drag, as there is no longer any thrust.
- The rocket will eventually reach a certain maximum height, which one can measure using simple measurements of length, angle and trigonometry.
- The rocket will then begin to fall back to Earth due to gravity.
- While the rocket is coasting, a delay charge burnt slowly in the rocket engine creates no thrust but can produce a small stream of smoke that makes the rocket easier to see from the ground.
- At the end of the delay charge, the launch charge is ignited, which pressurizes the body tube, blows off the nose cone, and deploys the parachute.
- The rocket then begins a slow descent under the parachute for recovery. The forces acting here are the weight of the vehicle and the drag of the parachute.
- After the rocket is recovered, you can replace the engine and fly again. It is a reusable rocket, which also uses reloadable motors for the next ignition.

Design Process

In this section, we will discuss the design procedure for this project.
The first step in designing a model rocket is to determine the desired distance traveled.
Model rockets are classified into three categories based on the distance they travel: low-powered, medium-powered, and high-powered. The table below compares the three categories.

Low Powered	Medium Powered	High Powered		
Less than 20g of propellant mass	Less than 62.5g of propellant mass	Greater than 62.5 grams of propellant and have a maximum total impulse of 160N seconds		
Level 0	Level 0	Level 1	Level 2	Level 3
A,B,C,D	E, F, G	H and I	J, K, L	M, N, O

Table 1: Comparison of Different Categories of Model Rockets [10]

We estimated that the model rocket will achieve a flight of 1000 feet. Based on this, the next step is to calculate different parameters of the model rocket, such as the length, width, and height of the body; the aerodynamic and gravitational forces; the center of gravity; the center of pressure; propulsion; thrust; and electronics.

The Model Rocket Consists Of Several Systems, As Follows:

- **Body and Structure:** The body of the rocket provides structural support and houses the other systems.
- **Aerodynamics:** The aerodynamic design of the rocket determines its stability and flight characteristics.
- **Propulsion System:** The propulsion system provides the thrust that propels the rocket.
- **Electrical Ignition System:** The electrical ignition system initiates the combustion of the rocket's propellant.
- **Avionics:** The electronics system controls the rocket's functions, such as ignition, separation, and recovery.
- **Recovery System:** The recovery system ensures that the rocket can be safely returned to the ground after flight.
- **Launchpad:** The launchpad provides a stable platform for launching the rocket.

We divided all the systems among the team members for a better research and design approach. We will discuss each system in more detail in the following sections.

Body and Structure of the Rocket

The body and structure of the rocket consist of the outer body, motor mounts, engine blocks, and body couplers.

The outer body of the rocket is a cylindrical structure with different dimensions for each stage. To design the outer body, the length, width, and thickness must be calculated, taking into account the material density of the material to be used, ensuring light weight, safety parameters, and accommodation for all the parts that will go inside the body.

The figure below shows the final CAD model of the outer body of the upper and lower stages with fin mounts for both stages. The upper stage outer body has a length of 210 mm, a diameter of 5 mm, and a thickness of 2 mm. The lower stage outer body has a length of 120 mm, a diameter of 5 mm, and a thickness of 2 mm.

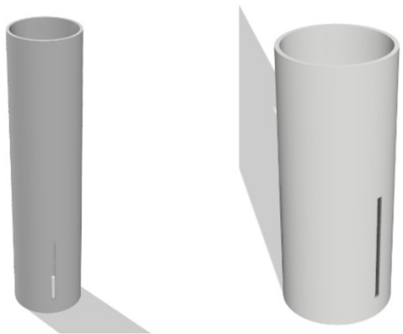


Figure 3: CAD Model of the Upper and Lower Stage Body Structure of the Rocket

The motor mounts consist of a cylindrical structure for holding the motor or engine for both stages, with a ring structure (also known as an engine block) for holding the motor mount inside the outer body of the rocket. The body couplers are cylindrical structures for coupling the bodies of the two stages. The figure below shows the final CAD model of the motor mounts with a ring to hold and the body coupler for both stages. The motor mount is 80mm long, 25mm in diameter, and 2mm thick. The engine block is 46mm in outer diameter, 5mm in inner diameter, and 5mm thick. The body coupler is 30mm long, 46mm in diameter, and 2mm thick.

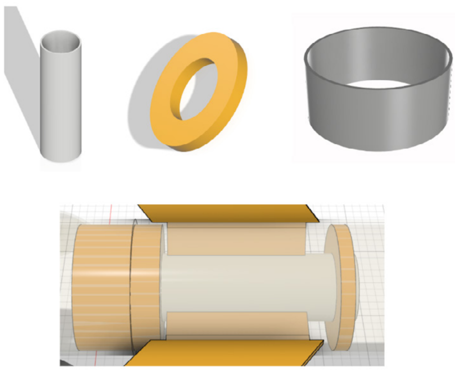


Figure 4: CAD Model of the Motor Mount and the Engine Blocks

Aerodynamics

Aerodynamics is the most important part of the model rocket design for achieving maximum altitude and for understanding the airflow and aerodynamic forces acting on the rocket during flight. Aerodynamics also plays a vital role in stabilizing the rocket by generating a centre of pressure that balances the forces.

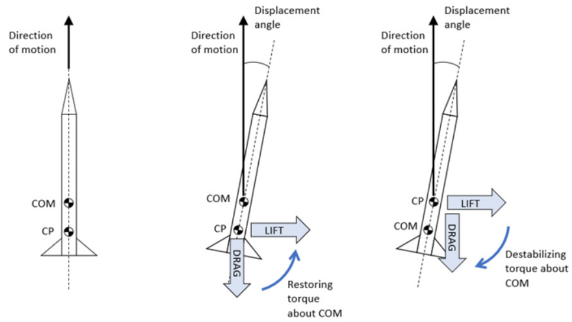


Figure 5: Forces Acting on the Rocket at the Time of Flight

- **Left:** The centre of pressure (CP) and center of mass (COM) are aligned, so there is no net aerodynamic torque about the COM. This means that the rocket will maintain its orientation regardless of any disturbances it encounters during flight.
- **Centre:** The CP is behind the COM. This creates a restoring torque about the COM, which means that the rocket will tend to return to its original orientation if it is disturbed. This is the most common and desirable configuration for model rockets.
- **Right:** The CP is in front of the COM. This creates adestabilizing torque about the COM, which means that the rocket will tend to deviate further from its original orientation if it is disturbed. This configuration is undesirable for model rockets, as it can lead to loss of control and instability.

The Aerodynamic structures include the nose cone and the fins for both stages. It is designed to consume less drag force and uplift the flight of the rocket opposing the airflow and maintaining the stability of the rocket. The below figure illustrates the sketch diagram and the final CAD model of the nose cone and the fins of both stages with the dimensions.

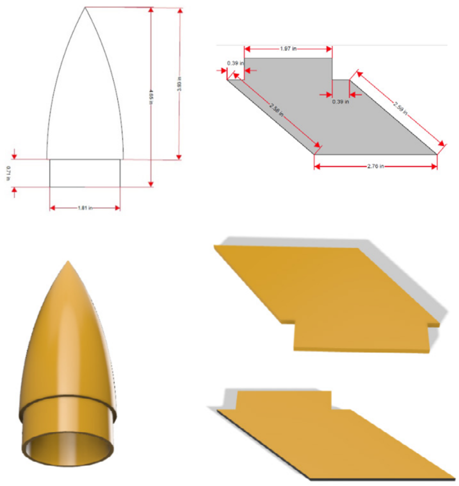


Figure 6: Sketch and Cad Model of the Nose Cone and the Fins

Propulsion System

The propulsion system of a model rocket consists of rocket motors. Rocket motors are essential for any rocket, as they provide the thrust that propels the rocket. A model rocket motor is available in different sizes and shapes, all rocket motors comprise a black powder inside them which is the main driving force and that is the actual part of the motor that burns. Almost all rocket motors available have a standard code written on them which comprises letters as well as numbers, this code is essential in motor selection as each letter or number of the code signifies the way the motor behaves and hence is necessary while deciding on the motor according to the results desired to be achieved. The below figure shows the construction of the solid engine or motor used in model rockets.

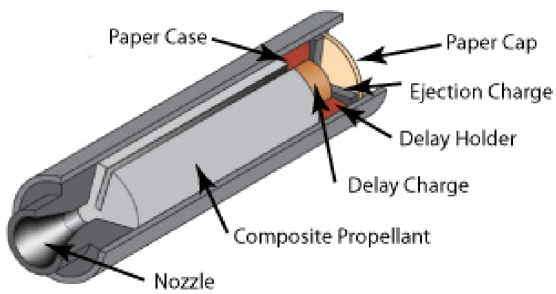


Figure 7: Construction of a Model Rocket Solid Engine or Motor

The below figure illustrates When the engine is ignited using the electric igniters, it produces the thrust and boosts the rocket into the sky after the propellant is used up, the delay is activated producing tracking smoke and allowing the rocket to coast After the delay is used, the ejection charge is activated which deploys the recovery system, in our case its parachute.

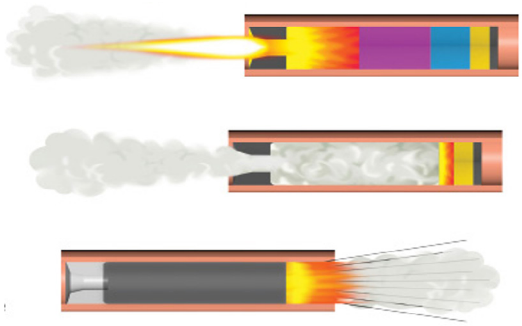


Figure 8: Working of a Model Rocket Solid Engine or Motor

Generally, the code on a model rocket motor consists of three or four characters, each of which has its own significance: The first character is most commonly a letter, which indicates the total impulse of the motor. Total impulse is the integral of the thrust over burn time. The second character is a number, which indicates the average thrust of the motor. Average thrust is the force applied by the motor over the burn time. The third character, if present, is a number, which indicates the delay time of the motor. Delay time is the time from motor burnout to ejection charge activation. In some special cases, a letter T may be present at the end of the code to indicate a mini motor. Some motors have a 1/2 ahead of the first letter to indicate that the power is less than a full-power motor.

The figure below describes the code of the motors and the thrust produced concerning the time of some motors.

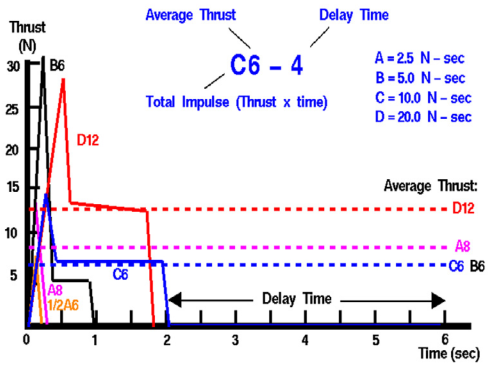


Figure 9: Code Description and Thrust Curves of a Model Rocket Solid Engine or Motor [11]

For the selection of motors, we used simulations to test different motors to meet the desired altitude of our rocket, taking into consideration its height, weight, and structure. The main motor we used was a D24-T motor. As our desired altitude was 1000 feet, we used a higher-class D motor, which allows the rocket to go up to 700 to 1500 feet. For the thrust, we used a standard and steady one as the rocket is of two stages and will also carry some amount of payload in terms of the electronics. For the delay, we decided to keep it at 4 seconds, which would be just enough to take our rocket higher and should work well. The T in the code stands for a telescoping motor, which is a compact motor that can be adjusted in our rocket with a small space covered and a good amount of thrust. As mentioned before, a delay time 0 motor is used for rocket staging, and since we intend to have two stages in our rocket, we will use a D2-0 motor at the separation of the first stage. We also used two A3 motors to separate out the parallel stages, as A motors have comparatively less power, which is just enough to separate the three parallel stages. The description, graphs and thrust curves of both motors are given below from the manufacturer.

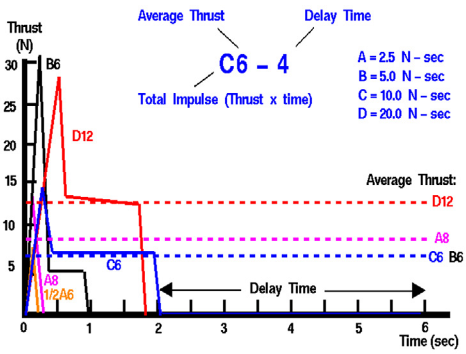


Figure 10: D24-T and A3 Motors from the Manufacturers Containing All the Parameters

Electrical Ignition System

Ignition systems are required to ignite the motor in order to launch the rocket. Igniters, which are usually provided by the motor suppliers, are used for this purpose. They can also be made easily using wires or even matchsticks. Igniters are installed inside the motors so that they make contact with the propellant because the propellant must be ignited for the motor to fire. A plug can be used for safety to ensure that the igniter remains inside the motor and in contact with the propellant.

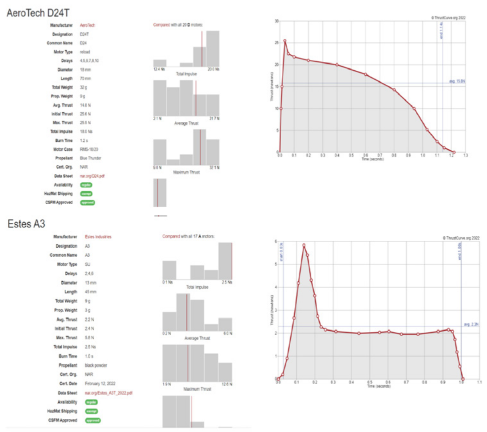


Figure 11: Electrical Ignition System Schematic

The above image illustrates the schematic of the Electrical Ignition System used. The ignition system includes a switch, battery/power supply connectors, and a safety lock. The typical current required to ignite the igniters is around 1.5 to 2 amps. This current requirement can be met using a 12-volt battery for the power supply. The safety interlock switch is a special type of switch that is always open (an incomplete circuit) unless the safety interlock key is inserted into it to complete the circuit. Once this key is inserted, electricity can flow from the dry cells through a wire to a micro clip and then through the igniter attached to the microclips. Once the switch and safety key are closed, the circuit is complete and the current flows through it and ignites the igniters.

Avionics

Our electronics system consists of a microcontroller for sensing, logging data, telemetry, camera operation, and second-stage ignition control. During the selection process of the microcontroller, we were searching for one that is readily available in the market, should fit inside the rocket, should be lesser in weight, can handle multiple operations at a single time, can process different types of sensor data, and has user-friendly sensor interfaces. It is the main controller for our model rocket and is responsible for executing the code for the different sensors, cameras, and complex calculations. Therefore, the microcontroller must have a high-performance, easy-to-program microcontroller unit (MCU). The MCU must be fast enough to handle fault conditions within the stipulated time period while also handling monitoring and logging functions. With these factors in mind, we researched and considered different microcontroller families to find the one best suited to the task.

Feature	Arduino Nano	Arduino Uno	Arduino Mega
Clock rate	16 MHz	16 MHz	16 MHz
Number of analog pins	8	6	16
Number of digital I/O pins	14 (of which 6 provide PWM output)	14 (of which 6 provide PWM output)	54 (of which 15 provide PWM output)
Flash memory	32 KB	32 KB	256 KB
SRAM memory	2 KB	2 KB	8 KB
EEPROM memory	1 KB	1 KB	4 KB
Length	45 mm	68.6 mm	101.6 mm
Width	18 mm	53.3 mm	53.3 mm
Height	3 mm	14.5 mm	25.4 mm
Weight	0.2 grams	2 grams	10 grams
Price	₹400 - ₹450	₹500 - ₹550	₹1000 - ₹1500

Table 2: Comparison of Different Categories of Model Rockets [10]

According to the comparison Arduino Uno is the best microcontroller, which is capable of performing the tasks which need to be performed, while there is a drawback with respect to the size and the weight. Due to this, we need to consider Arduino Nano as it can perform the tasks which need to be performed with size and weight which could fit inside the rocket. After selecting the microcontroller, we need to select the sensors and data logger. To meet the data requirements, we considered different sensors for sensing various parameters, such as altitude, GPS coordinates, humidity, temperature, pressure, acceleration, and velocity. We had to get components that were readily available at the local market and could provide the best data needed for further processing. When selecting components, we needed to consider basic parameters such as high communication range, sensor output accuracy, and weight.

The BMP280 sensor is a digital barometer that can measure atmospheric pressure, temperature, and altitude. It supports SPI and I2C communication protocols to communicate with Arduino Nano. The MPU6050 sensor is a 6-axis IMU that can measure acceleration, rotation, and temperature. It also supports SPI and I2C communication protocols to communicate with Arduino Nano. The SD Card Module is a device that allows an Arduino Nano to read and write data to an SD card. It supports SPI communication protocol to communicate with Arduino Nano. It can be used to log sensor data for further processing and validation of the rocket design.

The ESP32 Camera Module is a device that allows an Arduino Nano to capture and transmit video and images. It supports SPI communication protocol to communicate with Arduino Nano. It can be used to record live footage of the rocket launch and send the live footage to the ground using telemetry. The HC-12 Module is a wireless serial communication module with a range of up to 1 km in open space. It supports UART communication protocol to communicate with Arduino Nano. It can be used for wireless communication between the rocket and the ground and can act as a telemetry control unit. Two HC-12 modules are required, one inside the rocket and one on the ground, both connected to their respective Arduino Nano for wireless communication and control.

The 5V Relay Module is a device that can be used to control high-current loads with a low-current signal. It will be used as an electrical path between the battery pack and the igniters of the motors for the second stage. It will be responsible for the second stage ignition, and it will be controllable based on the altitude parameter as well as controllable using the wireless communication from the ground.

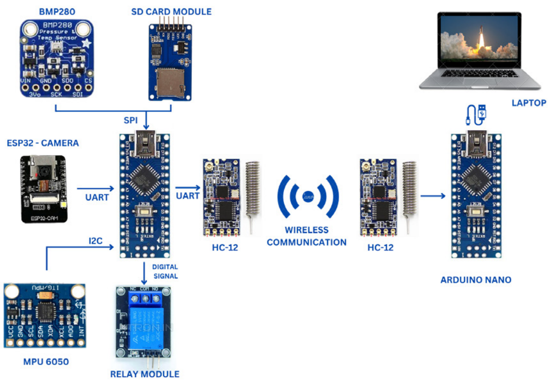


Figure 12: Block Diagram of Interfacing of the Electronics

The above figure illustrates the block diagram of the interfacing of electronics inside and outside the rocket.

Recovery System

To ensure the safe landing of the model rocket, a recovery system that includes a parachute will be used. This will help ensure the safety of the rocket and avoid damage to nearby property. The parachute is designed using simple, readily available household materials. It will have eight corners attached to the rocket using eight ropes.

The size of a parachute for a model rocket is calculated based on the following factors:

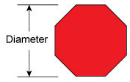
- **Weight of the Rocket:** The parachute must be large enough to support the weight of the rocket and all of its components.
- **Descent Rate:** The parachute must be large enough to slow the rocket's descent rate to a safe speed.
- **Wind Conditions:** The parachute must be large enough to overcome the wind and ensure that the rocket lands safely.

There are several formulas that can be used to calculate the size of a parachute for a model rocket. One common formula is

$$Parachute\ diameter = \frac{2 * Rocket\ Weight}{air\ density * descent\ rate * parachute\ drag\ coefficient}$$

In practice, it is often easier to use a parachute sizing chart to determine the appropriate size parachute for a model rocket. Parachute sizing charts are available from several sources, including rocketry clubs and websites.

Octagon Parachute Selection Chart



Diameter (inches)	Diameter (m)	Area (m^2)	Mass (Slow Descent)	Max. Mass - grams (Fast Descent)
8	0.20	0.0358	20	32
12	0.30	0.0805	44	73
15	0.38	0.1257	69	114
18	0.46	0.1810	99	164
24	0.61	0.3218	177	291
30	0.76	0.5029	275	456
36	0.91	0.7241	397	657
42	1.07	0.9856	541	894
48	1.22	1.2873	706	1168
58	1.47	1.8796	1031	1705
72	1.83	2.8964	1589	2627

Figure 13: Parachute Sizing Chart [11]

Based on the calculations and the references, the parachute size was decided to be 20 inches.Below is the parachute made using below is the image of the parachute made using polyester material.

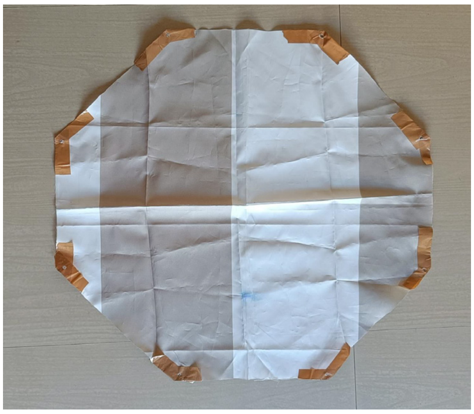


Figure 14: (I) Parachute Made Using Polyester Material of 20 Inches in Diameter (II) Parachute Attached To the Lower Stage of the Rocket

When the motor burns out, the parachute will eject and help bring the particular stage of the rocket down safely. It will act as a recovery system. This parachute will be attached to the lower stage above the motors. In the upper stage, this will be attached between the nose and the body of the upper stage. It will be responsible for getting both stages back to the ground when the propulsion of both stages is over.

Launch Pad

Model rocket launch pads hold the rocket before and stabilize it during launch. The launch pad consists of a launch rod that aims and stabilizes the rocket's initial trajectory and a blast deflector plate or a wooden plate that protects the ground and launch pad itself from the flames of the engine. The launch rod is the vertical tower structure in the center of the launch pad that the model rocket attaches to, usually connected via a launch lug. A launch lug is a small hollow tube attached to the outside of the rocket that the launch rod can slide through. The figure below shows the Launch Pad and the rocket attached to the launch pad with the side-mounted hooks

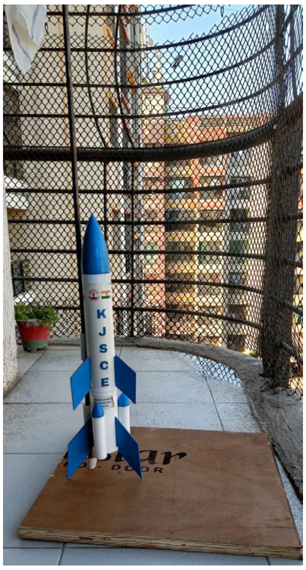


Figure 15: Launch Pad with Rocket

Simulations

After theoretical calculations, we inserted them into the Open Rocket simulation software to validate the rocket's predicted velocity, flight, thrust, altitude, acceleration, stability, and other parameters. Additionally, CFD (Computational Fluid Dynamics) analysis will be performed on the nose and fin structure to provide information on the aerodynamic forces and drag acting on them. Below Figure illustrates the schematic of the model rocket in the Open Rocket software with all the systems in it.

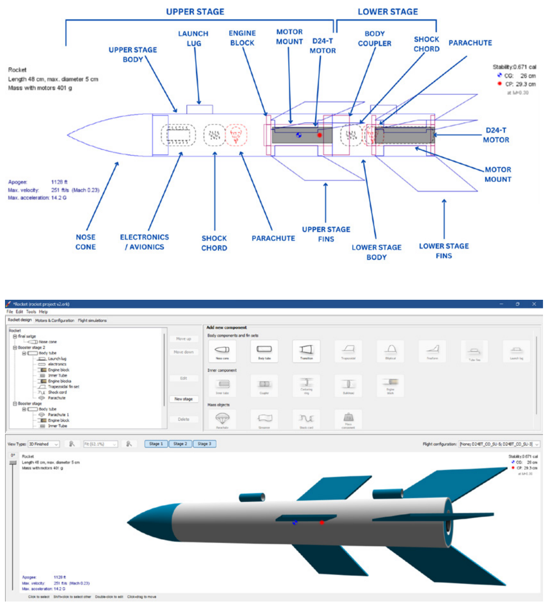


Figure 16: Schematic of the Model Rocket in the Open Rocket Software

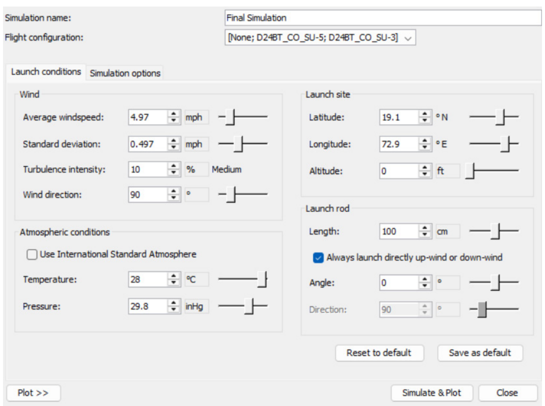
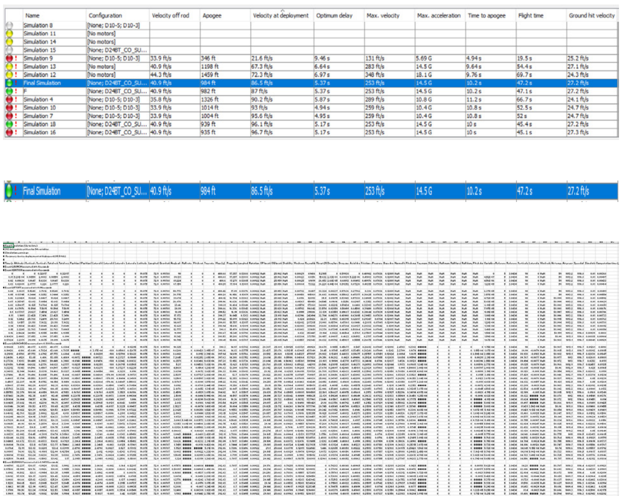


Figure 17: Input Parameters for the Simulation of the Launch Site

With the help of the open rocket software, we put out the different systems with different parameters input for each of the systems with the input of the latitude and longitude, wind direction, barometric pressure and temperature of the launch site to get the desired results such as altitude, acceleration, velocity, stability margin, the center of gravity, the center of pressure, aerodynamic forces which take into consideration of all the necessary parameters for designing a model rocket for achieving the desired altitude with a lesser weight and with a good stability margin. The final results achieved by the simulations are as follows.

Parameter	Value
Length	48 cm
Diameter	5 cm
Wet mass (with motors)	401 g
Dry mass (without motors)	310 g
Center of gravity	26 cm
Center of pressure	29.3 cm
Stability margin	0.671 cal
Motor for upper and lower stages	Aerotech D24-T
Motor for parallel stages	Estes A3
Maximum altitude	985 ft
Maximum velocity	253 ft/s
Maximum acceleration	14.5 G
Ground hit velocity	27.2 ft/s

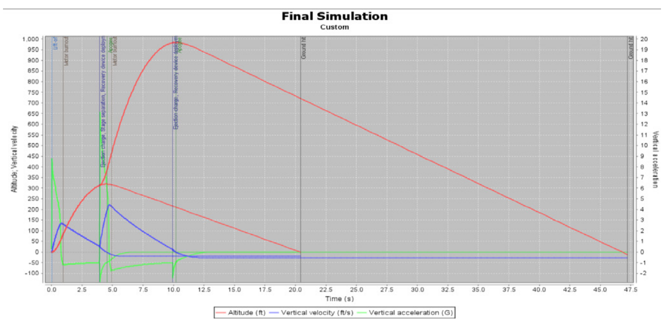
Table 3: Simulation Results for the Rocket Parameters



Name	Configuration	Velocity off rod	Apogee	Velocity at deployment	Optimum delay	Max. velocity	Max. acceleration	Time to apogee	Flight time	Ground hit velocity
Simulation 8	[None; D10-5; D10-3]									
Simulation 11	[No motors]									
Simulation 14	[No motors]									
Simulation 15	[None; D24BT_CO_SU...									
Simulation 9	[None; D10-5; D10-3]	33.9 ft/s	346 ft	21.6 ft/s	9.46 s	131 ft/s	5.69 G	4.94 s	19.5 s	25.2 ft/s
Simulation 13	[No motors]	40.9 ft/s	1198 ft	67.3 ft/s	6.64 s	283 ft/s	14.5 G	9.64 s	54.4 s	27.1 ft/s
Simulation 12	[No motors]	44.3 ft/s	1459 ft	72.3 ft/s	6.97 s	348 ft/s	18.1 G	9.76 s	69.7 s	24.3 ft/s
Final Simulation	[None; D24BT_CO_SU...	40.9 ft/s	984 ft	86.5 ft/s	5.37 s	253 ft/s	14.5 G	10.2 s	47.2 s	27.2 ft/s
F	[None; D24BT_CO_SU...	40.9 ft/s	982 ft	87 ft/s	5.37 s	253 ft/s	14.5 G	10.2 s	47.1 s	27.2 ft/s
Simulation 4	[None; D10-5; D10-3]	35.8 ft/s	1326 ft	90.2 ft/s	5.87 s	289 ft/s	10.8 G	11.2 s	66.7 s	24.1 ft/s
Simulation 10	[None; D10-5; D10-3]	33.9 ft/s	1014 ft	93 ft/s	4.94 s	259 ft/s	10.4 G	10.8 s	52.5 s	24.7 ft/s
Simulation 7	[None; D10-5; D10-3]	33.9 ft/s	1004 ft	95.6 ft/s	4.95 s	259 ft/s	10.4 G	10.8 s	52 s	24.7 ft/s
Simulation 18	[None; D24BT_CO_SU...	40.9 ft/s	939 ft	96.1 ft/s	5.17 s	253 ft/s	14.5 G	10 s	45.4 s	27.2 ft/s
Simulation 16	[None; D24BT_CO_SU...	40.9 ft/s	935 ft	96.7 ft/s	5.17 s	253 ft/s	14.5 G	10 s	45.1 s	27.3 ft/s

Final Simulation	[None; D24BT_CO_SU...	40.9 ft/s	984 ft	86.5 ft/s	5.37 s	253 ft/s	14.5 G	10.2 s	47.2 s	27.2 ft/s

Figure 16: Simulation Result



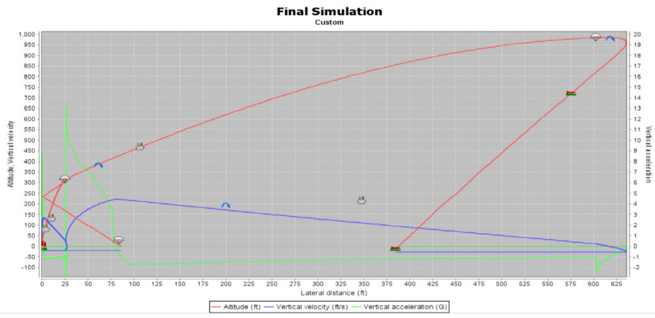


Figure 18: GraphDerived from Simulation (i) Altitude vs Time (ii) Altitude vs Lateral Distance

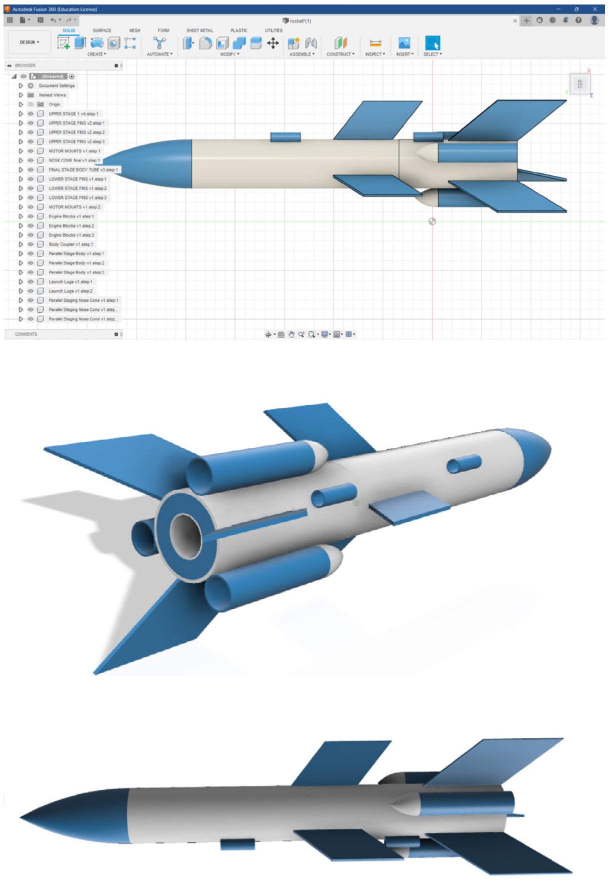


Figure 19: CAD Model of the Final Model Rocket in Fusion 360 Software

CAD Modelling

After achieving the desired results from both theoretical calculations and simulations, we proceeded to design the CAD model of the model rocket. The CAD model was created using Fusion360 software, incorporating the parameters validated by the simulations, ensuring optimal performance.

Different CAD models were created for each component, as detailed and illustrated in the "Design Process" section. These individual models were then integrated into the final assembled rocket model, ensuring proper fit and function. The below figure illustrates the CAD model from different perspectives.

Figure 20: Final Design of the Model Rocket

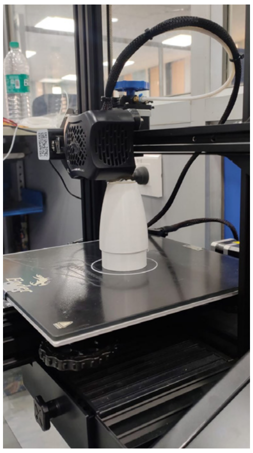
Manufacturing

After finalizing the structural model, we opted for the 3D printing method for manufacturing our model rocket due to its effectiveness, accuracy, and speed.

Considering the potential heat generated by the motors during ignition, we estimated a temperature increase. Therefore, we needed to select a material that could withstand this heat. While the heating effect may not be critical for all model rockets, we chose to prioritize safety in our design.

Taking into account key parameters like temperature, material density, and fire retardancy, we chose FR-ABS. This flame-retardant ABS is a combination of ABS and polyvinyl chloride (PVC). This material was developed to meet various rigid flammability standards and is suitable for a wide range of applications where flame resistance is critical.

We commenced 3D printing of all the parts individually, starting with the nose cone, upper-stage body tube, fins, lower-stage body tube, couplers, and so on. Below are some images captured during the manufacturing process for reference.



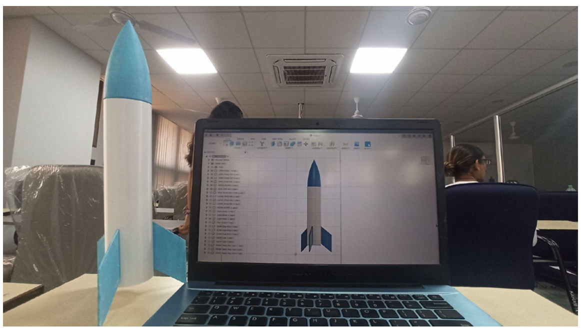
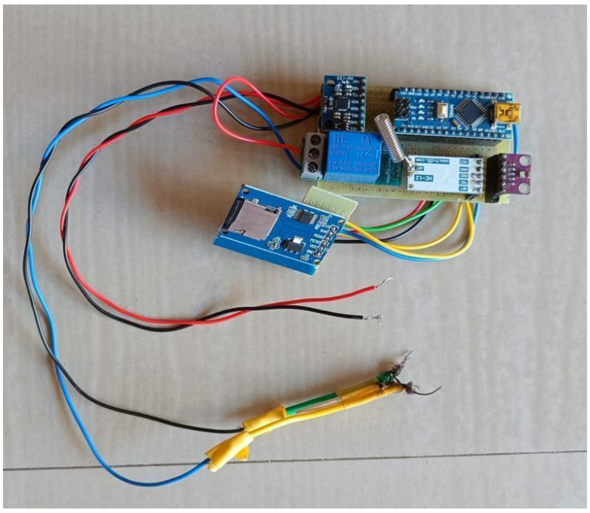


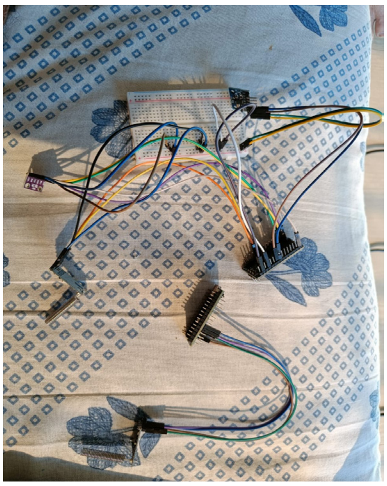
Figure 21: 3D Printed Model Rocket

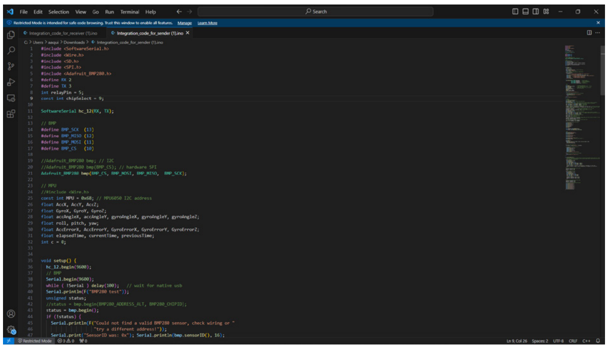
Testing

Following the manufacturing process, the next critical step involved assembling and testing each individual subsystem. This ensured seamless operation, safety, and validation against the simulation results. A dedicated test bench setup facilitated thorough testing of all electronics subsystems individually. The setup also allowed subsequent integration and verification of safe and seamless operation.

Below are the details of the tests performed for each electronic component present in the rocket:







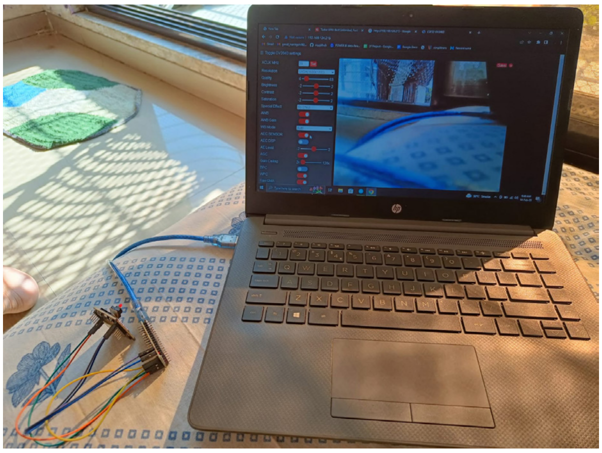


Figure 22: Testing of Integration of Electronics Sensors, Controllers, Camera and Software

The provided snippet of code and images demonstrates the integration of all sensors, data logging, transmission via the HC-12 module, and live camera feed for real-time monitoring during flight. The software was developed using the Arduino IDE, an open-source platform with extensive library support for various modules and communication protocols like I2C, UART, SPI, and external CAN. This allows for efficient and stable software development.

Additionally, The Rocket Will Undergo Various Tests To Ensure Safe Operation:

- **Static Tests:** Involving testing the rocket motor without launch, this helps determine thrust, burn time, and motor pressure.
- **Altitude Tests:** Launching the rocket and recording its maximum altitude using an altimeter determines the achievable height.
- **Recovery Tests:** Launching the rocket and deploying the parachute or recovery system verifies its functionality for safe landing.
- **Structural Tests:** Subjecting the rocket to simulated launch and flight conditions assesses its sturdiness.

Following these individual tests, the entire rocket will be assembled and launched for a comprehensive test. This will validate the simulation data and confirm the functionality of the integrated electronics.

Launching of Rocket

As our model rocket was designed to reach an altitude of 1,000 feet, acquiring permission for testing became necessary.

We contacted various authorities, including the Police Commissioner's office, the DGCA, and the fire brigade. However, we discovered that no established rules or guidelines existed regarding the testing and launching of model rockets.

With the assistance of our college's Electronics Department, we approached local police stations near our planned launch sites. Unfortunately, due to the lack of regulations specific to model rockets and the existing restrictions on all flying objects exceeding 100 meters in height, permission to test our project was ultimately denied.

The absence of clear guidance from the authorities led us to the difficult decision to refrain from testing the model rocket.

Further Advancements

Model rocketry represents a valuable tool for igniting passion and curiosity about aerospace technology in young minds. This project lays a solid foundation for further exploration and learning within this exciting field.

The concept of an entirely autonomous rocket operation presents an ambitious goal for future endeavors. One avenue for investigation involves the use of Programmable Logic Controllers (PLCs) and Supervisory Control and Data Acquisition

(SCADA) systems. A PLC module could wirelessly transmit data to another PLC module, enabling real-time monitoring. SCADA could then be utilized for data logging and analysis, facilitating further advancements.

Additionally, research into Ionic Thrusters or Electric Propulsion powered by high-voltage electricity offers significant potential. This technology, employed in advanced spacecraft, utilizes the principles of electromagnetism to generate thrust. By applying power to electrodes, an electric field is created in the air, and oxidants are used to produce thrust. This technology could be explored for rocket ignition and solar-powered flight, allowing for extended duration in the air.

With certain modifications, this project can serve as a stepping stone towards understanding missile systems. Further development could lead to the creation of guided autonomous missiles, a critical technology in the field of defense.

Conclusions

In conclusion, designing a model rocket equipped with electronics for monitoring, controlling, and logging data proves to be an innovative and captivating project. By integrating electronic components like sensors, microcontrollers, and telemetry systems, real-time data acquisition and analysis become possible, empowering rocket enthusiasts to optimize their designs for both performance and safety.

Successful implementation of this design demands meticulous planning, thorough testing, and unwavering adherence to established safety guidelines. When proper precautions and procedures are implemented, this project can offer a rewarding and challenging experience for individuals passionate about rocketry and electronics. Ultimately, this project represents a significant contribution to the field of rocketry and showcases the immense potential for future advancements in this exciting domain.

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