MA^2R^3S

MAY, 2024

1ST EDITION

APCP ROCKET

The image above showcases our third generation of rocket fuel, which produces an astonishing flame because of our specially designed catalyst. (Captured May 1st, 2024)

Mary Yu
Amy Dong
Andrew Dai
Ryan Zhao
Ryan Zhan
Rain Chen
Steven Chen

website:ma2r3s.space

All MA^2R^3S work is completed through self-exploration and collaboration with friends and teachers.

OPENING

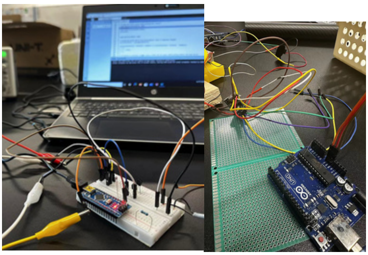
Ryan Zhao

On the afternoon of December 14, 2023, I started my journey. I was working on repairing my radio project, which seemed to be completely broken. I was desperately hoping to find someone who could help me fix it. Obviously, very few people would be interested in listening to me talk about these tiny electronic components. So, I decided that once I completed this, I wanted to undertake a project that was truly valuable, challenging, and impactful. Most importantly, I wanted to assemble a team that could inspire others to realize their **unlimited potentia**l and work towards a cause bigger than themselves. Suddenly, an idea ignited in my mind like a shooting rocket—an idea for building an **actual rocket**.

INTRODUCTION

Ryan Zhan- Logistics

On December 14, 2023, I started on the exhilarating journey of exploring rockets. My passion for chemistry and physics is not only driven by personal interest but also by a profound belief in the practicality of knowledge. I am determined to apply what I already know, diligently study what I have yet to learn, and ultimately inspire others to join me in the pursuit of knowledge and their own life goals



Steven Chen: Website building

Rain Chen: 3-D designs and models

Ryan Zhao: Core

Andrew Dai-Photographing

I am the photographer, I have captured many valuable moments for the team. In addition, I also assisted Ryan with the design, cutting, and polishing of materials such as our fins and fasteners. I am also responsible in designing our logo and the coating of our rocket.

Details see section "behind the scenes"

Amy Dong -Parachute design

I tried different materials to make the most suitable parachute and helped with the experiment on the ejection system of the parachute.

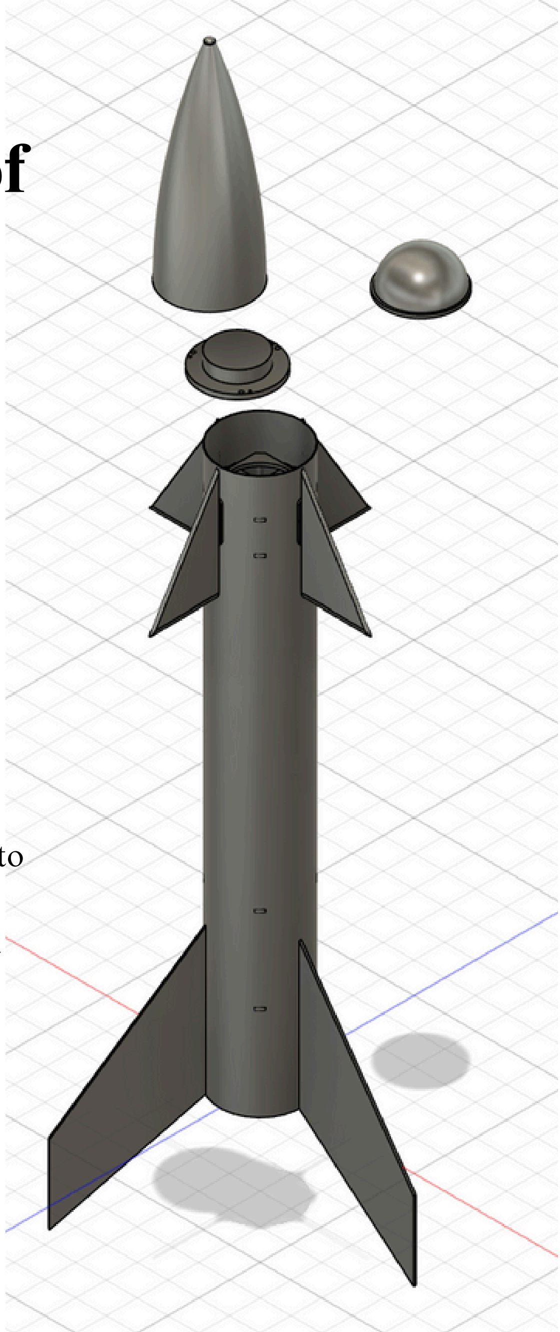
Mary Yu- Writing and Graphic designs

With the help of our teammates, Dr. Chantal and Dr. Ke, the internet, and some Chatgpt (no direct copying, I promise), I converted our work into words, including most of this brochure, and a part of the poster.

Written by Mary Yu

Basic understanding of a rocket

The first modeled draft for our rocket



What is a rocket?

A rocket is any type of jet-propulsion device carrying either solid or liquid propellants that provide both the fuel and oxidizer required for combustion.

Why rockets can fly?

A rocket van fly as it uses the principles of action and reaction to generate thrust and motion. It burns a fuel-oxidizer mixture in a combustion chamber, creating high-pressure, high-velocity exhaust gases that are expelled through a nozzle, imparting momentum to the rocket and propelling it forward.

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2023-2024

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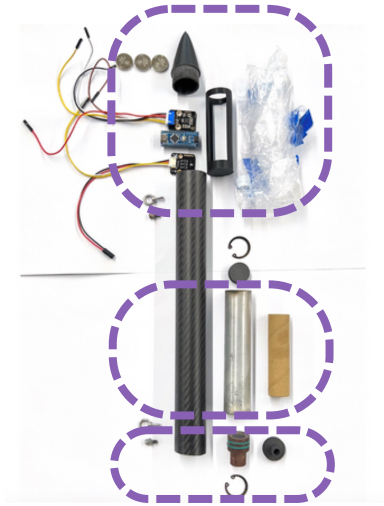
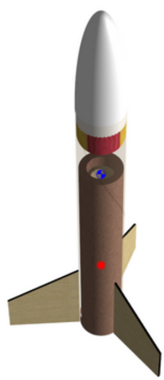


Picture of self-made rocket components



OpenRocket simulation

NECESSARY COMPONENTS

Written by Ryan Zhao, Finalized by Mary Yu

The Rocket

Propellant

Propellant 1 G1-Sugar rocket fuel--KNSU and KNSB (1.1)

Component: For KNSU, the two materials are *potassium nitrate* and *sugar*. For KNSB, sugar needs to be changed to Sorbitol. The fundamental idea of KN-based rockets is that when burning, KNO3 will decompose and release oxygen. This provides oxygen to accelerate the burn rate.

Making process: KNO3 is very likely to absorb water. Exposing it to air for 10 mins will even cause agglomeration. When KNO3 powder becomes lumps, it cannot react efficiently, which means all water in the fuel needs to be removed to achieve the best performance and all components need to be carefully grind before mixing. The best ratio by calculation is to mix about 60% KNO3 and 40% sugar or sorbitol, but the best ratio after testing is to mix 65% KNO3 and 35% sugar or sorbitol. There are two ways to mix them:

1. dissolve and recrystallize.
2. Heat with stirring.

The second way of mixing is recommended because the sugar will turn to a paste phase when the temperature exceeds 110 degrees. Sorbitol will melt under 100 degrees, which makes it much easier to pour than KNSU.

Problems: KNSU and KNSB do not generate huge impulses. Also, residues left inside the combustion chamber affect the combustion rate. Some catalysts such as Al and CuO were added to improve it, but it did not work well, so we moved on to the next possible propellant.

1.1

Drafted by Ryan Zhao, Finalized by Mary Yu

Propellant 2 Black Powder(pic 1.2)

Components: For making black powder, Sodium nitrate, sulfur, and charcoal are needed. Black powder is a low-explosive material that burns fairly quickly and generates a moderate amount of impulse.

Problems: Black powder is harder to ignite compared to other types of fuels and it produces a lot of residuals and black ashes

1.2

Propellant 3 Ammonium Perchlorate Composite- Epoxy (pic 1.3)

Component: Ammonium Perchlorate Composite Propellant (APCP) is a type of fuel often used in rockets for space exploration and other aerospace applications. It's chosen for its simplicity and reliability, providing enough thrust for tasks like launching spacecraft and boosting aircraft. It's been used in big projects like the Space Shuttle's Solid Rocket Boosters and NASA's Mars Exploration Rover's descent stage retrorockets. The specific impulse, which is a measure of performance, ranges from 180 to 260 seconds, which is good enough for these kinds of missions.

NH4CLO4: Ammonium perchlorate (NH_4ClO_4) is a white crystalline powder that provides a large amount of oxygen for the combustion process when combined with a suitable fuel, thus acts as an oxidizer.

Aluminum: During combustion, the aluminum powder reacts with the oxidizer, releasing a large amount of energy in the form of heat. The reaction between aluminum and the oxidizer is highly exothermic, meaning it releases a significant amount of heat. NH4CLO4 and aluminum need to be mixed thoroughly to successfully achieve the exothermic reaction and to release oxygen.

1.3

Written by Mary Yu

Bisphenol A epoxy: BPA epoxy is a thermosetting resin, which means it undergoes cross-linking and hardening when exposed to heat that converts the liquid or semi-liquid epoxy into a solid, rigid material with high mechanical strength. The high cross-link and the tightly interconnected polymer chains impede the propagation of flames and slow down the combustion process. Additionally, As the NH4CLO4 and aluminum mixture is in powder form, and it will leak outside of the rocket body, Bisphenol A epoxy here converts the mixture into a solid, rigid material with the help of heat.

Ether: As Bisphenol-A-epoxy is way too hard to stir, which makes the mixing process of NH4CLO4, aluminum, and itself very hard, Ether is used to soften it. The softening effect of ethers on Bisphenol-A-epoxy occurs due to their ability to disrupt the cross-linked network structure formed during the curing process. The cross-linked structure restricts molecular motion and imparts stiffness to the material. Ethers, being relatively small molecules, can penetrate the cured epoxy matrix and disrupt the cross-linking bonds. They insert themselves between the polymer chains, creating more space and introducing flexibility. This intercalation weakens the cross-linked network, which leads to a reduction in the material's stiffness and an increase in its ductility.

Amine: Amines have the ability to scavenge reactive species, by reducing the presence of these reactive species, amines help maintain the stability and integrity of the propellant, ensuring its performance and safety.

Problems: Although AP-based fuel is very efficient, its raw materials are not easy to get. Materials need to be self-made, but finding a way to make high-purity fuel is not easy.

Drafted by Ryan Zhao, finalized by Mary Yu

Propellant 4 APCP-HTBP (pic 1.4)

NH4CL4 and Aluminum are still used in this propellant but with and replacement of Bisphenol A epoxy, ether, and amine to HTBP, DPI, and TDI.

HTBP: Hydroxyl-terminated polybutadiene is used by NASA in various rocket and spacecraft applications. HTBP is a type of synthetic rubber polymer that is composed of polymerized butadiene monomers with hydroxyl (-OH) terminal groups. The hydroxyl groups allow HTPB to be cross-linked with other compounds, such as isocyanates, to form a solid propellant composition. Bisphenol-A-epoxy is later replaced by HTPB mainly because HPBP is safer and less sensitive to accidental ignition or detonation compared to Bisphenol-A-epoxy-based propellants.

DPI DPI acts as a plasticizer. A plasticizer improves the flexibility, malleability, and impact resistance of the propellant, making it easier to process. The plasticizing effect of DPI helps prevent cracking or fracturing of the propellant during handling, storage, and operation.

TDI Triethylene Diisocyanate acts as a curing agent, helping to cross-link and harden the propellant mixture. The curing properties of TDI contributes to the mechanical stability and structural integrity of the solid propellant grains.

Making Process of NH4CLO4: Through Electrolysis, it is possible to make an intermediate product of NH4ClO4. For electrolysis, stable electrodes such as Pt and Ti electrodes that are resistant to erosion are required. As Pt electrode is very expensive (its price even exceeds gold), thin Pt flake and Pt wire are used to maximize surface area and to lower the cost. The electrolysis device is built using a 2L plastic seal bucket, electrodes, funnel, polypropylene tube, beaker, pointed file, 2A, 12V stable power supply, and glue. During electrolysis, we must pay attention to any waste gas being produced because it will cause danger as it accumulates.

1.4

The making process of Propellant 4-APCP-HTBP Created by Ryan Zhao and Dr. Chantal

Written by Mary Yu

Combustion Chamber

The combustion chamber is where the propellants are stored and ignited, generating high-temperature, high-pressure exhaust gases that are expelled through the nozzle, creating an upward thrust for the rocket. Two key standards of combustion chambers are durability and air tightness.

Combustion Chamber 1: PVC tube. A PVC tube is first used as the material for the combustion chamber, but it lacks air tightness in order for the pressure built by the combustion is not secured there for undermines the thrust of the propellant also, plastic is not durable for combustion.

Combustion Chamber 2: Threaded aluminum pipe. Though threaded aluminum pipe is much more durable, its air tightness ability is not stable, as under high temperatures, the screw thread will be distorted and the air pressure maintained will be negatively influenced.

Combustion Chamber 3: Circlip aluminum pipe. (pic 2.1) Ultimately, a circlip aluminum pipe is used to secure the air pressure difference and durability of the combustion chamber, though with a trade-off of a complicated assembly process.

Liner

A liner is the inside layer of the combustion chamber that to an extent protects the combustion chamber from the combustion process.

Liner 1: Plastic. Plastic is used as the material of the liner at first, but its chemical odor during the combustion is too strong and it melts, making it hard to clean the combustion chamber.

Liner 2: Hard paper roll (pic 3.1) Though paper seems extremely inflammable, paper survives the combustion process well because there is rarely any oxygen to combust inside the paper material.

2.1

3.1

Written by Rain Chen

NOSE CONE DESIGN

Power Series Nose Cone

Information List

Type: Power Series

Equation:
$y=17.5x^{0.66}$

Where:
y = current radius (mm)
x = current length (mm)

Parameters

Length: 60mm

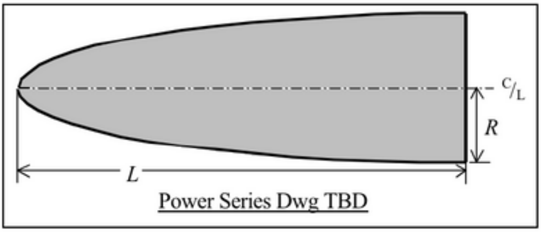
Maximum Radius / Base Radius: 17.5mm

Design Objectives

- A cone with proper aerodynamic shape
- A cone that is easily modelled and 3D printed
- A light cone that also allows for stuffing inside

Practical adjustments

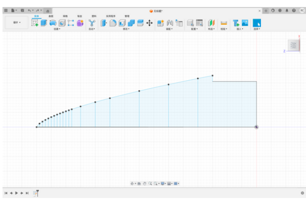
The "Von Karman nose cone" is the optimal nose cone to operate under supersonic regime. However, determining the exact equation to generate the cone is overcomplicated. As curves modeled by power model equations resembles the Von Karman shape and proves to work out well, the ultimate blueprint involves the power series nose cone rather than a real Von Karman nose cone.



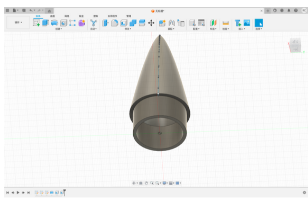
For $0 \leq n \leq 1$, $\quad y = R\left(\frac{x}{L}\right)^n$

P.S. The greater "n", the more blunt the nose cone is

Fusion 360 Design



Sketch



Model Output

References

- https://rshare.library.torontomu.ca/articles/thesis/Aerodynamic_Optimization_of_the_Von_Karman_Nose_Cone_for_a_Supersonic_Sounding_Rocket/14635638
- https://nakka-rocketry.net/articles/Descriptive_Geometry_Nosecones_Crowell_1996.pdf

Nozzle

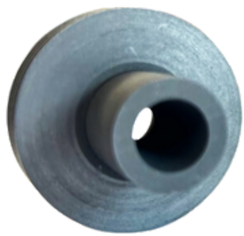
The nozzle is an important component of the rocket body because the nozzle creates a controlled expansion of the exhausted air, converting the thermal energy into kinetic energy and orientating the directionality of the exhaust plume.

Nozzle 1:Aluminum. Aluminum is usually used for relatively slow rockets, but as time passes the high-velocity, high-temperature exhaust gases passing through the nozzle can cause significant erosion and wear of the aluminum material over time, changing the nozzle's geometry, affecting the acceleration of the exhaust, and ultimately reducing the engine's efficiency and thrust.

Nozzle 2: Phenol formaldehyde resins. Phenol formaldehyde resins are used next. It is known to be susceptible to moisture absorption. In the harsh, high-temperature environment of a rocket nozzle, any moisture present can lead to further degradation and structural issues.

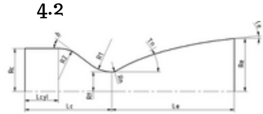
Nozzle 3: Graphite. (pic 4.1) As Graphite exhibits superior erosion resistance compared to the previous two materials, and it can be relatively easily machined and fabricated into the complex shapes required for a rocket nozzle, and its cost efficiency, it is ultimately used as the material for the nozzle.

4.1

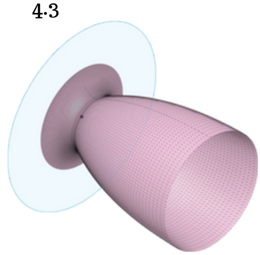


The design of the nozzle (pic 4.2, 4.3): The Laval nozzle, also known as a convergent-divergent (CD) nozzle, is a critical component in the design of rocket engines. The Laval nozzle has a unique converging-diverging geometry. The convergent section starts with a smaller diameter and gradually narrows down to the throat of the nozzle, the point of minimum cross-sectional area. The divergent section then expands outwards, allowing the exhaust gases to accelerate and expand, resulting in a high-velocity jet. We determined the shape of the nozzle based on parameters such as the mass flow rate, average mass number of gas molecules, chamber volume (for L*), etc. Most importantly, data from our first test on May 26. [See section “testing” for details]

4.2



4.3



Written by Mary Yu

Written by Mary Yu

Parachute

The parachute's main function is to maximize the work done by air resistance during the process when the rocket free falls to the ground so that the velocity of the rocket before just reaching the ground will be reduced to protect the rocket body.
Three important standards for the parachute are lightness gas Proofness and resilience.

Parachute 1: Fire Resistant Paper. The material is used for making the Kongming lantern. It is light and air proofed but it takes up too much space within the rocket body, so we looked for thinner materials instead.

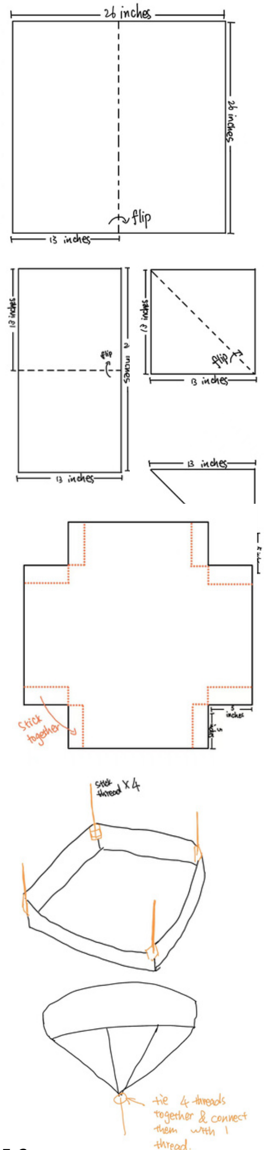
Parachute 2: Thin Plastic. Thin plastic of course is light and air-proofed, and it can be but it is often soon thin so that it lacks the resilience to confront the high impulse exerted by air resistance.

Parachute 3: Huge plastic bags. The plastic bag is thicker than the thin plastic we used before. Maintaining the advantage of lightweight and the ability to be compressed into a small volume, this material has enough resilience to the impulse exerted by the wind.

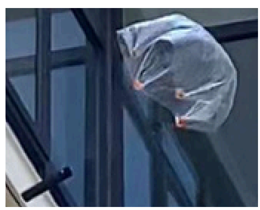
The design of the parachute (pics 5.1)

During testing (5.2), the velocity of the rocket body significantly decreased after the ejection of the parachute which means the parachute itself is successful. Although the parachute itself without the ejection process is successful, there is some problems with the ejection process. *[for details, please see section "Ejection charge"]*

5.1



5.2



Written by Mary Yu

Ejection charge

Two main standards for an ejection charge are to generate a large amount of gas and simultaneously with minimum inflammation because the major function of an ejection charge is to exert an upward force to open the rocket nose and expand the parachute.

Nitrocellulose is used for the ejection charge, the same as the ignition powder. [For details, see section The Ignition System]

Testing of the ejection process (pic 6.1): During the ejection of the parachute, the parachute was successfully ejected but the parachute was burned and damaged (pic 6.2). To improve the ejection process in the future, fireproof cotton should be stuffed between the ejection powder and the parachute to prevent the combustion process from harming the parachute.

The Ignition System

Ignitor structure (pic 7.1)

Igniter: The primary component of the electronic ignition system is the igniter, which is responsible for generating the high-energy source to start the propellant combustion. Ni-Cr alloy is used here because will generate a lot of heat when connected to electricity.

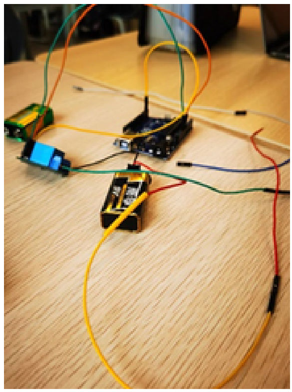
Ignition Circuits: The electronic ignition system utilizes dedicated ignition circuits to provide the necessary electrical power and control signals to the igniter. The ignition circuits are designed to be highly reliable and capable of withstanding the harsh conditions encountered during rocket launches.

Ignition Sequence and Timing: The electronic ignition system is integrated with the rocket's flight control and guidance systems to precisely time and sequence the ignition event. A 5-second interval of time between the time when the signal is given and the actual ignition is designed for safety reasons.

6.1

6.2

7.1



Written by Ryan Zhao, edited by Mary Yu

Ignitor powder synthesis

To ignite the rocket, we need to use something that is fast burn and also easily catches fire so it can catch on fire by the amount of heat that the Ni-Cr wire releases and generate enough heat to ignite the rocket.

Black Powder (pic 7.2): Black powder is used first because of its easy-making process and the large amount of heat it can generate. However, black powder is hard to ignite by a tiny nichrome wire. We have tried this for over 3 weeks with different proportion blending but the activation energy is still too high.

Nitroglycol (7.3): Nitroglycol in theory is a powerful ignition charge. However, it burns slowly instead of detonating when there is not enough heat or impulse. The nichrome wire cannot provide such energy so it does not work at all.

Nitrocellulose (pic 7.4, 7.5): nitrocellulose. It is moderately hard to make, only takes about 25 hours to make and neutralize. It works pretty well and is easy to attach to the wire. It also provides enough heat without leaving a lot of ashes. We are now working on how to make it completely ash-less.

7.2

7.3

7.4

7.5

Fins

Fins are stabilizing structures that make sure the rocket body is following a smooth trajectory and to maximize the rocket's aerodynamics.

The making process of the fins: First we cut out the shape of the fins from the carbon fiber board. Then the fins are fitted into a 3-D printed mold to prevent the fins from falling off when the glue is not dried yet. The glue we used is Bisphenol A epoxy, which is also used in our third generation of propellant. After the glue was dried, we used a small rubber hammer to hammer off the mold. (pic 8.1)

8.1

Test Instruments

After completion of the design of the rocket's motor, during the development phase, static tests of rocket motors are conducted to evaluate and qualify the performance of propulsion systems.

The Thrust Plate

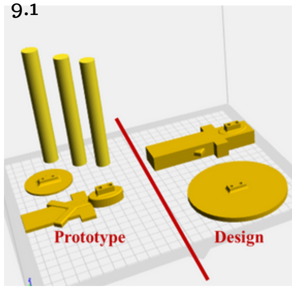
The main purpose of the thrust plate is to measure the thrust of the propellant that it can generate. The thrust stand typically consists of a load cell, which is a device that measures force, and a mounting plate to which the engine is attached. The load cell is connected to a data acquisition system, which records the force measurements over time. (pic.9.1, 9.4) The engine is mounted to the plate and ignited to use a thrust stand. As the engine burns and expels propellant out of the engine, it generates a force that is measured by the load cell. The data acquisition system records the force measurements over time, allowing the thrust profile of the engine to be analyzed.

The load cell was developed by AutoDesk Fusion and 3D printing. Force measurements were taken by the development of a microcontroller system and force sensor HX711. (pic 9.2-9.3)

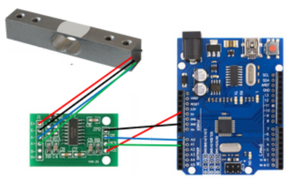
Our system was calibrated by comparing the signal of 0 weight and signal with a known weight to calculate the measuring factor. The original design of the amplifier had to be modified as it was previously running at 10 Hz. Modifications to the wiring on the chip board allowed for changing the frequency collection to 80 Hz. This fixed the problem of a 0.5 s delay on the sensor, which had caused a significant error6 when measuring constantly changing thrust.

Software code design in Arduino included allowance for (a) calibration of load plate (b) measurement of sensor at 80 Hz (c) output of data at 80hz into appropriate data streamer excel programme and (d) dual back-up to SD card in case of one card failing.

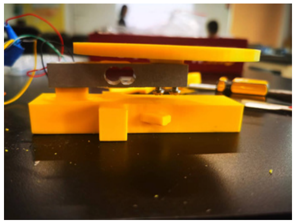
9.1



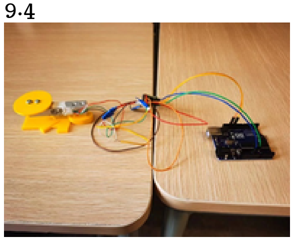
9.2



9.3



9.4



Written by Mary Yu, Dr. Chantal and Dr. Ke

Code segments (calibration, calculation, data logger......)

Written by Ryan Zhao

TESTING

5/26 Tests

Test one (successful ignition pic 10.1):

Conditions:

1. The nozzle is not yet attached to the combustion chamber to mitigate the risk of a potential explosion.
2. The propellant is ignited manually using a spark instead of electronically due to time constraints.

Results:

1. The spark duration was shorter than anticipated, lasting approximately 3 seconds.
2. The combustion of the propellant lasted around 5 seconds, generating approximately 1kg of thrust. It is estimated that with the addition of the nozzle, the thrust could reach 2kg. The calculated impulse is around 22.7N, and even without a nozzle, it is estimated that it could reach 100 km/h.
3. The combustion of the propellant exhibited significant instability, primarily attributed to air bubbles within the solid propellant.
4. The high heat distorted both the thrust stand and the carbon fiber cover of the combustion chamber.

Test two (successful ignition pic 10.1):

Conditions:

1. The Ring of the upper rim was left unattached, which assume that the thrust direction is directly towards the ground, minimizing the risk of the engine escaping the thrust plate and stand.
2. The propellant was manually ignited by Ryan, who affixed a piece of paper towel to the spark for added safety measures.

Results:

1. The propellant and its liner escaped the combustion chamber, detonating outside the designated thrust stand area.
2. No data was successfully collected, rendering any potential data meaningless.
3. The high heat further distorted the thrust stand and the carbon fiber cover of the combustion chamber.

10.1

10.2

Written by Mary Yu

Test three (unsuccessful ignition):

Conditions:

1. The Ring of the upper rim was secured for safety reasons.
2. Anticipating windy conditions.

Results:

1. Due to windy conditions, the ignited paper towel fell onto the electronic wiring.

Test Four (successful ignition) pic 10.3:

Conditions:

1. Given the distortion and damage to the thrust stand holding the engine, additional tape was used to secure the testing instruments.
2. The Ring of the upper rim was reattached, again, for safety precautions.
3. The electronics sustained damage, so the analysis relied on photographic documentation for this trial.

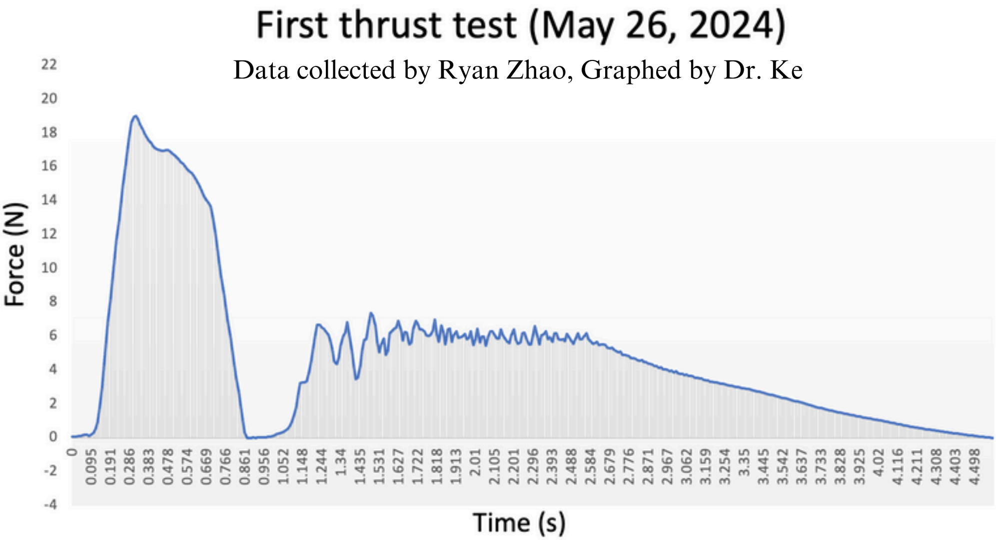
Results:

1. The propellant was successfully ignited, with only photographic evidence available for analysis.

Data Analysis of 5/26's results

1. The thrust data is recorded by our load cell at a frequency of 80 hertz, with an error range of less than 0.01 N.
2. Total measured impulse is approximately 23 N s by integrating area under the curve.
3. At t = 0.861 s, force drops significantly suggesting a surge in the engine.
4. From t = 1.053 s to t = 2.584 s, force oscillates in periodic pattern, which indicates unstable combustion. Nozzle is not attached because the impulse and oscillation data are crucial for future optimization of the nozzle design.

Written by Mary Yu, edited by Ryan Zhao, Dr. Chantal, Dr. Ke.



Issues to address on 5/26:

Thrust plate and stand:

The temporary connection between the thrust plate and stand using tape during the 5/26 testing poses significant safety risks. Proper attachment is crucial to prevent the engine from escaping, as observed in Test Two.

Due to the low quality of the 3D-printed thrust stand and limited material options, printed additional stands are needed for quick replacement in case of breakage.

Ignition device:

Manual ignition of the propellant proved hazardous and ineffective in Tests One and Three, highlighting the need for an electronic ignition system. Developing a reliable electronic method requires specialized knowledge in circuitry, which Ryan was the most prominent in

Protection of circuit board and electronics:

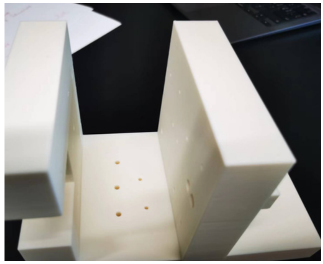
Any slight disturbance in the circuit wires can impact measurement accuracy and data transmission. To address this, methods to secure the wires to the circuit board should be explored to prevent disruptions and ensure accurate data collection during future tests.

Written by Mary Yu

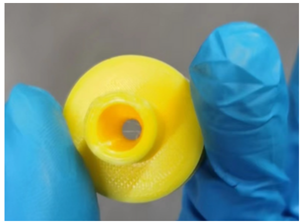
Plans and Works from 05/26 to 06/7

- Update design by adding screws to better secure the engine from shifting.
- Build a horizontal launching pad for engine thrust measurement to eliminate errors due to mass loss of the propellant. (pic 11.1)This new launching pad also separates the electric circuits and the combustion chamber. In this way, we can prevent the high heat from the combustion process from damaging the circuits.
- Make more nozzles (pic 11.2) with new geometries to experiment with engine performance with varying L* parameters (ranging from 1000 mm to 2000 mm).
- Develop a more reliable remote ignition module.
- Spray painting and artistic cover of the rocket.
- Investigate Comsol Multiphysics simulation for thorough understanding of pressure, temperature, airflow, thrust, etc.
- Investigate more material and manufacture options for the thrust stand, for better mechanical properties and quick replacement.
- Use integrated circuits to ensure good electric connections and miniaturization.
- Investigate ESP microcontroller to improve sensor communication.
- Develop more on the parachute recovery system so that parachute ejection time can be controlled and to ensure the fire-proof quality of the material used under the ignition of the ejection charge.

11.1



11.2



11.3

Written by Dr. Chantal, Dr. Ke and Ryan Zhao, edited by Mary Yu

06/08 Tests

Test one：

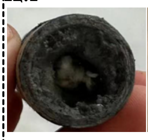
Conditions:

1. The test was conducted using the newly developed horizontal testing platform.
2. While the software and hardware of the electronic ignition system had previously functioned properly, the hardware failed to operate on the day of testing for unspecified reasons.
3. Once the hardware was functioning, the ignition charge did not lead to the combustion of the propellant for unknown reasons. We doubted that the ignition charge lacked contact with the propellant, but as we opened up the rocket engine, the residual of the charge is well reached inside the liner. (12.1)
4. To eliminate confounding variables, a substantial amount of ignition charge was inserted into the liner to ensure the ignition of the propellant. (12.2) Additionally, the nozzle was removed to assess whether the unsuccessful ignition was due to the propellant.
5. Despite these measures, the ignition remained unsuccessful. Subsequent testing revealed that the issue was not related to the ignition charge or the propellant, but rather the instability of the ignition hardware. Instead of the electronic ignition system, paper towels, and propellant waste were utilized to initiate ignition manually. (12.3)

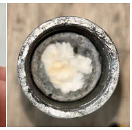
Results:

1. The propellant combusted at a high rate, resulting in a longer tail compared to previous tests conducted on 5/26.
2. Both numerical and photographic records were successfully captured. (pic 12.4, and for numerical records, see section “data analysis”)
3. The carbon fiber of the rocket body remained in good condition following the combustion.

12.1



12.2



12.3

12.4

Written by Mary Yu

Test two:

Conditions:

1. The addition of the nozzle to the combustion chamber was implemented in response to the discovery that the failure of ignition is attributed to the unstable electronic ignition hardware solely
2. Manual ignition continues to be utilized due to time constraints and the unresolved issues with the electronic ignition hardware.

Results:

1. The propellant initially combusted at a rapid rate similar to test one but ultimately combusted at a slower rate with a shorter tail (pic 12.5). This is attributed to slight variations in the manufacturing process and the solidification process of the propellant.
2. The prolonged combustion led to the ignition of the carbon fiber of the rocket cover (pic 12.6), which was promptly extinguished by fire extinguishers (pic 12.7).
3. The two test both proved the success of the new thrust plate developed. Third thrust plate is vey stable during testing. No vibration, no rotation.

12.5

12.6

12.7

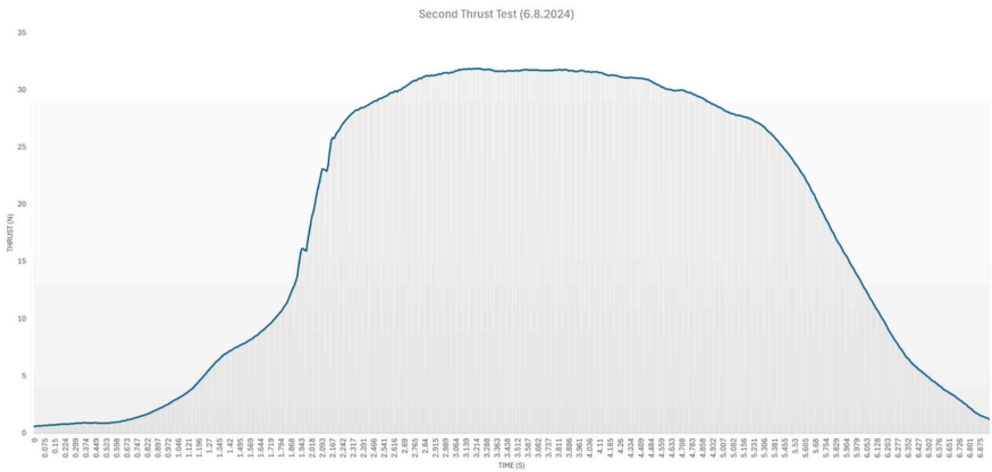
Issues to address on 06/08:

1. We improve the ignition system, but it is hard to set up and unstable for ignition. Investigate the potential source of ignition failures in the electronic ignition hardware. The manual ignition method used during these tests, in the absence of a spark, allows minimal time for personnel to safely evacuate the testing area. Even if the flame is horizontally expelled (which is relatively safer than manually igniting it vertically), significant safety hazards remain.
2. Rework the ignition method to optimize the positioning of the nozzle and the ignition process. On 6/8, the two copper wire ends, along with their Ni-Cr alloy, will need to be inserted through the narrow nozzle channel for ignition to occur.

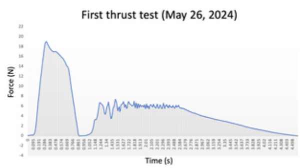
Written by Mary Yu

This process not only requires a significant amount of time to complete, but also poses a risk of damaging the wires once the propellant is successfully ignited, potentially resulting in their expulsion from the nozzle due to the high temperature gases and flames.
3. Future tests on parachute ejection systems to investigate the fire proof cotton's efficiency on protecting the parachute from the ejection charge.

06/08 Results



- New Teensy 4.1-based thrust plate system collect thrust data at a very stable 80hz frequency.
- The data collected presents a smooth and roughly symmetrical curve.
- **About 122N*S of total thrust** is generated with the nozzle attatched to the combustion chamber. This is more than 5 **times greater** than than the data measured without the nozzle on 05/26/2024. **This already met the requirement for a Level G certified rocket motor.**
- This success could be contributed to the recalculation of the nozzle design and the recasting of the propellant. By this way, the combustion of the fuel is more stable.



Written by Ryan Zhao

OUR JOURNEY

WRITTEN BY RYAN ZHAO

Written by Ryan Zhao

TIME LINE

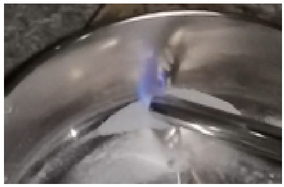
First stage(1st rocket fuel):

12.14.2023 First idea of building a rocket

12.16.2023 First “rocket motor” attempt

12.24.2023 First ejection charge (failed)

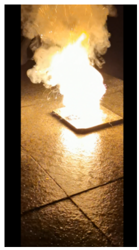
1.13.2024 Second rocket motor attempt (Black powder)



1.17.2024 New proportion of rocket fuel

1.17.2024 First sugar rocket motor success

1.17-1.23 9 trials of different proportions and catalyst



Second stage(1st colorful flame, 2ed fuel):

1.21.2024 Sugar-black powder fuel mixing (failed)

2.14.2024 New tools, smaller grains, longer mixing time. Open test of sugar black powder.

2.21.2024 Unassembled many boxes of fireworks. Making the first catalyst-flame fuel (Mg, CuCl, Al, Zn).

2.22.-25 10 more tests.

Written by Ryan Zhao

TIME LINE

Third stage(90% HSO4 and 80% HNO3):

2.9.2024 Start preparing. Learning filtration, fractional distillation, azeotrope, and acid reaction.

2.13.2024 First attempt to distract HSO4 from 1 M stock solution.

2.14.2024 After 24 hours of distillation, I failed completely because of the azeotrope.

2.18.2024 Using spike condenser for distillation. (Failed)

2.19.2024 Double the length of the condenser. Still unsuccessful because of vigorously boiling.

2.20-2.27 6 more failures due to steam leakage, distillation time, erosion of rubber seal, and contamination by moisture. Wrong wrong calculation of reactant. breaking of the condenser. Acid spills out because of vigorously boiling which damages the heater.

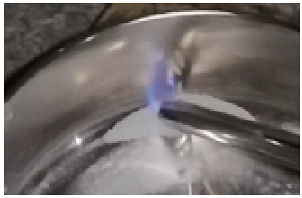
3.1.2024 First success of fractional distillation. (product: HSO4 around 60%)

3.2.2024 Several more successes of fractional distillations. The final distillation took 8 hours.
(products: approximate 90% HSO4, 80% HNO3, density of 1.47.)

Written by Ryan Zhao

TIME LINE

Forth stage (1st ignition powder):



3.3.2024: Test black powder ignition (failed)

3.4.2024: Testing thermite powder ignition

3.5.2024 (failed)

3.6.2024 Fail to synthesize nitroglycerin.

3.8.2024 Fail to neutralize NC.

3.9.2024 Sample of NC destroyed by heavy rainfall

Nitroglycerin Inflammation (burn too slowly)

3.12.2024: Second NC test. The flame is too big.

The First ignition powder does not fit my standard. I abandon the research on it after 2 weeks of failures.

Fifth Stage (3rd rocket fuel)

3.9.2024 Inspired by a rocket from the US in 1950, start to prepare for the first ammonium perchlorate composite fuel.

Built the first electrolysis device.

3.16.2024: First electrolysis experienced severe

3.18.2024: erosion. Electrodes get oxidized and contaminated water.

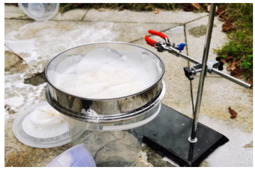
Finished repairing the device. Use

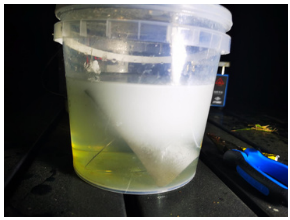
3.19.2024 titanium, Platinum electrode.

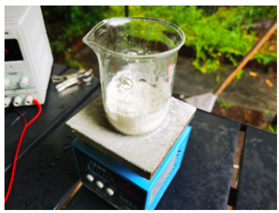
Written by Ryan Zhao

TIME LINE

3.20.2024	An electrolysis cell exploded because a tiny spark on the anode.
3.21.2024	I fixed the device. Solder all wires and use a larger titanium electrode.
3.23.2024	Wires were oxidized by salty vapor. The water was seriously contaminated.
3.24.2024	Spend a whole day filtering all dirty water.
3.25.2024	Dry the solution using heaters and ovens. After cleaning up, get 330.2 g of pure crystals。
3.29.2024	Try to use the double replacement at the same time. Did not get any of the final product. Concentration was too small and reaction temperature was wrong.
4.2.2024	Repeat all the procedures. Double check temperature. Still getting no product.
4.3.2024	Repeat all the procedures. Filtered all solutions and make saturated solution at 80 degree Celsius.
4.5.2024	After a week of continuous problems, 102.1g of final product NH_4ClO_4 is collected. Percent yield 44.2%.







Written by Ryan Zhao

TIME LINE

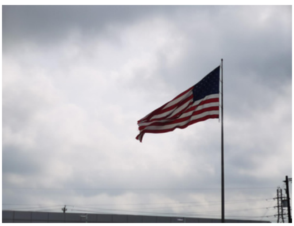
4.11.2024 First blend of new oxidizer and fuel(epoxy)

4.12.2024 Spend a whole night testing amide and ether proportion mixing in the fuel.

4.13.2024 First test of APCP-epoxy fuel(successful under a heavy rain)

4.14-22

Went to Space Center Houston for further researching rocket.



Arrive at Houston

Studying structure of falcon 9

Researching on nozzle design

Communicating with professional force sensor team

Learn heat resistant layer from Saturn 6 (real one)

Written by Ryan Zhao

TIME LINE

April 24.2024

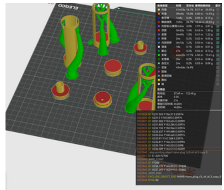
After I came back from America, I was truly impressed by people's creativity, imagination, initiative, and incredible capacity for self-learning. <u>What we can do, learn, and achieve extends far beyond the confines of knowledge from school and goes well beyond what we learn there</u>. It's just that school helps us open the door to the world. I have now gained a deeper understanding of myself and have become even more determined.

We will make a rocket; <u>if not us, who? And if not now, when</u>?

I wrote a detailed plan and split the project into four parts. Thrust plate, parachute, rocket body, and rocket fuels. I distribute different tasks to all team members and make sure that every part proceeds at a similar speed. As a result, we progress at an incredible rate.

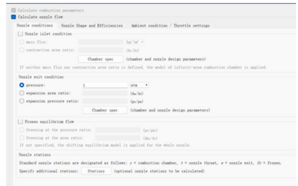
Written by Ryan Zhao

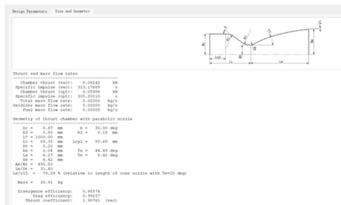
TIME LINE

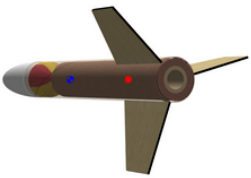


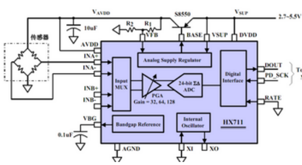
May 1 - June 9

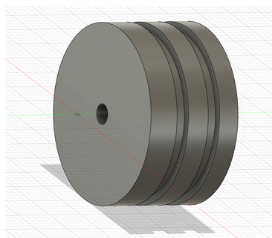
In a month, we learn CAD design, Arduino coding, rocket sensors, rocket aerodynamics, fuel simulation, and the organic synthesis of ignition powder. We complete three rocket main bodies, 2 data logger systems, engine designs, rocket flying computer, 5 parachutes, three force plates, two ignition systems, fuel grinding, casting, and four nozzles.

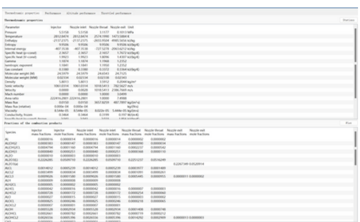


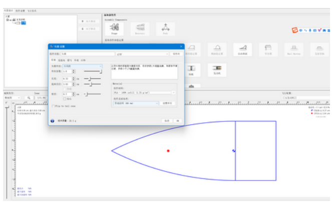


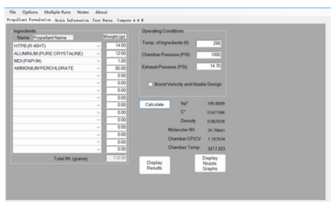












Although this may serve as a concluding statement, it is more like a new beginning. Our exploration will never cease, and our passion will continue to burn brightly. We aspire to inspire others through our endeavors, hoping to **ignite inspiration** and help individuals **discover their true passions**.

If you have any questions about rockets, please don't hesitate to reach out to us. We are more than happy to share our designs. We **will openly provide all the details, down to the smallest intricacies and the challenges we personally encountered**. This is unprecedented on the internet because most of the information available doesn't truly enable individuals to build a rocket from scratch without a solid foundation. (For example, although SpaceX has open-sourced some information, the majority of their technologies remain inaccessible to ordinary people, making it challenging to effectively transfer knowledge to the masses.) We will continue to update and enhance all of our resources and videos on our website, **www.ma2r3s.space**.

Feel free to explore all that we have to offer. Together, let's embark on a journey of learning, inspiration, and the pursuit of extraordinary achievements.

BEHIND THE SCENES

WRITTEN BY ANDREW DAI

How Do We Capture Each Fascinating Moment?

Photographer:
Andrew Dai

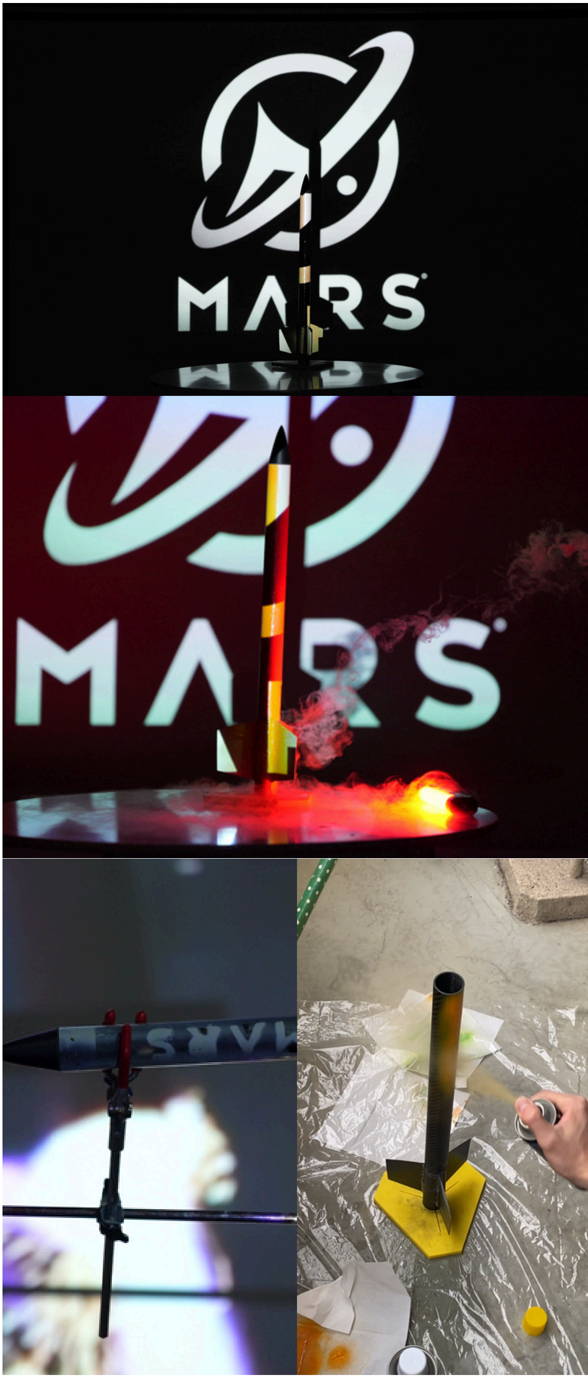
We employed a dual-camera setup, with the SONY ILCE-7RMV paired with the 70-200GM OSS II f2.8 lens for wide shots of the rocket's overall state, and the Canon R7 with the EF 400mm f5.6 L lens for capturing detailed close-ups. This combination allows us to have excellent coverage and playback for post-experiment review.

Due to the extremely high brightness and rapid speed of the flames during shooting, we had to use a high shutter speed of 1/3000s, a low ISO of 100 to reduce exposure, and a small aperture of f8 to limit the amount of light entering the camera. These settings enable us to capture every detail of the flame's ejection clearly, allowing us to observe the flame's shape, trajectory, and direction during playback.

Additionally, the color temperature and metering technique need to be adjusted based on the background light and specific experimental fuel to adapt to different tones and brightness levels. This ensures that the actual colors are accurately reflected.

Written by Andrew Dai

Rocket Coating Design&Inspiration

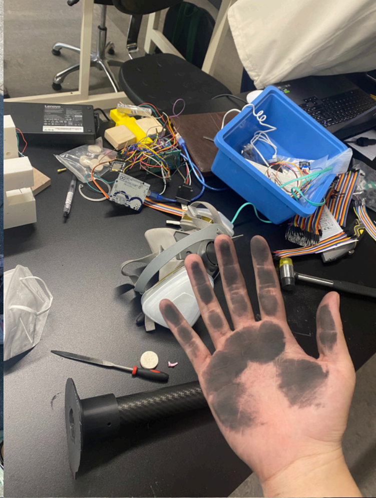


Orange: We chose orange as the primary color for the rocket because it symbolizes energy, vitality, and innovation. This vibrant color not only has a strong visual impact but also provides higher visibility in the vast field when we are searching for the rocket to reuse.

White Mars Logo: The white Mars logo on the rocket symbolizes the future. This design highlights our determination to explore the universe and venture into the unknown. White also resonates with the high-tech and clean environment of space exploration, conveying our commitment of a high standard of environmental friendly design.

Black: black design of the rocket's head not only provides aesthetic contrast but also conveys deeper symbolism. Black symbolizes the infinite space and unknown realms, inspiring us to keep exploring. This choice of color adds a sense of mystery and sophistication, emphasizing our commitment to venturing into the uncharted territories of space.

Written by Andrew Dai

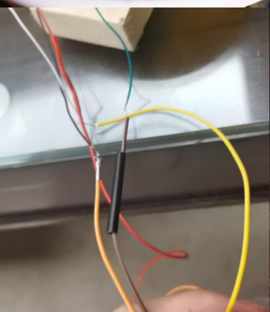
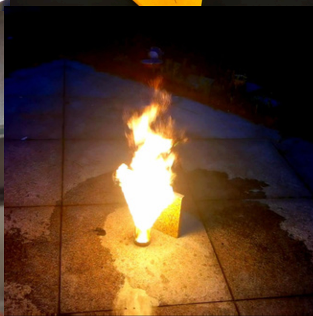











Te
Tellurium
Iodine
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Sb
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Polonium
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Astatine
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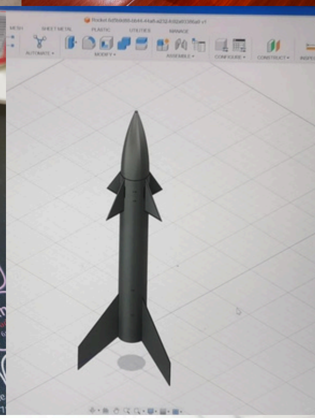
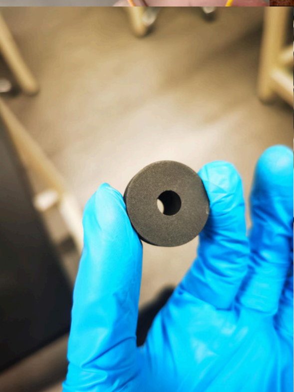
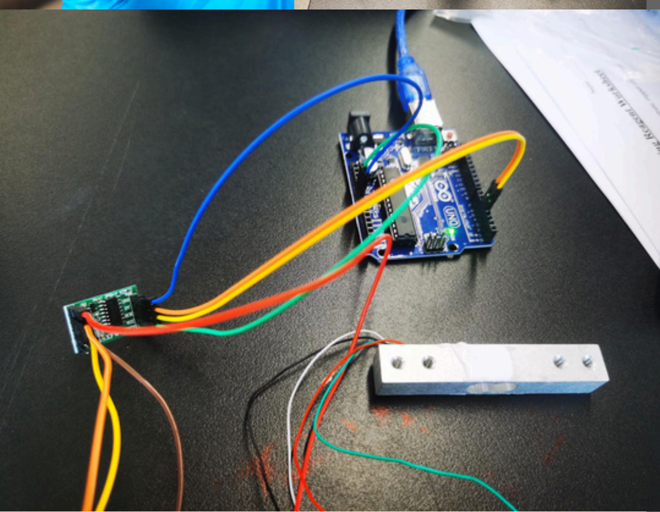
Tennessine








MARS

ACKNOWLEDG-MENTS

BY RYAN ZHAO

Acknowledgments

We gratefully acknowledge **Professor Fan, 樊臻** and **Professor Ma, 马增益** of Zhejiang University for insightful discussions and for supervising our rocket testing.

We would also like to thank **Dr. Mary Mu** for providing remarkable chemistry knowledge in synthesis.

We gratefully thank **Dr. Chantel Rudman** and **Dr. Ke Huajie**'s support and **our teammates**' work.

References

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Paper: Davenas, A. (2003). Development of Modern Solid Propellants. Journal of Propulsion and Power, 19(6), 1108–1128. https://doi.org/10.2514/2.6947

Website:

https://www.nakka-rocketry.net/sorb.html#QC (KN based fuel)

http://www.chlorates.exrockets.com/ammper1.html (sp method to make NH_4ClO_4)

Reliant Robin — Breaking Ballistics. (n.d.). Breaking Ballistics. https://www.breakingballistics.com/reliant-robin

Software:

OpenRocket, openMotor, AutoCAD Fusion, RPA, KiCad