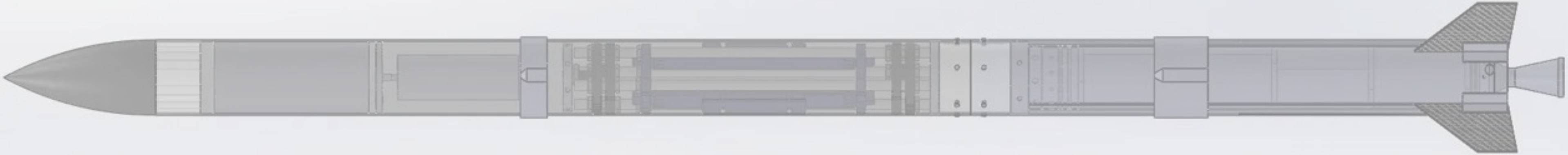
Nakuja project

Presentation by interns 2023
Nakuja project



10th May 2023
iPIC exhibition room, JKUAT

NAKUJA PROJECT
DESIGN.MAKE.LAUNCH

Who we are

About 30 students and supervisors

Propulsion	Avionics
Airframe	Flight control

Launch liquid propellant rocket to bring nanosat into LEO by 2025

Age of *NEW SPACE*

Establish rocket industry in Kenya

Our activity

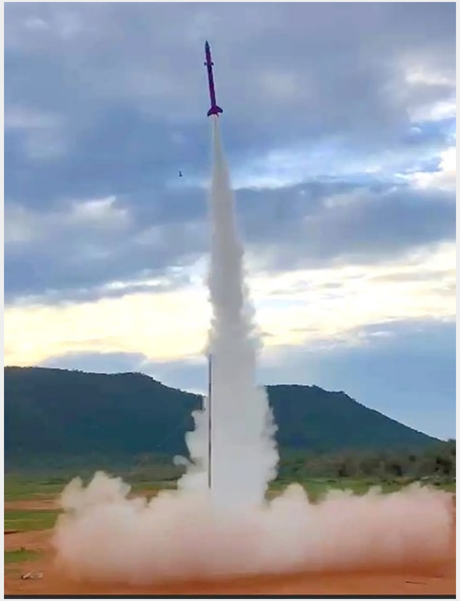
Design & Fabrication

Experiment & Analysis

Collaboration with Kenya Space Agency (KSA)

Visit Broglio Space Centre @Malindi

Space Expo 2022 @Sarit Centre

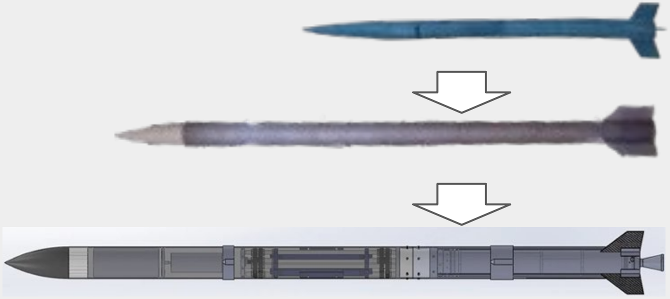


Launch N-2 rocket


N-2 ROCKET 1ST LAUNCH
April 2022

Internship 2023

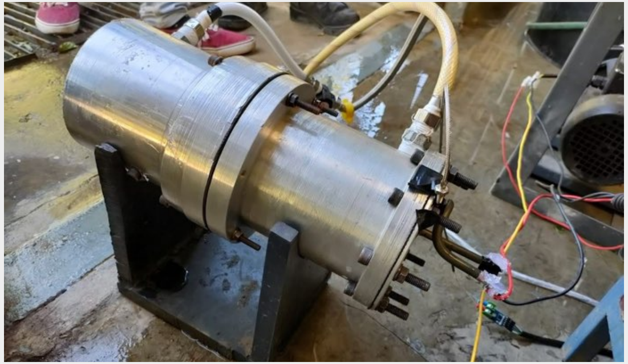
19 students (JKUAT and KU)



N-1 (2021)

N-2 (2022)

N-3 (2023)



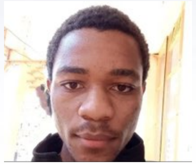
1) N-3 rocket development

2) Liquid engine development

Airframe	Recovery	Solid Propulsion	Liquid Propulsion
(5)	(6)	(5)	(3)

AIRFRAME PROGRESS REPORT

To infinity and beyond



MWADIME LAWRENCE

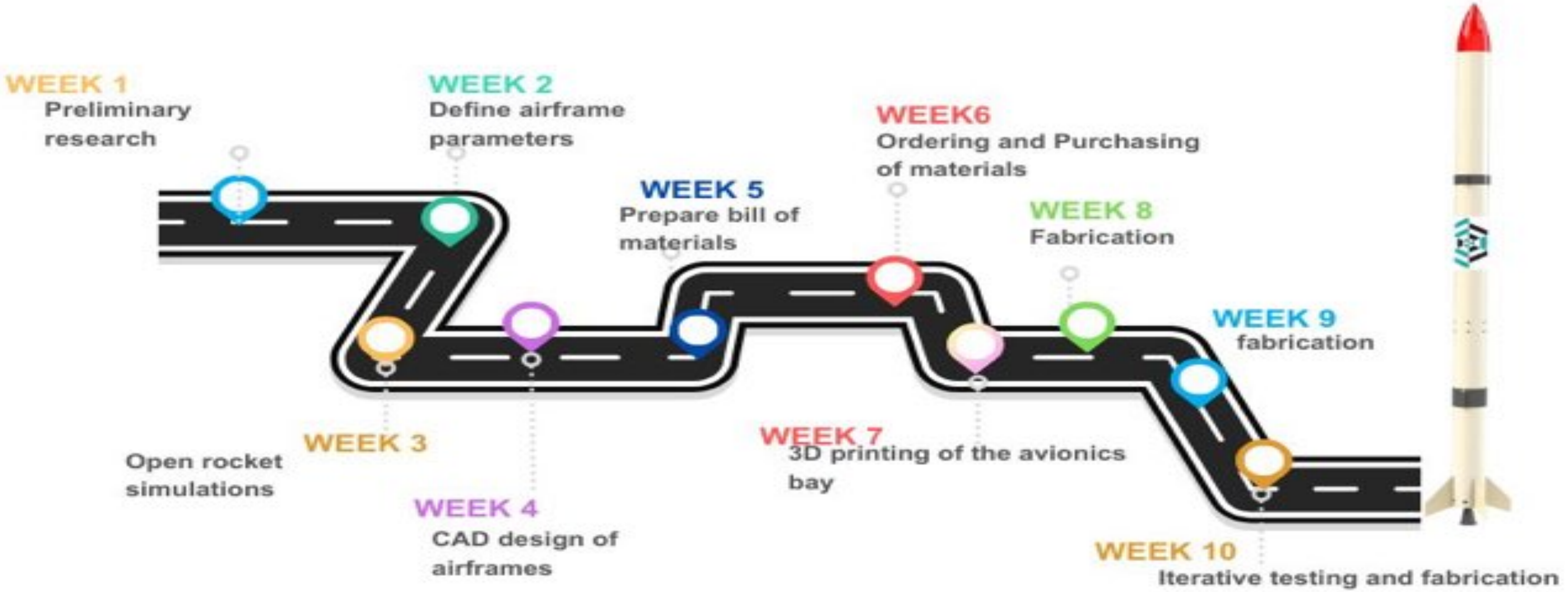
KARIITHI ANNE

GACHUNGA FRANCIS

TINEGA SAMWEL

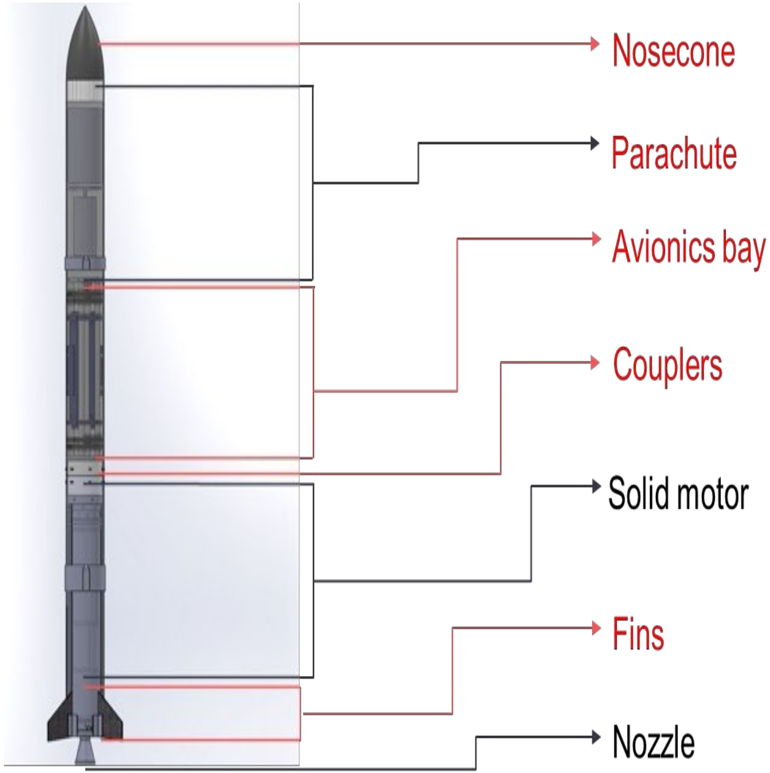
NAMUYE INNOCENT

AIRFRAME TEAM TIMELINES



ABOUT AIRFRAME TEAM

- Airframe refers to the **rocket body** that holds sub components
  - Avionics bay
  - Payload
  - Parachute
  - Rocket motor mount
- The task of the airframe team
  - Design, fabrication, and test of the airframe
  - Estimation of forces in the flight path
  - Structural analysis (Compressive and buckling loads)

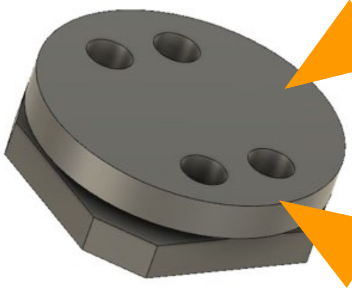


GOALS AND OBJECTIVES

The Nakuja N3 rocket airframe had the following improvements:

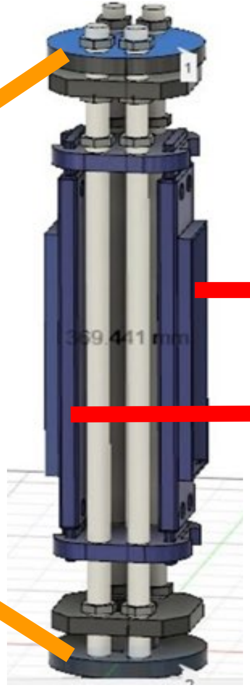
- Aluminum and fibreglass airframes
- Target apogee of 2000m
- Easy assembly and disassembly of the rocket
- Improved sub-components structure

THE AVIONICS BAY



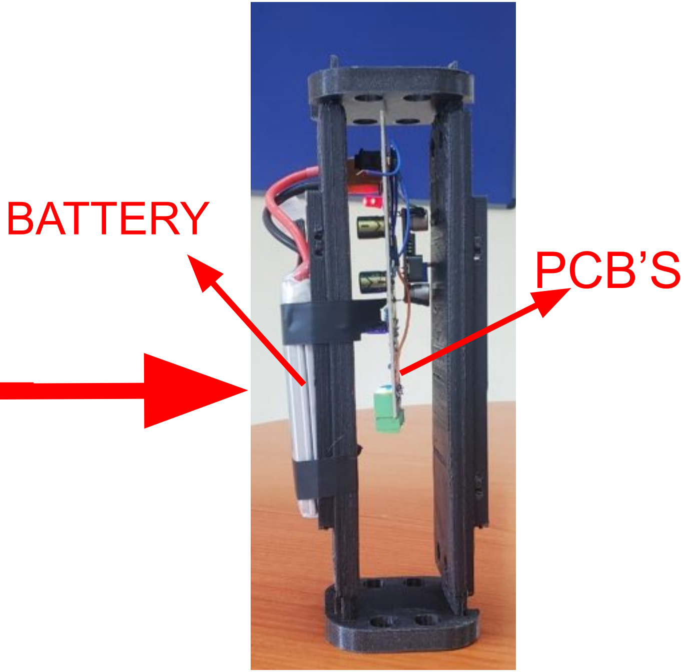
Holder

- fixes the bay in the airframe for ease of assembly and disassembly



Avionics bay

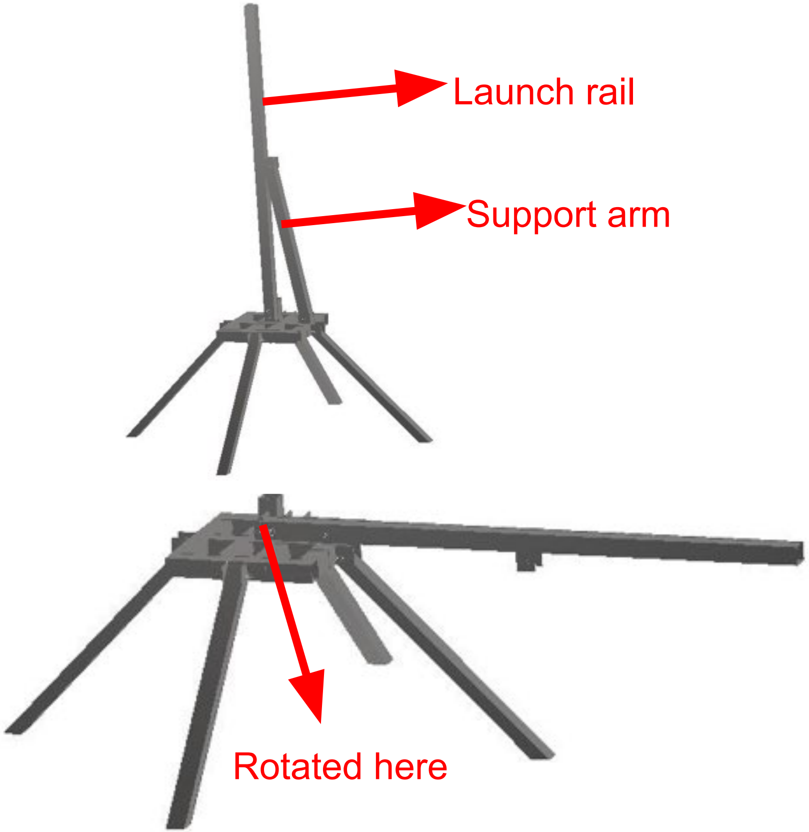
- holds the electronics components (avionic)



Electronics bay

- holds the battery and PCBs on both sides

LAUNCHPAD AND LAUNCH RAIL

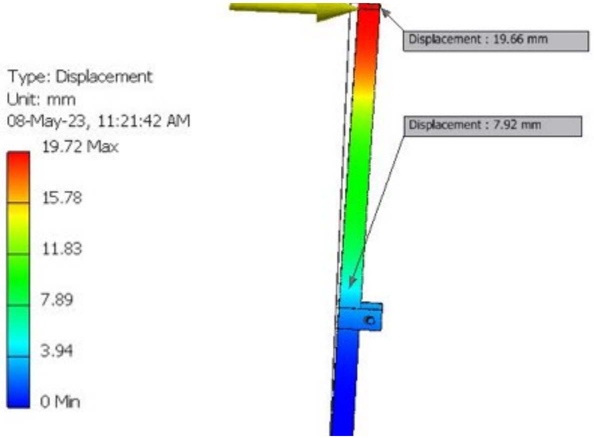


- Launch rail height (1.5m)
  - Optimized using Open Rocket simulation : Velocity and stability
- Revolute joint
  - Positioning launch angle
- Support arm
  - Added after structural simulation
    - Suppress high displacement

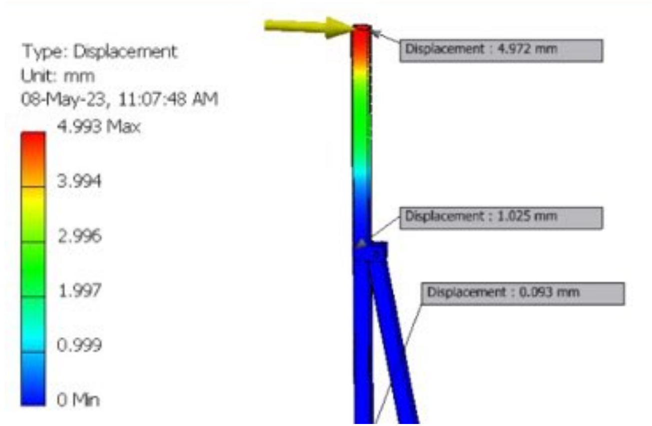
DESIGN ANALYSIS

- Assumption
  - Rocket inclined at 5° angle to the rail
  - Horizontal component of about 260N

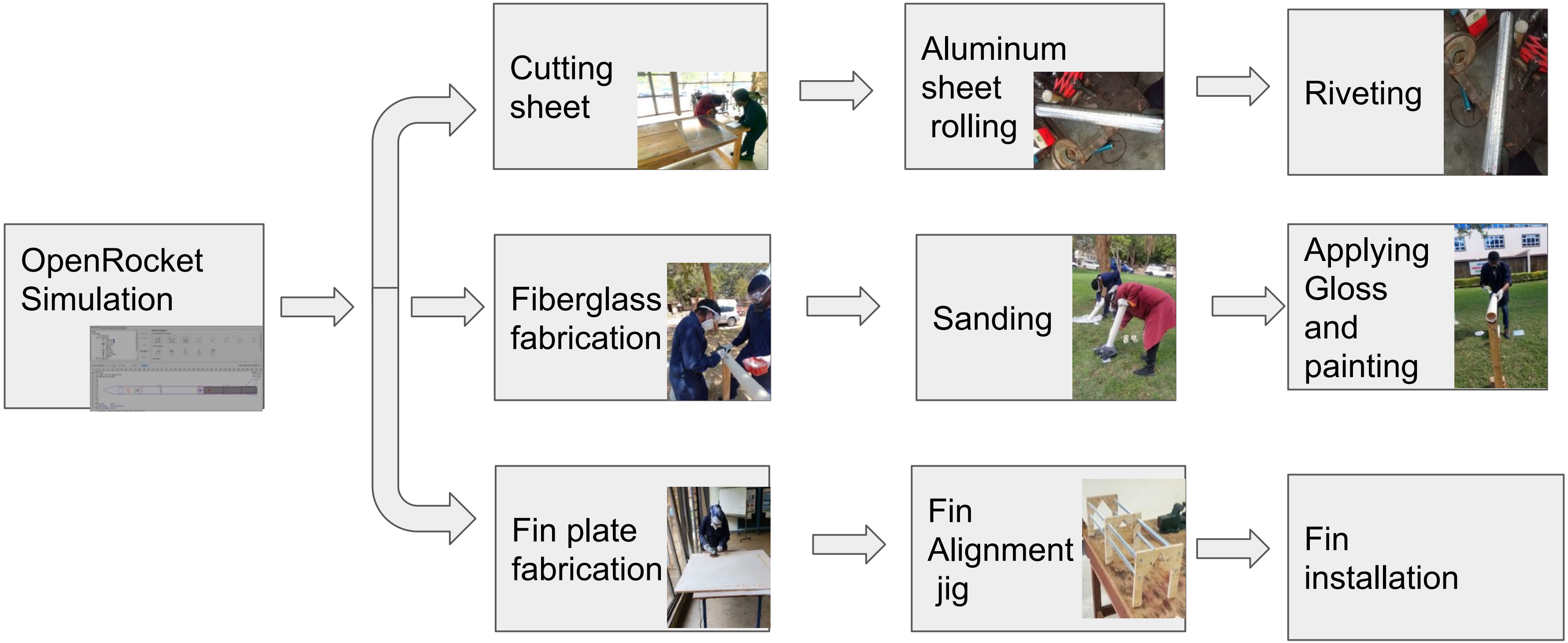
Maximum deflection without the support arm is **19.72mm**



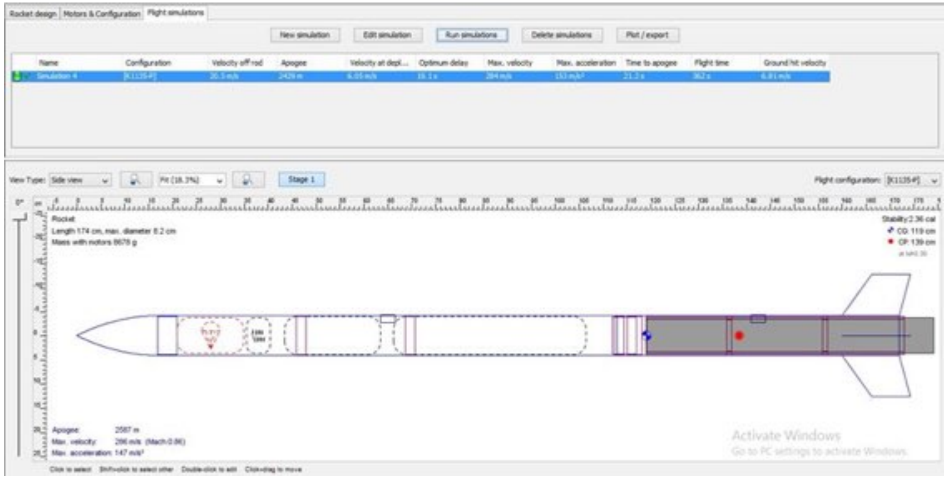
Maximum displacement with the support arm is **4.993mm**

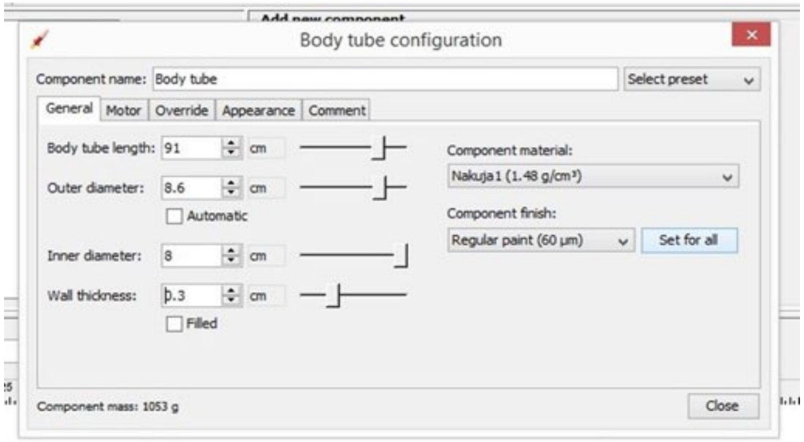


FABRICATION OF THE AIRFRAMES



OPEN ROCKET SIMULATIONS





Mass = 8678g Length = 174cm Apogee = 2429m

The simulation showed that the rocket will comfortably get to our targeted apogee of 2000m

FABRICATION OF ALUMINIUM SHEET

Marking out points to be drilled

Drilling

Rolling

FABRICATION OF FIBREGLASS BODY-TUBE

Application of resin on the fiber mat and glass

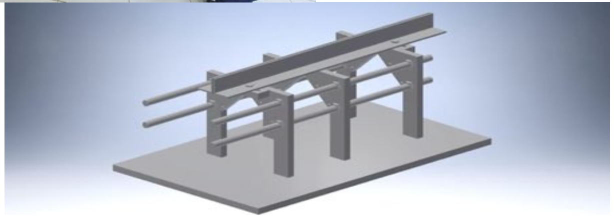
Sanding

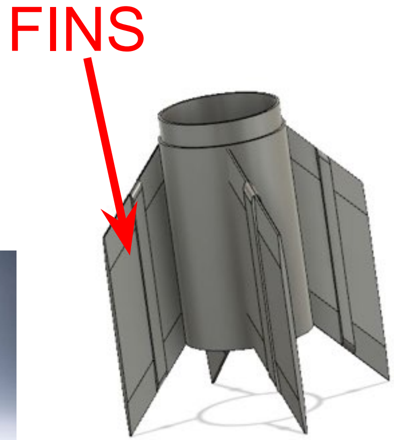
Applying gloss

Final body-tube

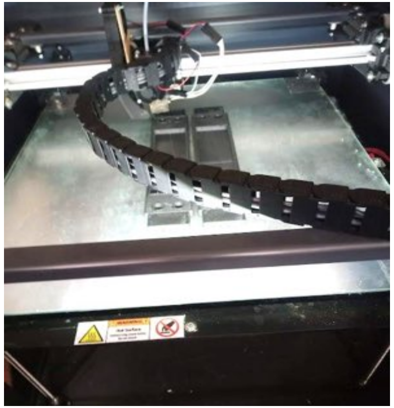
FABRICATION OF THE FIN ALIGNMENT JIG

- Fins determine aerodynamic properties
  - MUST be aligned orthogonally to the airframe
  - Necessity to make an original fin alignment jig





WHAT WAS LEARNT



Additive manufacturing

Fiberglass fabrication

Sheet rolling and riveting

Assembly techniques such and use of jigs

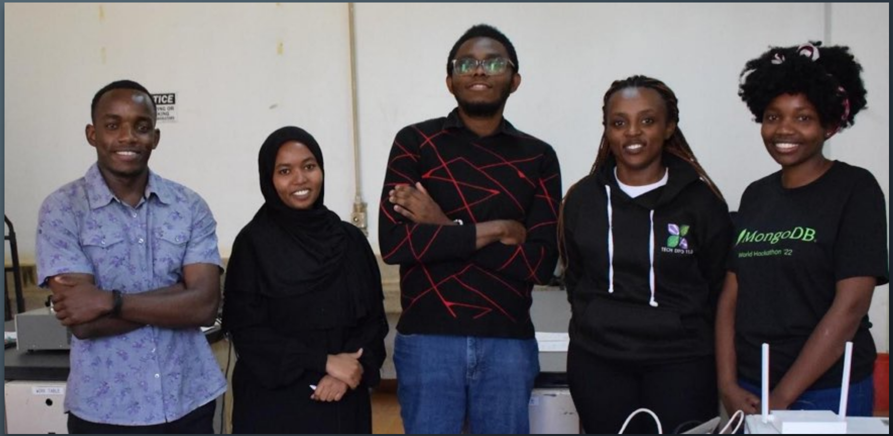
Use of Open rocket

CHALLENGES FACED

- Insufficient skills in various fabrication techniques
    - Inconsistencies in fabricated parts
- Inefficiency of the sheet rolling machine
    - Rolling of the aluminum sheet was difficult

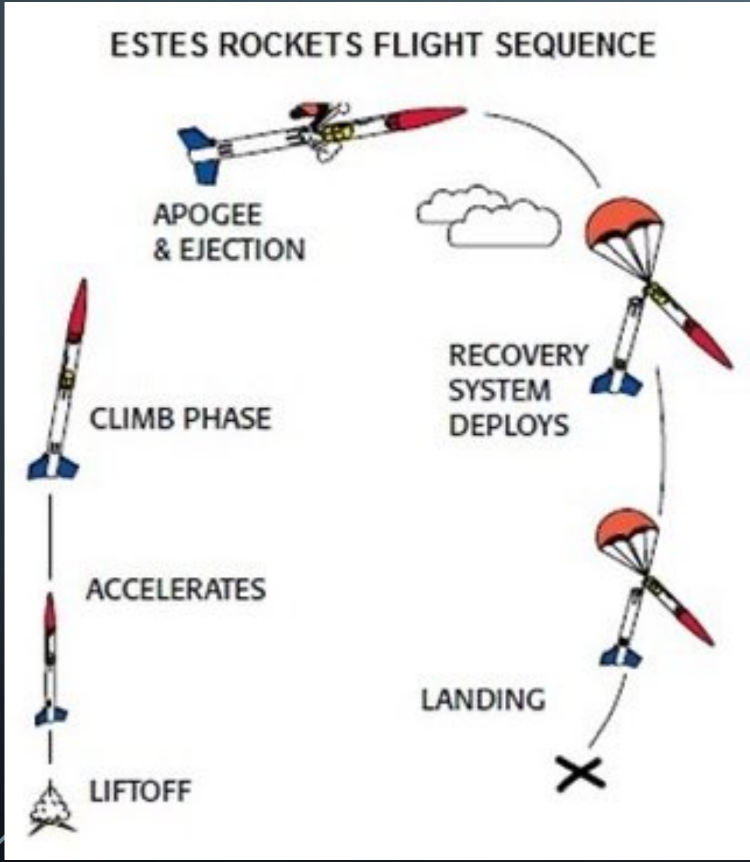
Recovery Team

- HISTORY
- RECOVERY
- TELEMETRY
- AVIONICS
- WAY FORWARD



- EDWIN MWITI SAFA OSMAN
- JONES KISAKA JUNN HOPE
- RUTH NAIBEI BETH WANOI

Rocket Recovery Overview



- Safely returning rocket to ground after launch
- Parachute deployed after apogee detection
- Why recover?
  - Safety hazard
  - Reusability
  - Compliance

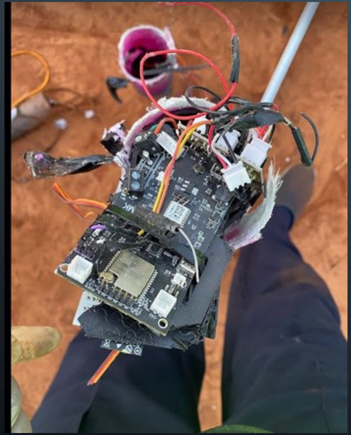
HISTORY

Shortcomings within N2 Avionics:

- Recovery system not deployed
- Onboard data logging unsuccessful
- Loss of Line of Sight Communication
- Flight Computer PCB constant reset issue

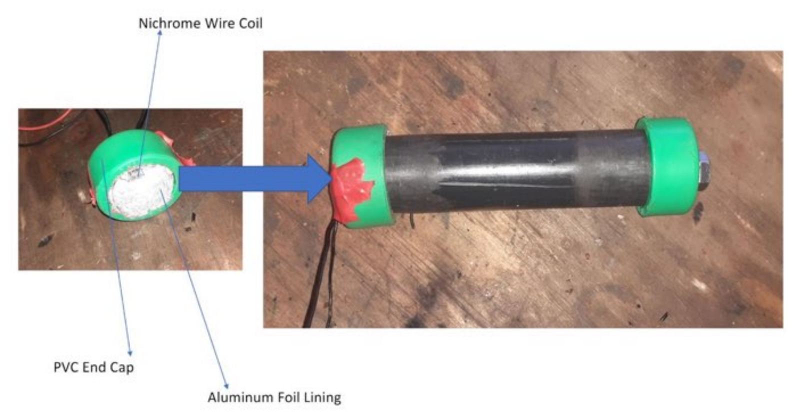
Nakuja N3 Recovery Team objectives:

- Successful recovery system.
- Continuous data logging
- Design a wrap-around patch antenna
- Redesign flight computer PCB



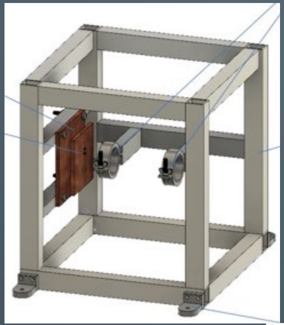
Recovery: Analysis of the N-2 ejection failure

- N2 Ejection mechanism - nichrome wire, crimson powder
  - -Apogee-driven recovery
  - -Manual override
- From Post flight analysis
  - Insufficient thrust to eject the nose cone
  - Manual override communication failure
- Use **piston** to provide sufficient thrust



Development of Ejection Force Measurement System

Initial testing
without teststand



Test stand for piston ejector

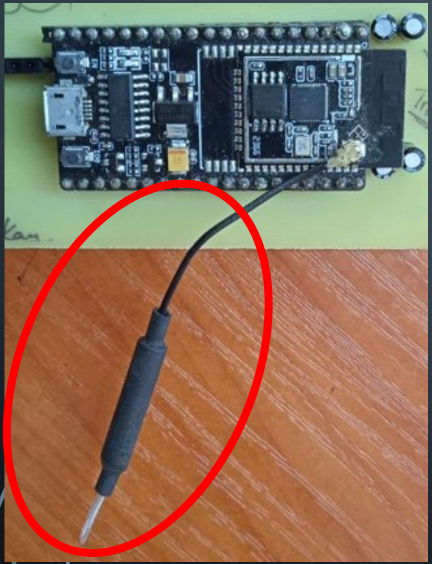
Measurement
In a **safety cage**

TELEMETRY: Communication Protocol

- N-3 target apogee: 2,000m
- Reliable communication protocol
    - Zigbee - Low Data rate
    - LoRa - doesn't support video transmission
    - WiFi - easy setup, available antennas
- Wi-Fi protocol chosen; leverage on powerful antennas

TELEMETRY: Improved antenna design

1. Line of Sight Communication Link
2. Wraparound microstrip patch array antenna
3. Antenna Fabrication & Testing



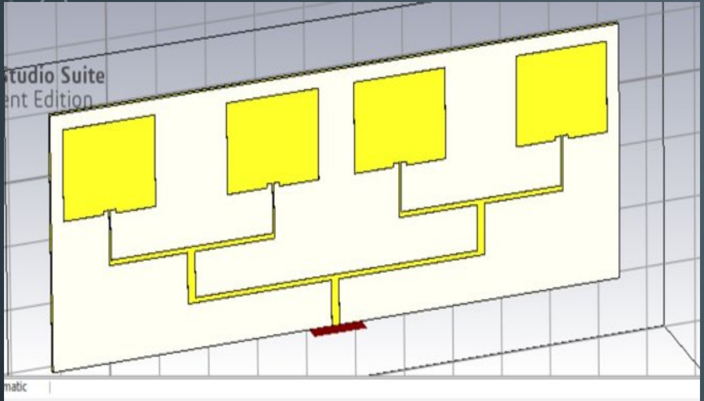
N2 Antenna

	N2 Antenna	N3 InHouse Antenna
Gain	2.5 dBi	5 dBi
Bandwidth	150 Mbps	200 Mbps
Frequency	2.4 GHz	2.4 GHz
VSWR	1.7	1.5
Impedance	50 ohms	50 ohms
Connector	UFL connector	UFL Connector

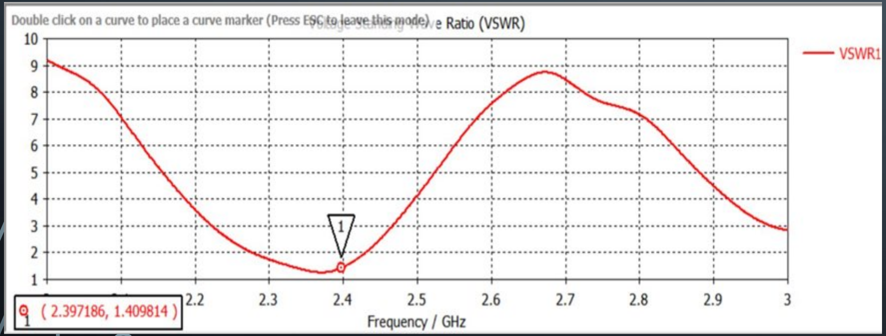
Comparison of N2 and N3 antenna

Proposed Antenna Design

TELEMETRY: Improved antenna design

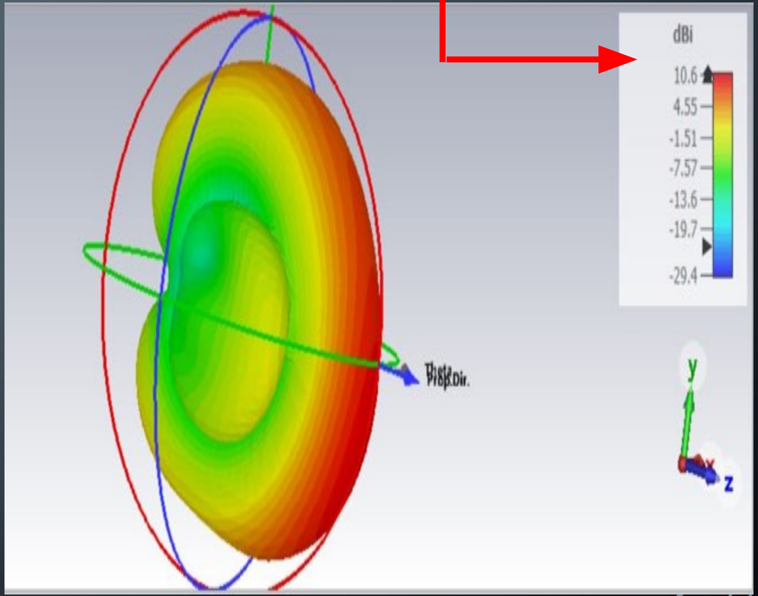


N3 antenna design



Reflection Loss reduced to 1.4

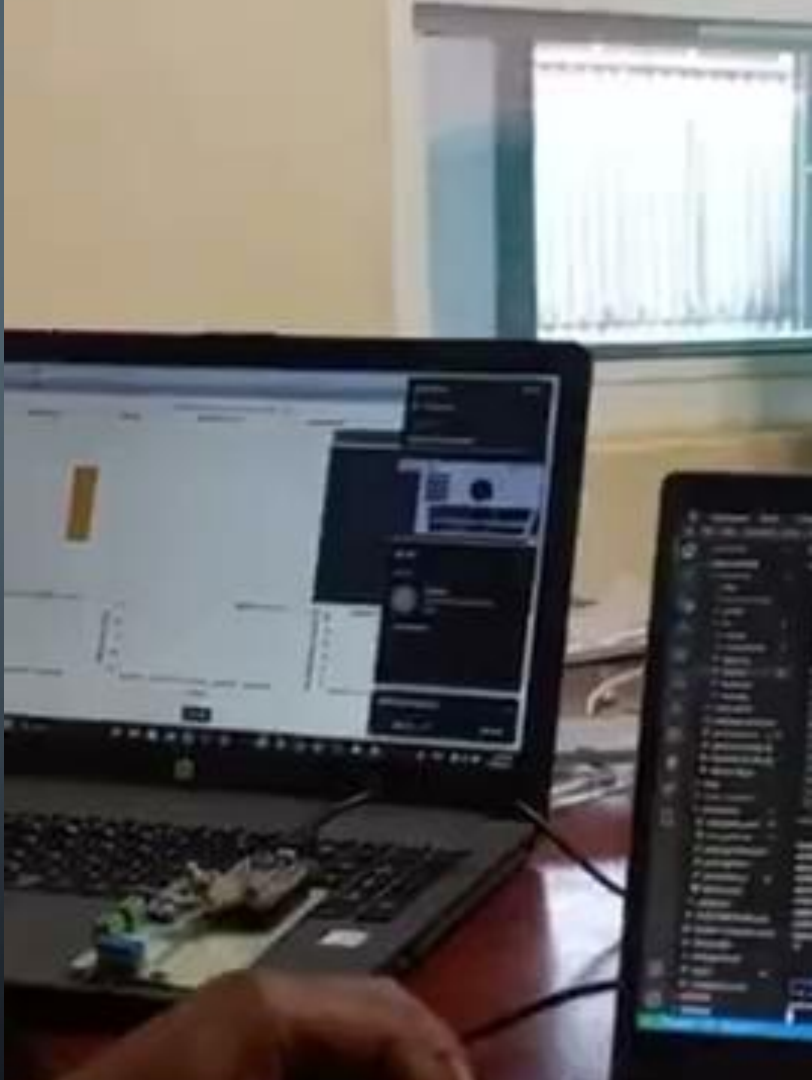
Gain increased to 10.6 dBi



TELEMETRY: Dashboard improvement

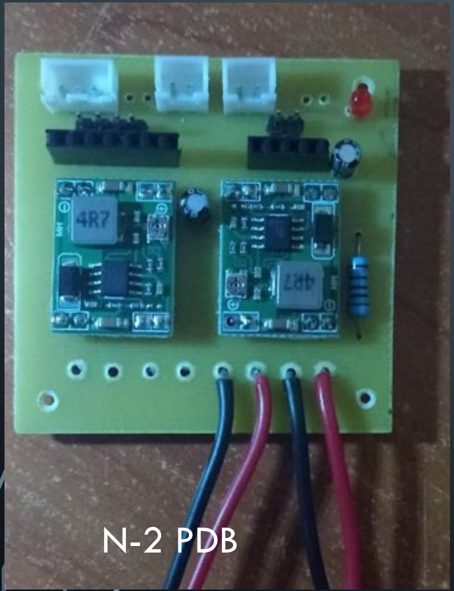
- Modified the existing dashboard to incorporate :

1. 3D live view of the rocket's orientation
2. GPS Mapping

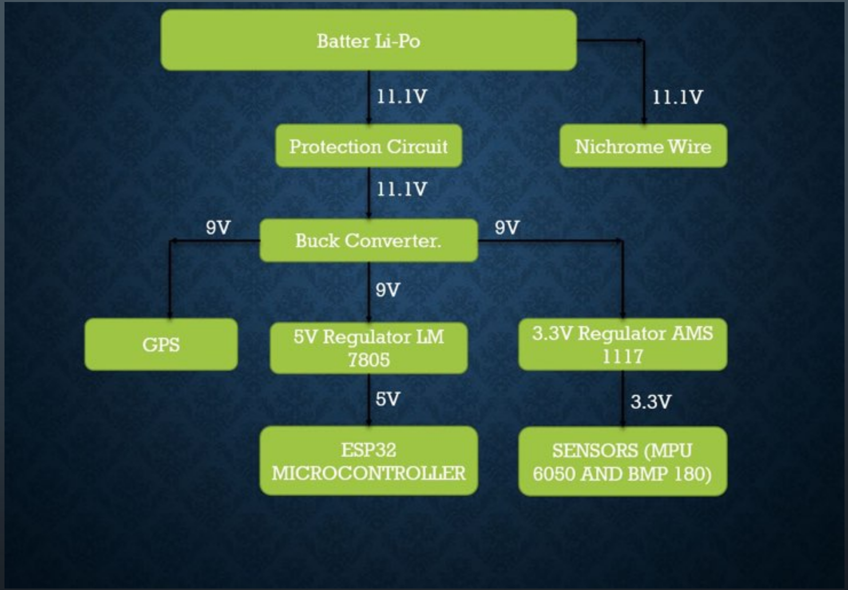


AVIONICS: Power distribution board

- Dedicated power distribution board (PDB)
  - Supply power to all various submodules independently



N-2 PDB

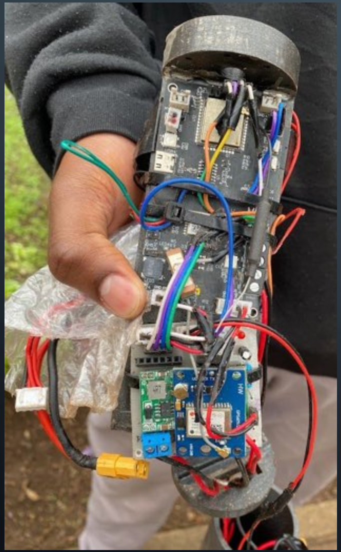


Power Distribution Flow Diagram

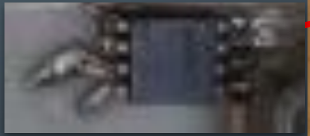
N-3 PDB (NEW)

AVIONICS: Flight computer PCB, Data Logging

- Added the following on N-2
  - Constant reset
  - Over The Air (OTA) updates
- Onboard flight data logging
  - **Flash Memory** over SD Card
  - **10 minutes** of data logging
- Integrated tests remain



N2 Flight PCB



Flash memory

N3 Flight PCB (NEW)

WAY FORWARD

- PARACHUTE DEPLOYMENT TESTS
- ANTENNA FABRICATION AND TESTING
- OVER THE AIR (OTA) UPDATES

SOLID PROPULSION

The propulsion team is made up of 5 members.

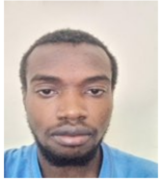
Their photos and individual courses are as below.

Shabach Baraka
BSc Mechatronic Engineering, JKUAT

Bruce Kibet
BSc Aerospace Engineering, KU

Faith Chelang'at Korir
BSc Mechanical Engineering, JKUAT

Collins Bett
BSc Mechatronic Engineering, JKUAT



Bildad Nzyoka
BSc Mechatronic Engineering, JKUAT

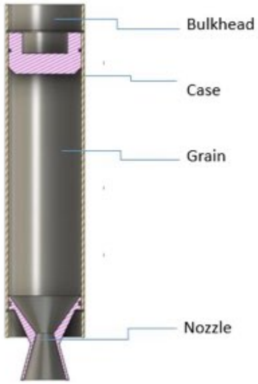
OBJECTIVES OF PROPULSION TEAM

- Confirm theoretical performance of **KNSB*** from **static tests**.
- Improvement of static test stand for **immediate static test**.
- Study on **Composite rocket propellant motor**.
- **Real time** static test analysis **dashboard**.
- **Dedicated circuit board** and **casing** for static test stand.

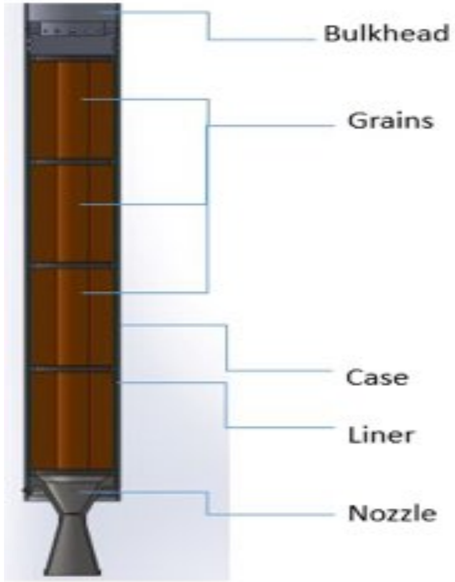
KNSB: Potassium Nitrate and Sorbitol

Scaling up the motor

N-2 motor



N-3 motor



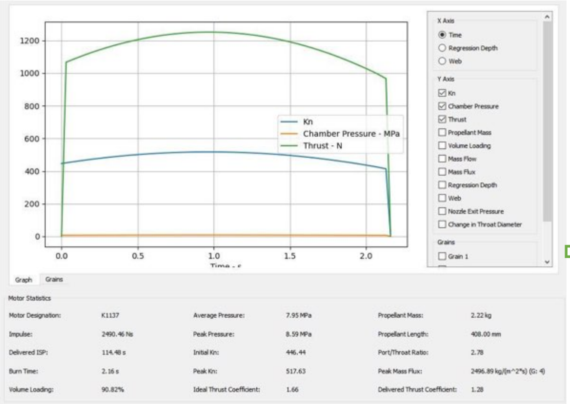
Diameter	56mm	**68**mm
Length	240mm	**500**mm
Isp	90.91s	**114.48**s
Thrust	80.87N	**1229.7**N
Burntime	2.375s	2.12s

DEVELOPMENT OF SOLID PROPELLANT

- Solid propellant is a heterogeneous mixture of **oxidizer**, **fuel** and **catalyst**
    - The combustion gas expands in the nozzle
- **KNSB**
    - Potassium Nitrate: **Oxidizer**
    - Sorbitol: **Fuel**
    - Iron(III)oxide-**catalyst**
    - The ratio of **65:35:0.2**
- **Four cartridges** will be used in a single motor




DEVELOPMENT OF SOLID PROPELLANT



Open motor Simulation

Mold design fabrication

Grinding Potassium Nitrate

Mixing all components

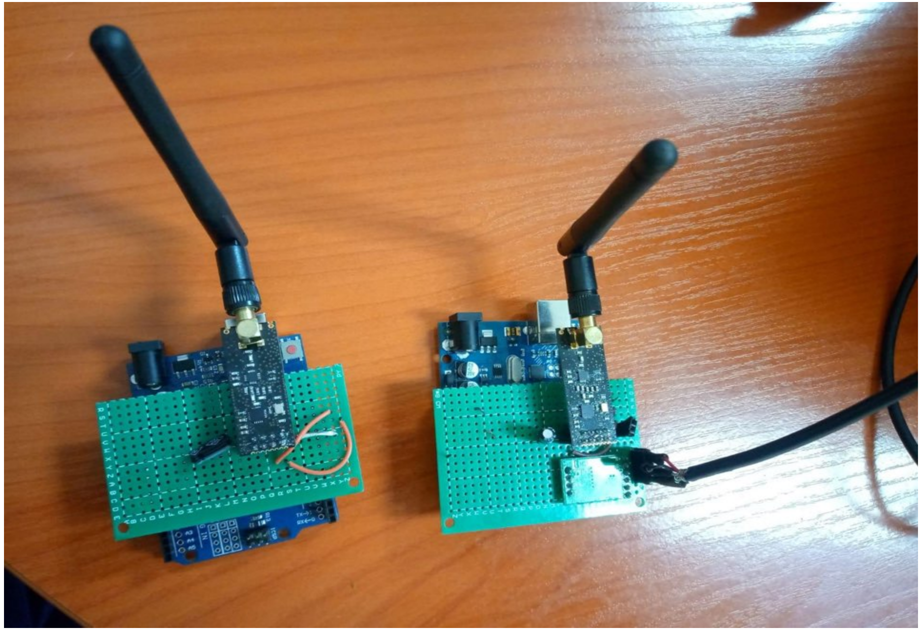
Cooking of propellants

End product from cooking

Finished cartridge

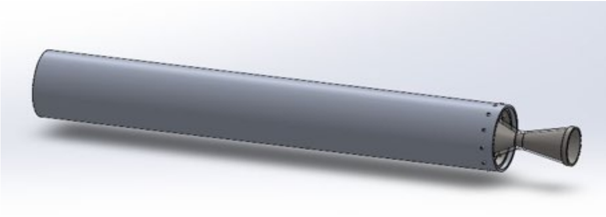
REMOTE IGNITION SYSTEM

- Previous test stand
  - Wired ignition and data acquisition
- New test stand
  - **Wireless** ignition
  - **NRF24L01** transceivers: **1Km Range**



DESIGN AND FABRICATION OF SOLID ROCKET MOTOR

- **Casing**, **nozzle** and **bulkhead**
- **Open motor** simulation with various cartridge sizes and nozzle dimension configurations to get specific impulse Isp
- Design the parts in **SolidWorks** and **Autodesk Inventor**



SolidWorks design

Casing
Length:500mm
Outer diameter:75mm
Inner diameter:68mm

Nozzle
Length: 121mm
Outer diameter: 68mm

Bulkhead
Outer diameter: 68mm

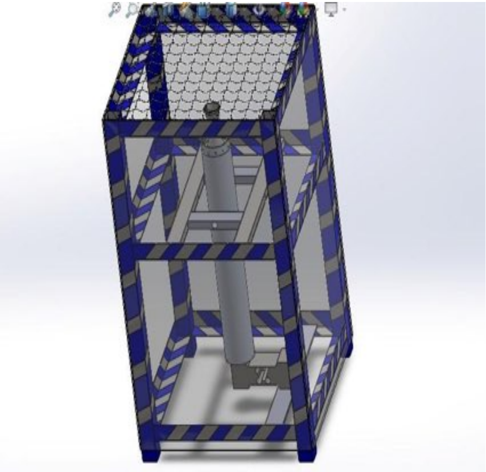
DESIGN OF TEST STAND

- A completely **new test stand** developed to accommodate bigger **N-3 rocket motor**

- Consideration for the design
  - **Safety**
  - **Complexity**
  - **Stability**

- Design considerations for the test stand
  - **Horizontal thrust vector**
  - **Upward thrust vector**
  - **Downward thrust vector**

N-2 test stand



N-3 test stand

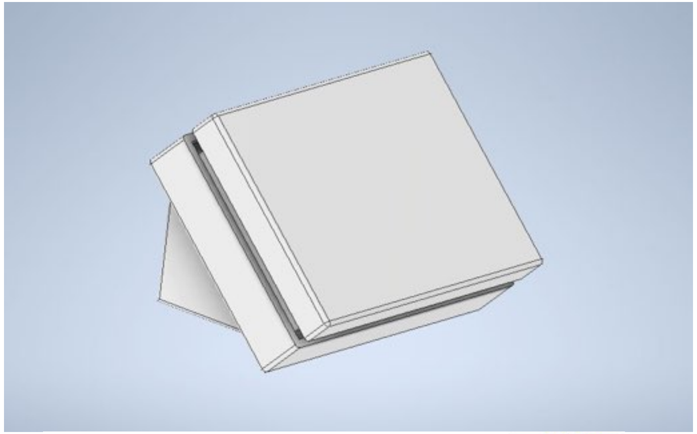
FABRICATION PROCESS OF TEST STAND

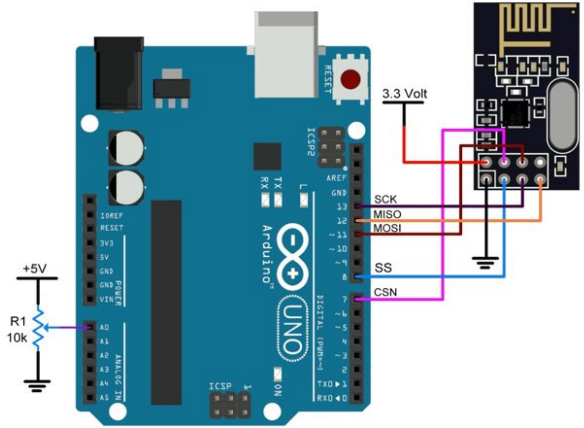
- **Welded at varying voltages** for the different thicknesses of materials
- **Grinding** the excess material to create smooth welded surfaces
- **Spray painting** to **add aesthetic** and also to **act as a hazard warning**

Welding process

DEDICATED CASE FOR TEST STAND

- The case houses the **transmitter board** that includes:
  - **Arduino board**
  - **NRF24L01 transceiver**
  - **Lithium batteries**
- The **receiver board** is connected to the laptop to monitor **real-time**
- Case is inclined
  - It can also be used on the **launch pad**





EXPECTED PERFORMANCE

- Expected performance
  - Burn time: **2.12 seconds**
  - Specific impulse (Isp): **114.48 [s]**
  - Peak Thrust**: 1229.7[N]**
- Possible improvement
  - Remove air bubbles to avoid thrust deterioration
  - Different ratios of oxidizer and fuel
    - Our sorbitol is actually **70% sorbitol** and **30% water**
  - Change grain configuration
    - **BATES** grain to **Rod and Tube**
      - Trade-off for the increase of **thrust** and **internal pressure**

CHALLENGES FACED

A. **Faults in welding**
For welding of metals with different thicknesses

B. **Acquisition of materials**
Difficult to find sellers who sell the exact quantity

C. Fabrication of the **casing**
Took time as the **lathe** kept breaking down and not being repaired on time

(A)

(B)

(C)

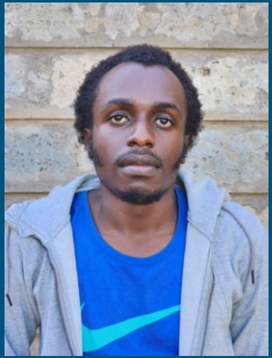
CONCLUSION

- Use of **CNC lathe** recommended over the normal lathe
  - To **reduce time** spent on fabrication
- Checking for the **availability** of a specific material
  - Necessary before settling on the material
- Building **experience** is necessary
  - To **hasten the fabrication** and **reduce faults** in the product
- Allowing other teams to **settle on their designs first**
  - To avoid the back and forth process

Liquid propulsion Team members

Lael Mukeni
Mechatronic Eng
4th year

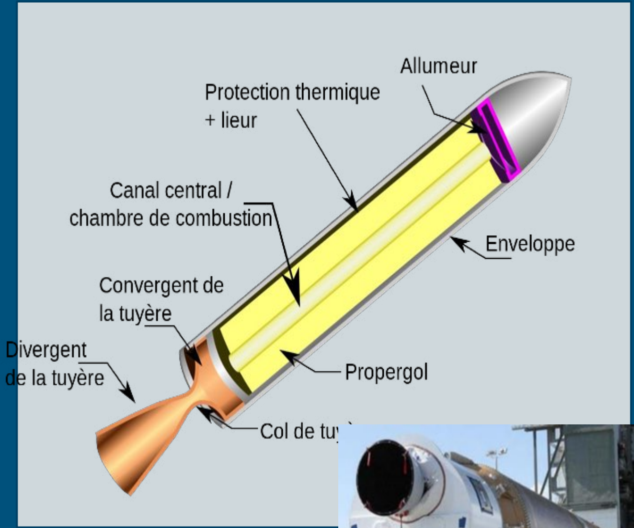
Paul Munyao.
Mechatronic
Eng.
4th Year



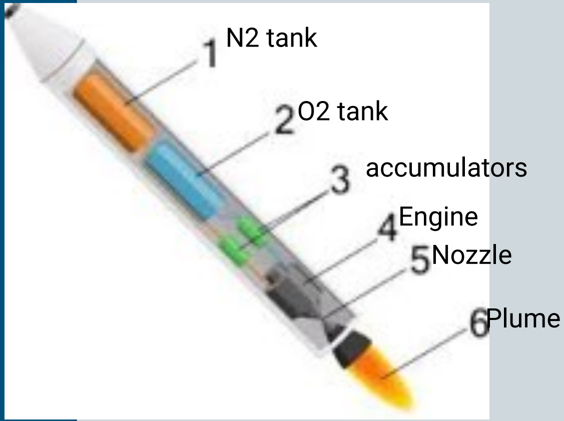
Edmund Munene
Mechatronic Eng.
3rd Year.

Liquid propellant vs. Solid propellant

Solid propellant rocket



Liquid propellant rocket



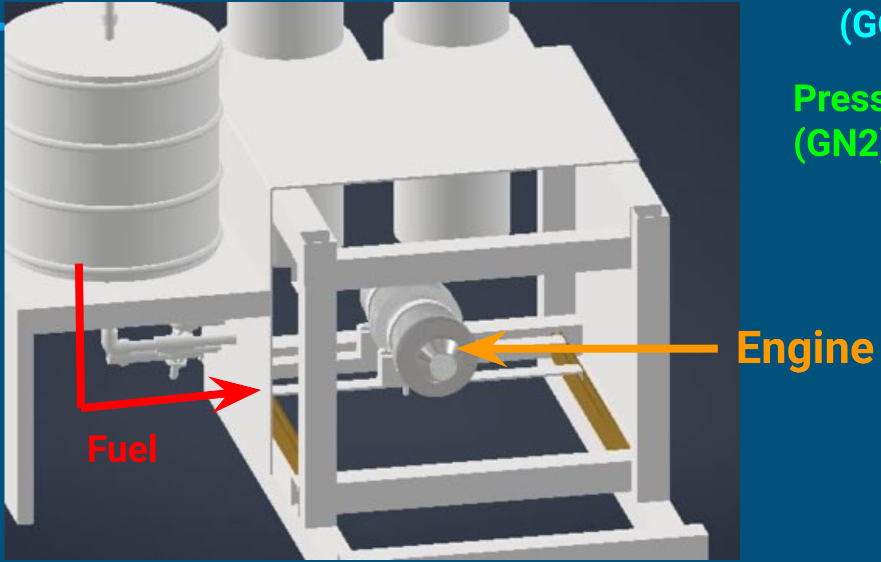
Main objectives

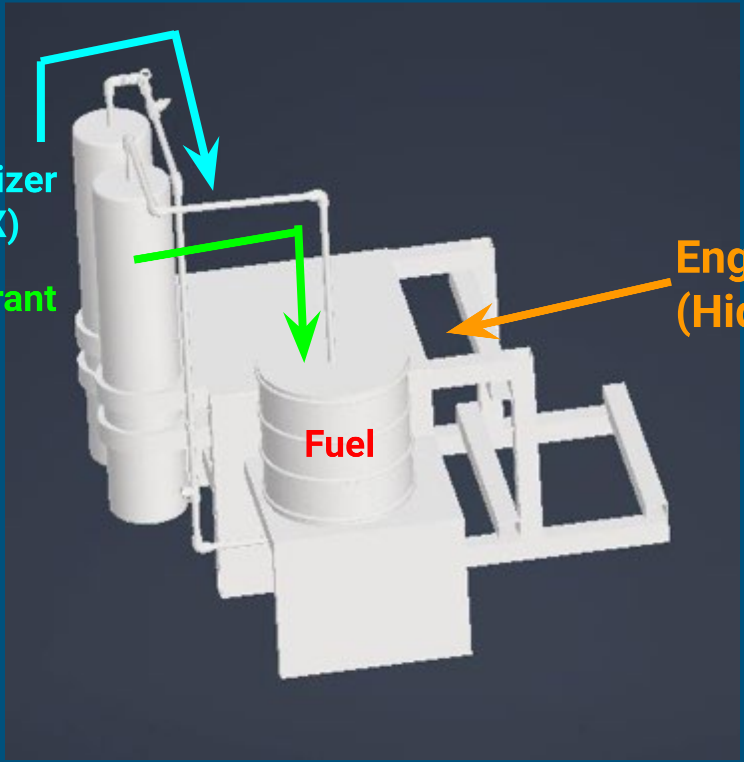
1. Complete the assembly of the test-stand
    a. Assemble the test stand and engine
    b. Electrical and control system design
    c. P&ID development
2. Conduct the water test

Engine parameters:

Thrust	2kN
Burn time	5s
Fuel	Ethanol
Oxidizer	GOX
Oxidizer/Fuel	1.5

Test stand diagram



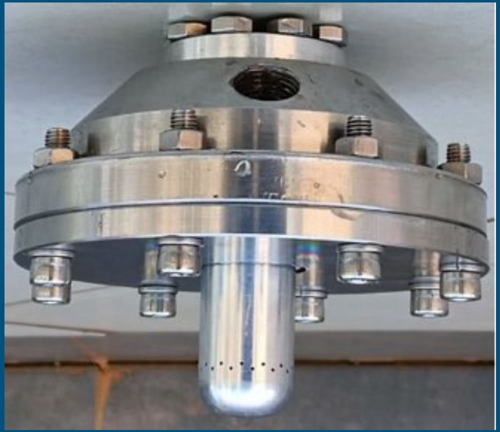


CAD assembly diagram of the liquid rocket test stand test stand.

Objective 1: Complete the engine test stand

Tasked to assemble 3 subsystems from previous teams.

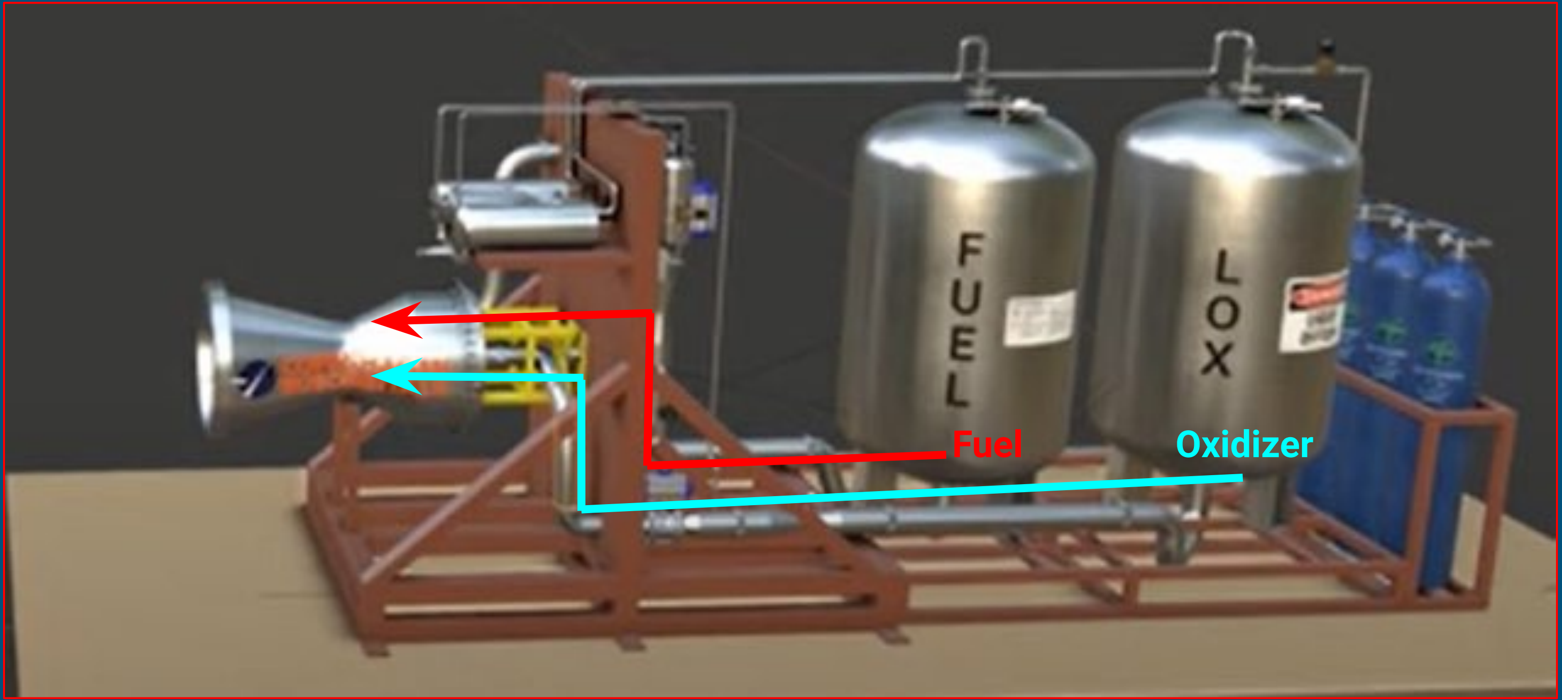
TestStand
(by Joy/Maureen)



Pintle injector
(by Martin/Samwel)

Engine (Combustion Chamber)
(by Michael/Felix)

Illustration of completed test stand



Full assembly of Rocket engine
(Image courtesy: Copenhagen suborbitals)

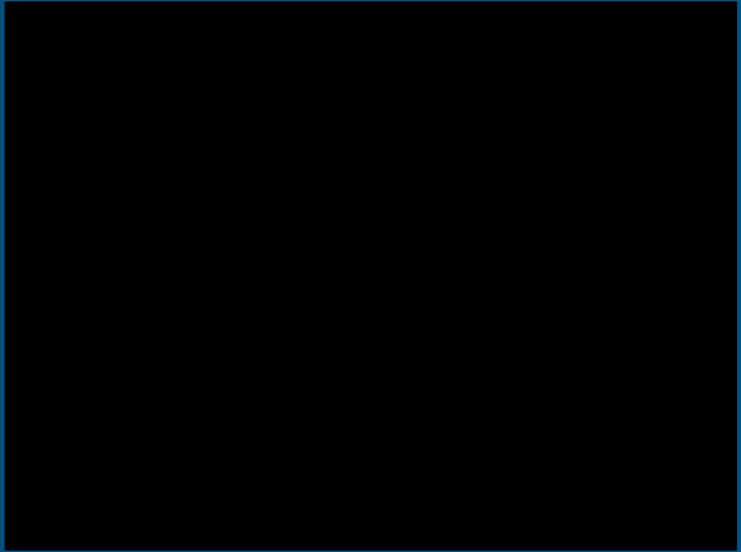
Assemble the engine

Emergent problems:

1. Engine leaks (were solved)
2. Spacer mismatch (redesign ongoing)

Resolution of leakage

Previous



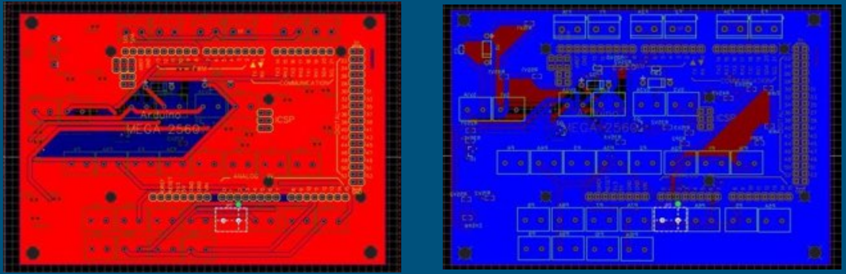
Engine with leaks

Current

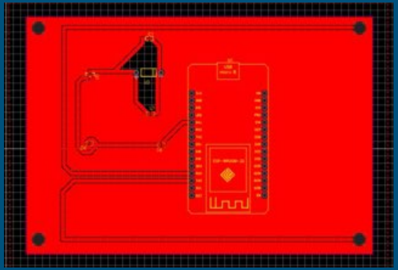
All leaks sealed

Electrical and control system design

1. **Electronics:**
   - Electronics design completed
   - PCB fabrication ongoing
2. **Coding**:
   - Program for control, monitor, and log the test
   - Test coding complete



Arduino Mega shield PCB (Double-sided)



ESP32 PCB (Single sided)

COM7


```
{"SVState":1,"Q FUEL":0,"Q GN2":0,"Q GOX":0,"P GN2":1.013,"P GOX":1.013,"P 3":1.012541,"P 4":0.9991,"P 5":0.9991}
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```
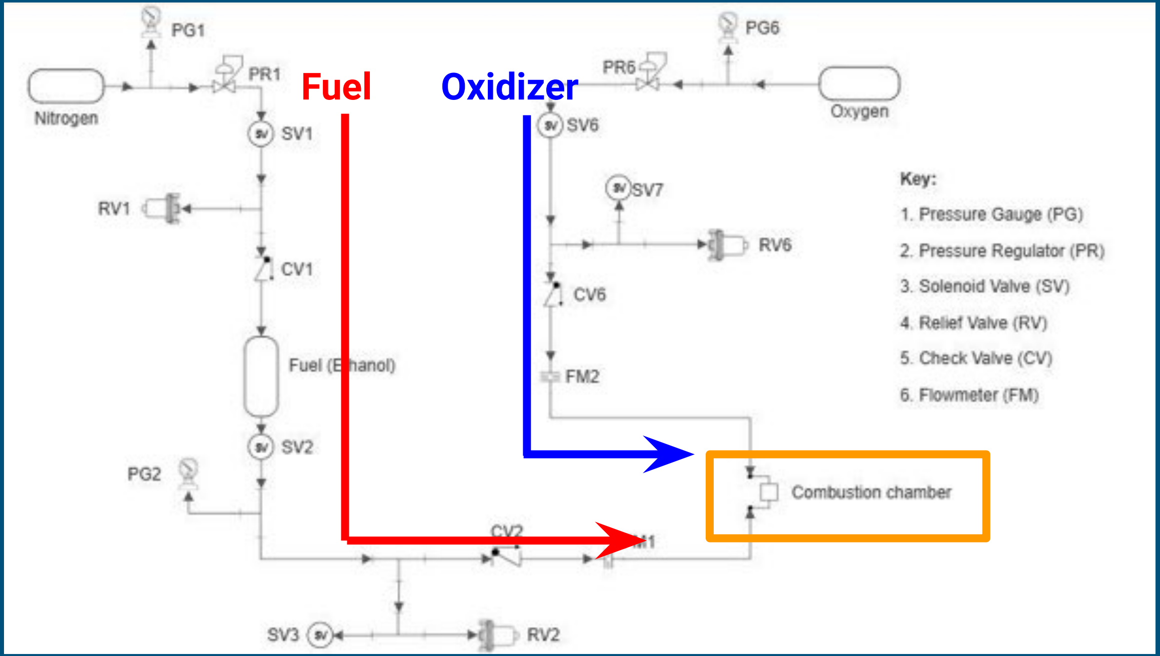


Output of the written code to be used during the tests (Microcontroller side)

The writing and subsequent testing of the code was successful with the output showing the following parameters of the test(Colour showing the line used to highlight the parameter of interest)

1. Blue: Indicates the solenoid valve being actuated.
2. Red: Flow-rate across the fuel line
3. Yellow: Flow-rate across the Nitrogen line
4. Green: Flow rate across the Oxygen line
5. Black: Pressure (Bars) across the Nitrogen and Oxygen lines
6. Purple: Pressure(Bars) of the rest of the sensors across the system

Piping and Instrumentation Diagram (P&ID)



P&ID for the test(To be updated)

Piping and Instrumentation Diagram designed with required parameters

Accumulators using beer keg

- **Modifications needed:**
    - Attach swagelok and AN fittings
    - Design a custom machine cap
- **Remaining task**:
    - Acquire fittings
    - Make the necessary modifications.

Purchased keg tank

Objective 2: Conduct a water test

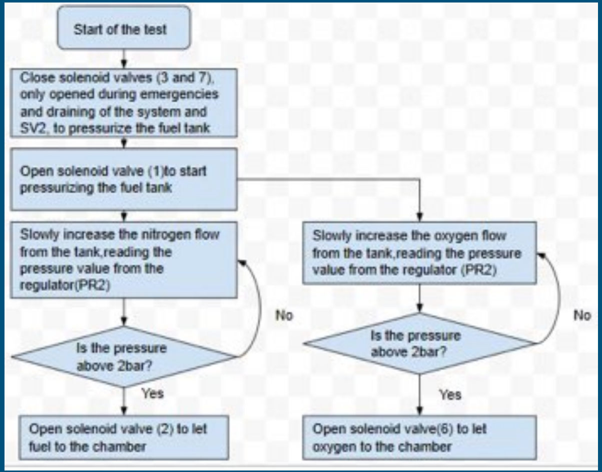
Sub-Objectives:

a. Research on methodology for conducting water test
b. Develop set-up for the water test
c. Formulate test procedure

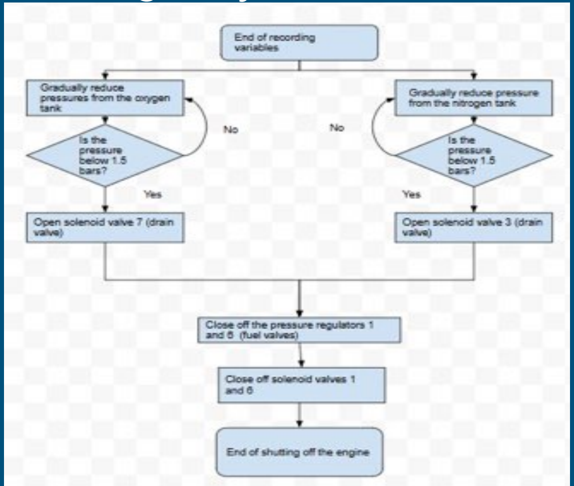
Procedure for water test (Open/Close sequence)

The formulated water test procedure included:

a. The procedure for opening the valves
b. A checklist for water test
c. Shut down procedure upon test completion/emergency



Flow chart for opening sequence



Flow chart for closing sequence

Challenges and Remaining Tasks

Challenges

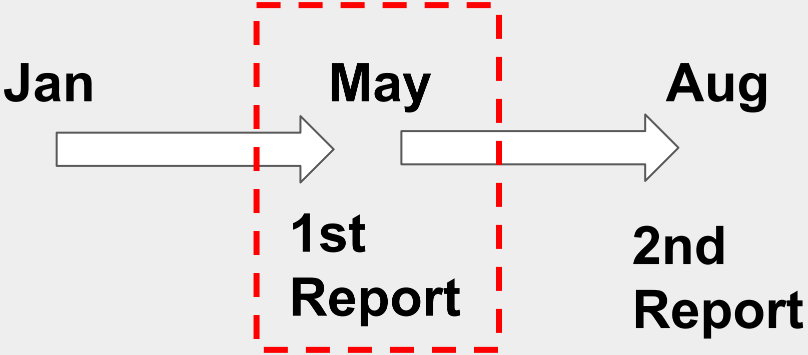
- Insufficient transportation funds made coordinating purchases difficult, causing delays
- Our staffing levels were inadequate
- Delays caused by imports

Remaining Tasks

- PCB fabrication
- Code testing
- Beer keg modification
- Functionality testing

What was learned?

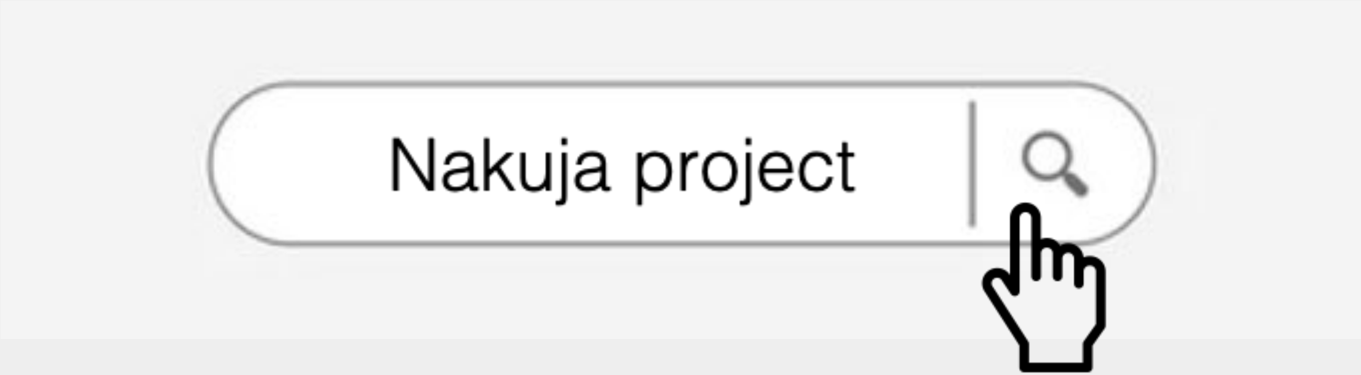
Way forward



2nd batch interns and final year students take over the role

Establish research group on Aerospace Engineering

Follow us



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