INTRODUCTION

N2 Development

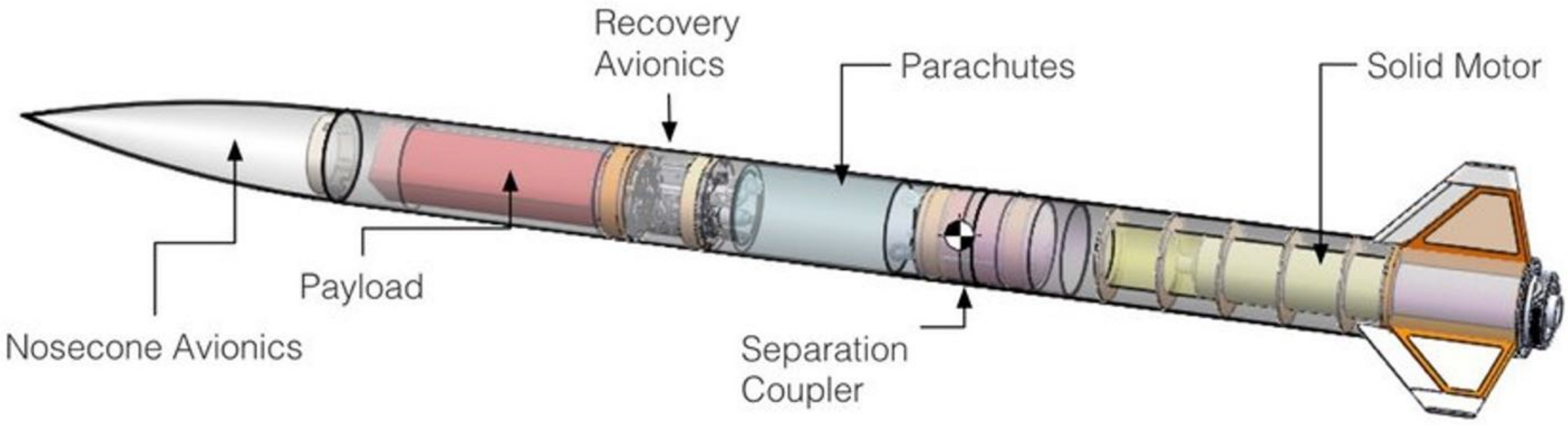
EVERYTHING IN A NUTSHELL

Experimental rocketry.

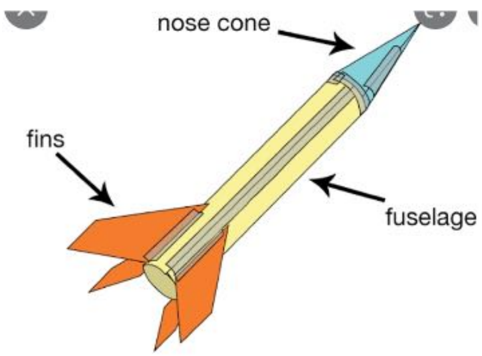
Why N2 rocket?

The teams involved.

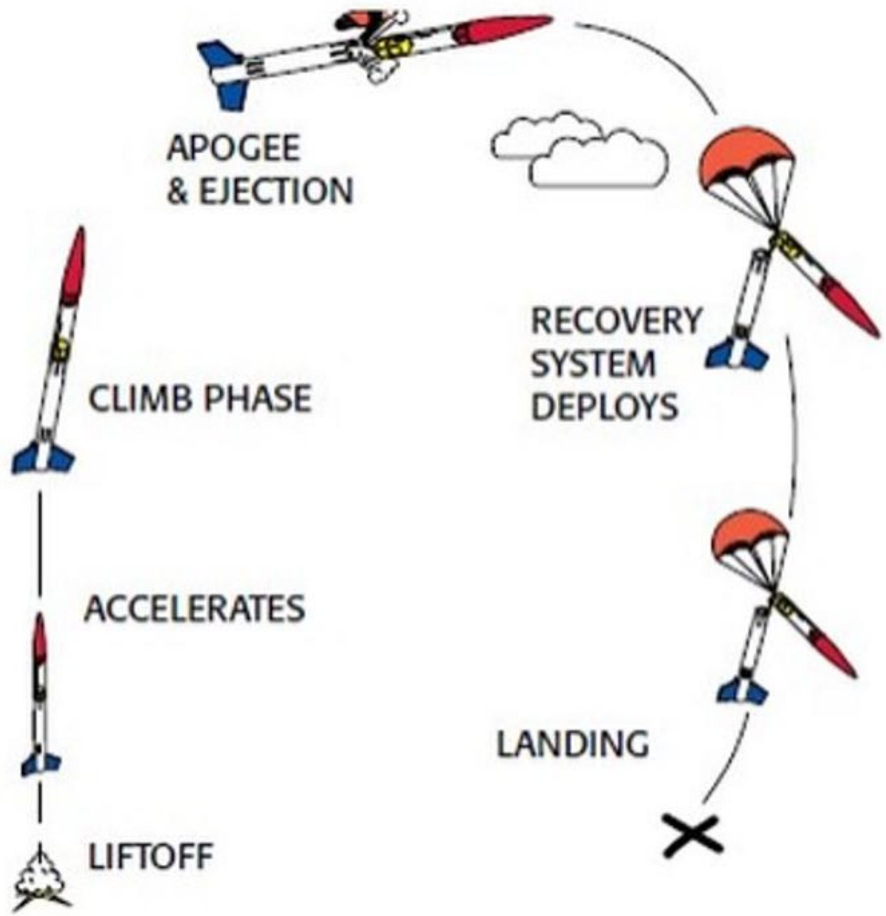
ROCKET COMPONENTS



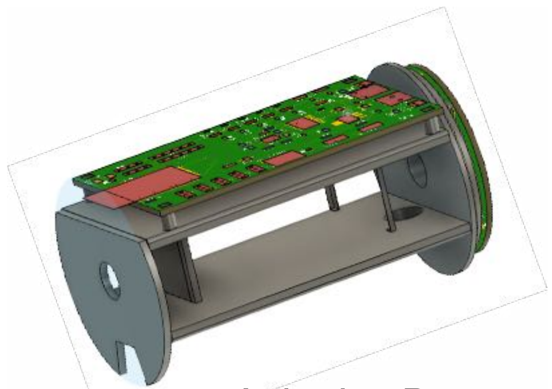
KEY TERMINOLOGIES



Fuselage



1. Ignition and Launch
2. Acceleration
3. Apogee detection
4. Parachute ejection
5. Descent & Recovery



Avionics Bay

Specification of N-2 rocket

Target apogee: 500m

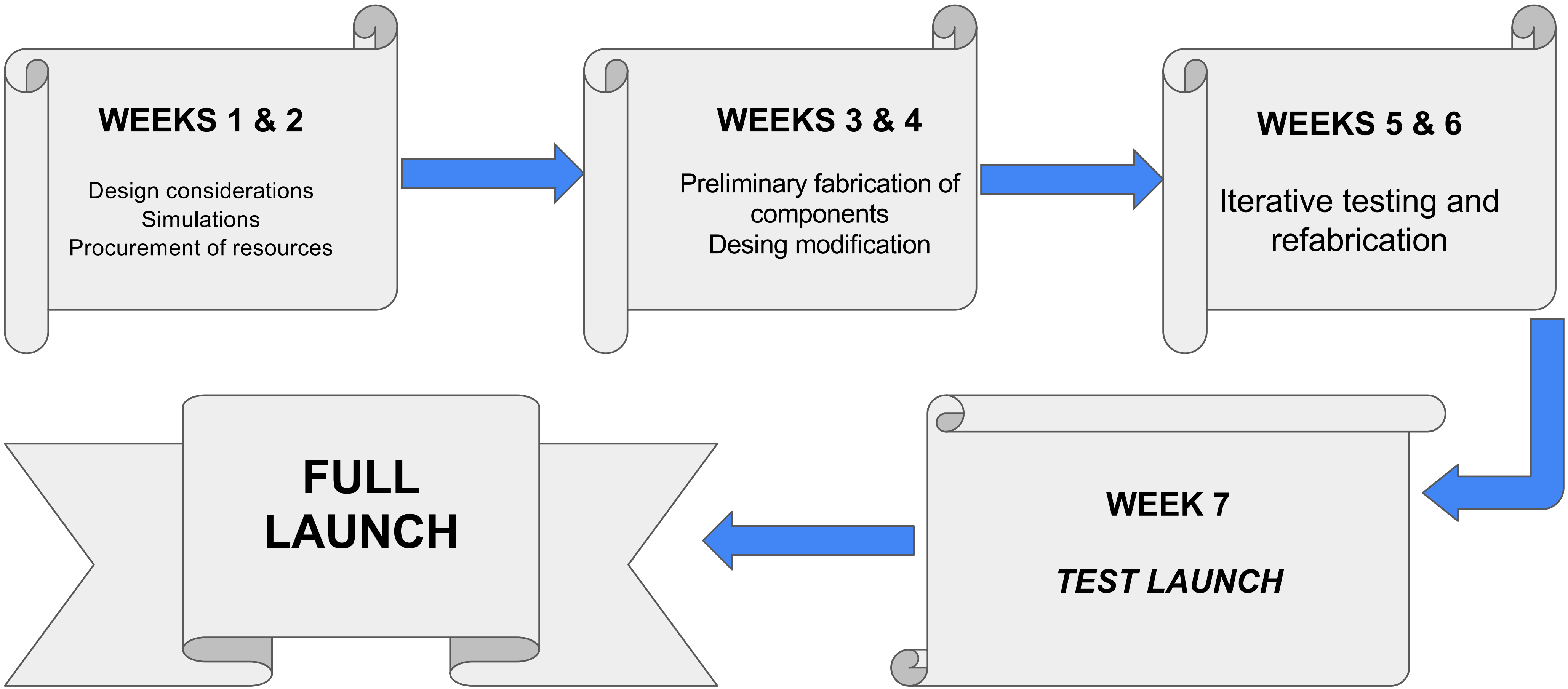
Roll control (Reaction wheel)

Data transmission to ground station (Real time)

Fibreglass airframe

I class KNSB Propellant

TIMELINES


WEEKS 1 & 2
Design considerations
Simulations
Procurement of resources
WEEKS 3 & 4
Preliminary fabrication of components
Desing modification
WEEKS 5 & 6
Iterative testing and refabrication
WEEK 7
TEST LAUNCH
FULL LAUNCH

TEST FLIGHT RESULTS

Apogee:- 280m

Data was successfully transmitted to the ground station during flight.

Recovery system failed

Data was not logged

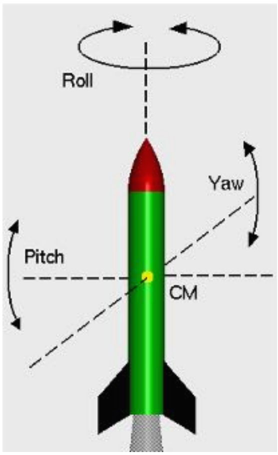
Remote ignition failed

THE TEAMS

AVIONICS

Avionics bay & Muchiri Ian Ng'ethe

FLIGHT CONTROL



AIRFRAME

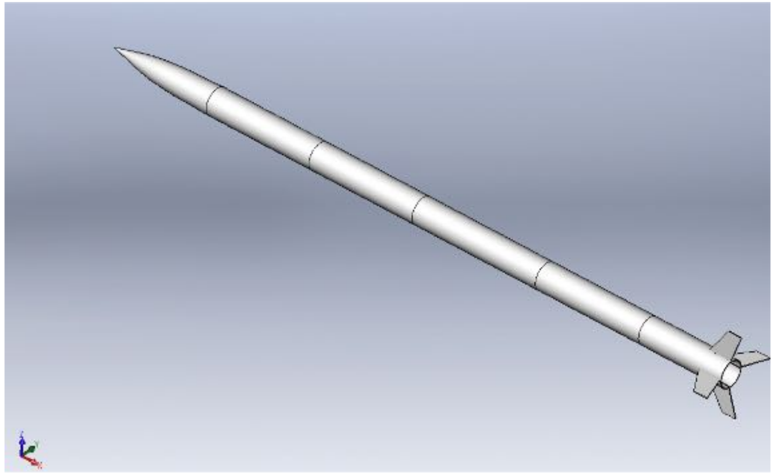
Mark Odhiambo with N2 Airframe

PROPULSION

Washington

Static test #8

AIRFRAME



N-2

GOALS & ACTIVITIES (AIRFRAME)

- **RESEARCH ON MATERIAL SELECTION, ANALYSIS/ PROPERTIES AND COST**
  - Material selected was fiberglass
- **DESIGN AND SIMULATION**
  - We also did design of the rocket parts and assembled the rocket on Autodesk Fusion 360 and simulated the rocket design on open rocket.
- **MAKE ROCKET AIRFRAME WITH FIBERGLASS MATERIAL**
- **MAKE A RECOVERY SYSTEM TO ACCOMMODATE A PAYLOAD OF APPROXIMATELY 3KG**
- **ROCKET SHOULD REACH AN APOGEE OF 500 Meters**


Open rocket design


Fibreglass material

FABRICATION AND ASSEMBLY (AIRFRAME)

- **We fabricated each of the following rocket airframe parts:**
  - Body-tube
  - Nose cone
  - Fins
  - **Accessories:**
    - Camera mount
    - Tee slot
- We did an assembly to have the final(complete) rocket airframe

MOLD AND BODY TUBE.

NOSE CONE

FABRICATION OF FIBREGLASS.

RECOVERY SYSTEM (AIRFRAME)

- **We made the recovery system**
- The purpose is to ensure that during the launching stage of the rocket, we are able to recover the rocket with its parts intact and to avoid it from crashing

We settled on parachute recovery

Material selected for parachute: **nylon fabric**

- Desirable characteristics:
    - Excellent wind resistance, the material is also lightweight, good elasticity, mildew resistance, comparatively cheaper

Parachute

ACHIEVEMENTS (AIRFRAME)

- **Design of the rocket parts and assembly of the rocket**
- Fabrication of the airframe with fiber glass material was progressively successful
- Recovery system was complete and tested
- The use of simulation for parameter optimization

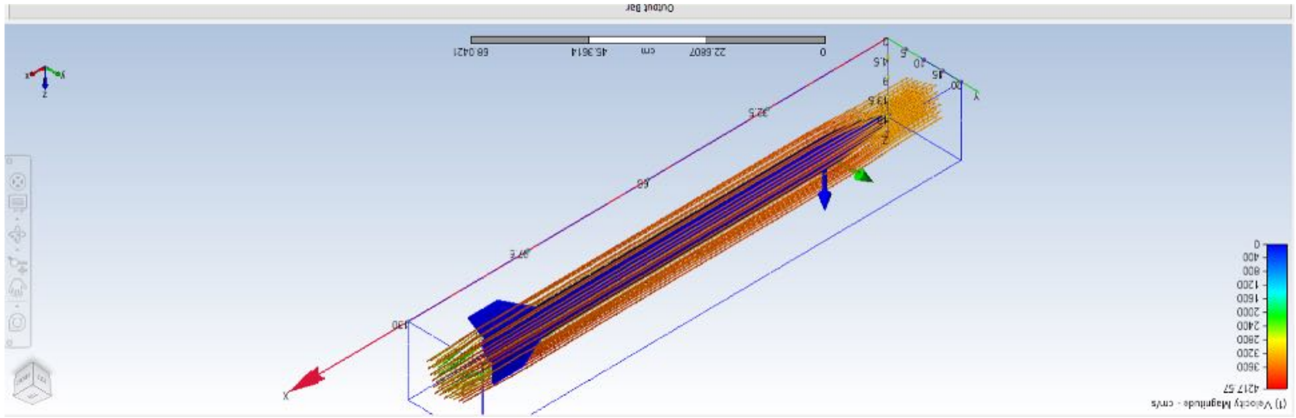
Rocket airframe fabrication with fiberglass

Nose cone design

Section of fabricated body tube and fins (conjoined)

WHAT WAS LEARNT (AIRFRAME)

- Use and handling of fiberglass material.
- CFD simulation
- Design and fabrication of the rocket airframe
- Use of various software: openrocket, ANSYS, SOLIDWORKS



Traces from CFD simulation

Complete Rocket Airframe

CHALLENGES (AIRFRAME)

- The parachute ejection system did not work as expected during launch.
- Post fabrication was difficult due to the brittle nature of fibreglass.

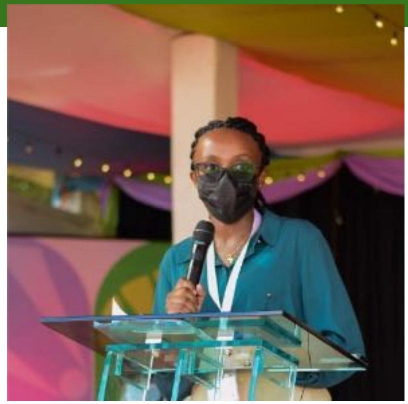
Post fabrication of fiberglass

Parachute failed to deploy during launch

AVIONICS

Edwin Mwiti
Bsc. ECE

Muchiri Ian Ngethe
Bsc. TIE

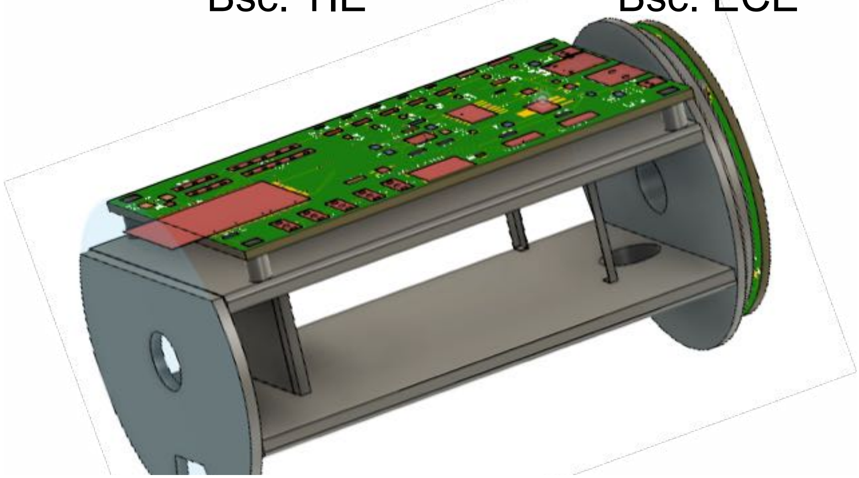


Junn Hope
Bsc. TIE

Caleb Mucheru
Bsc. ECE

George Bange
Bsc. TIE

Festus Muthama
Bsc. ECE

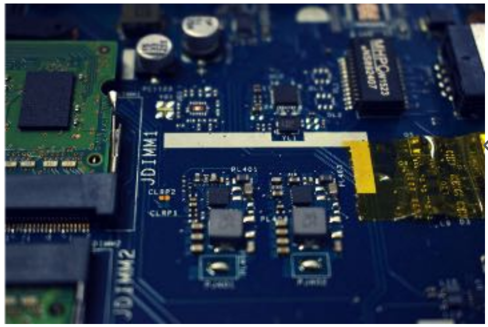


Avionics - Description

- Electronics used on aircrafts, artificial satellites and spacecraft
- Include systems such as:

  Communication, Navigation, Power Supply

- **Data is gold**



Ground station

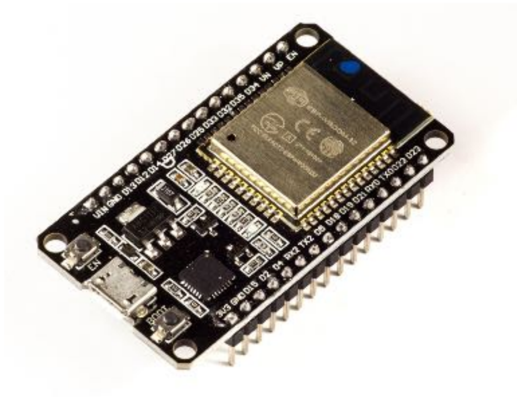
Ground antenna

Onboard avionics

Goals and activities

- Develop **PCB (Printed Circuit Board)** for the rocket flight computer

- Develop **Flight Software** to be used by this flight computer



Flight Software Development

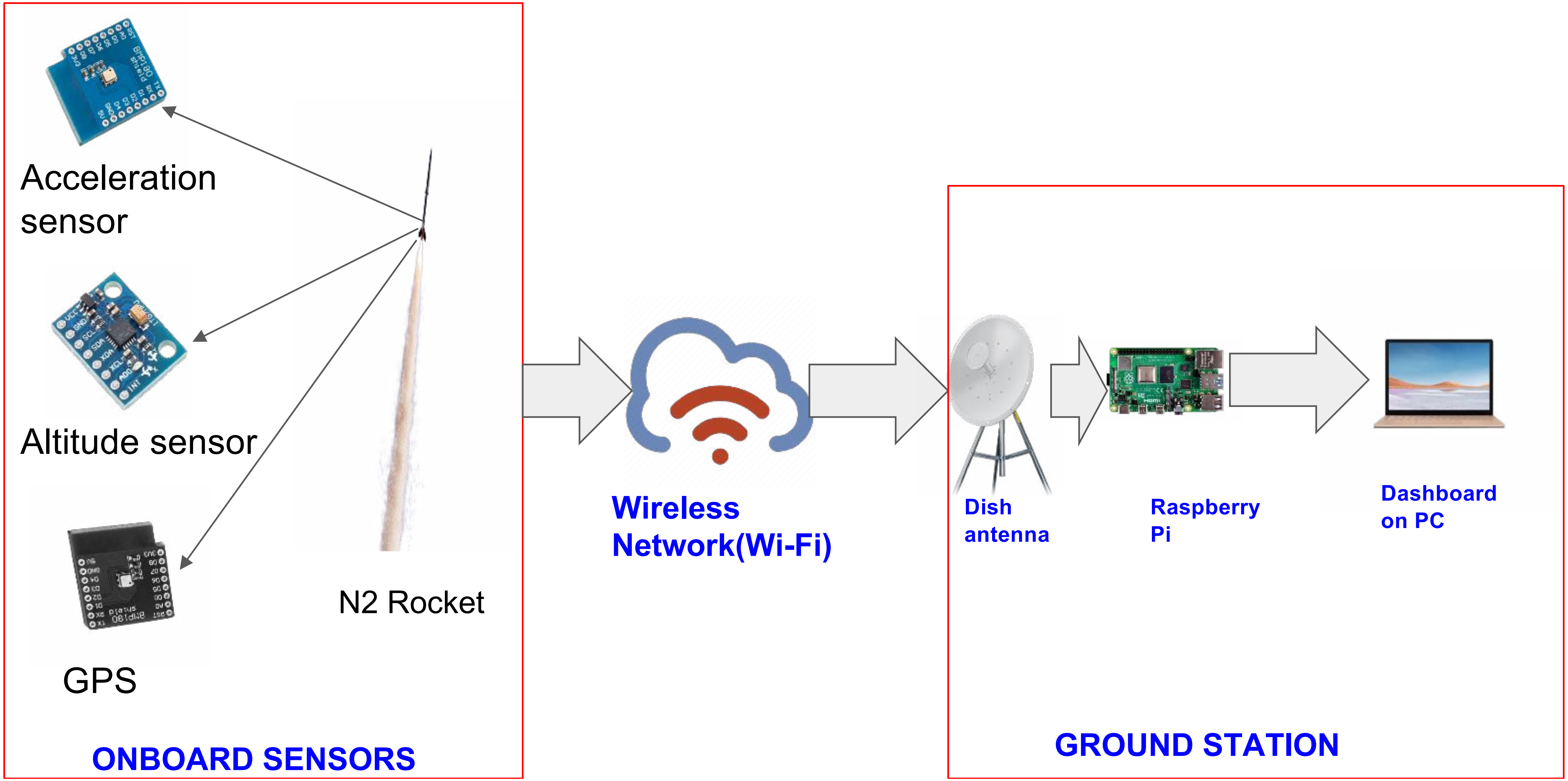
Purpose of Flight Software

- Responsible for processing data received by sensors
- Making critical flight decisions such as:
  - Logging data
  - State machine (Lift-off detection, Apogee detection
  - Parachute deployment)
  - **Telemetry data transmission-N2 introduced data transmission (major change)**
  - Payload camera

Languages used

- C++ language used for main code
- Python for dashboard and testing

Structure of telemetry system



Test using DRONE

-We carried out transmission Test using drone

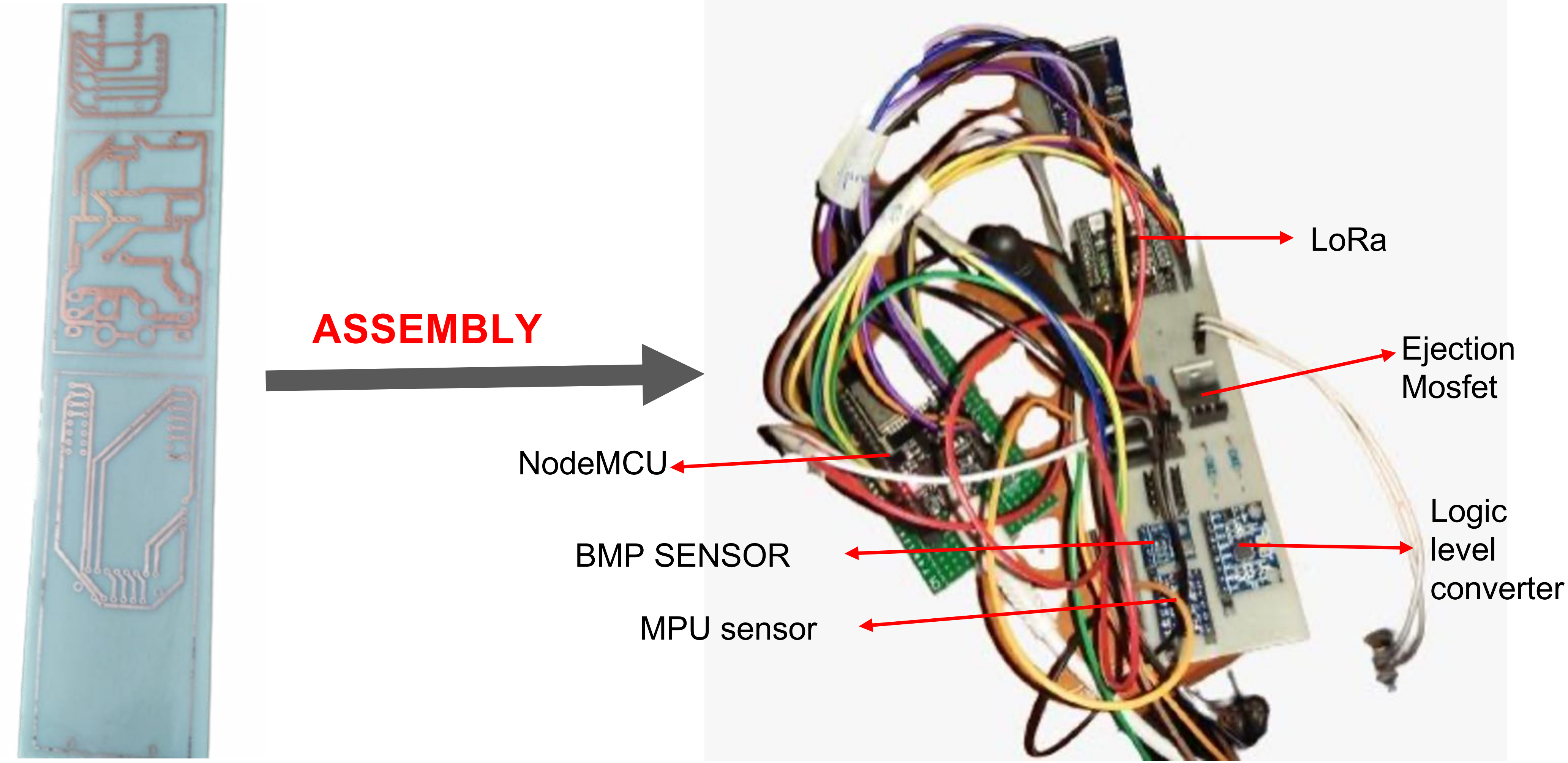
-Objective: Check whether we can transmit data from avionics to base station

-Flew to a height of **100m**

-FAILED: No data was received: **Interference** caused by the **drone's internal systems**

- Future testing using water rocket. Water rocket has no interference!

PCB design and fabrication



Antenna design

Ground station

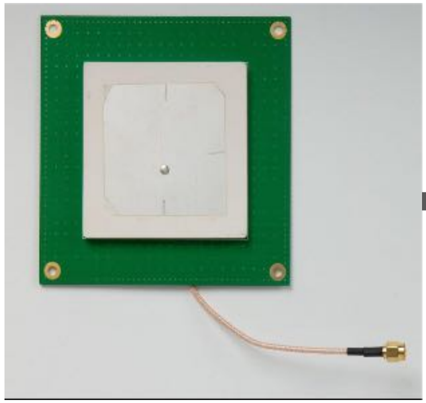
Gain: 16.74dBi

Upgrade

Gain: 18dBi

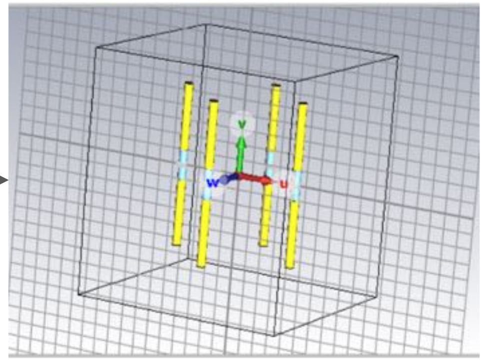
Onboard antenna

Gain: 6.8dBi

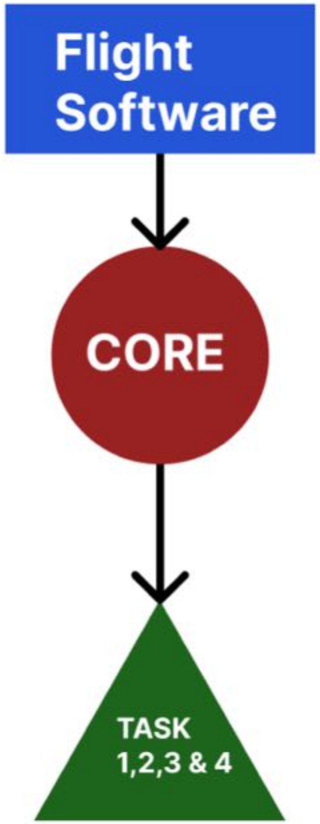


Design change

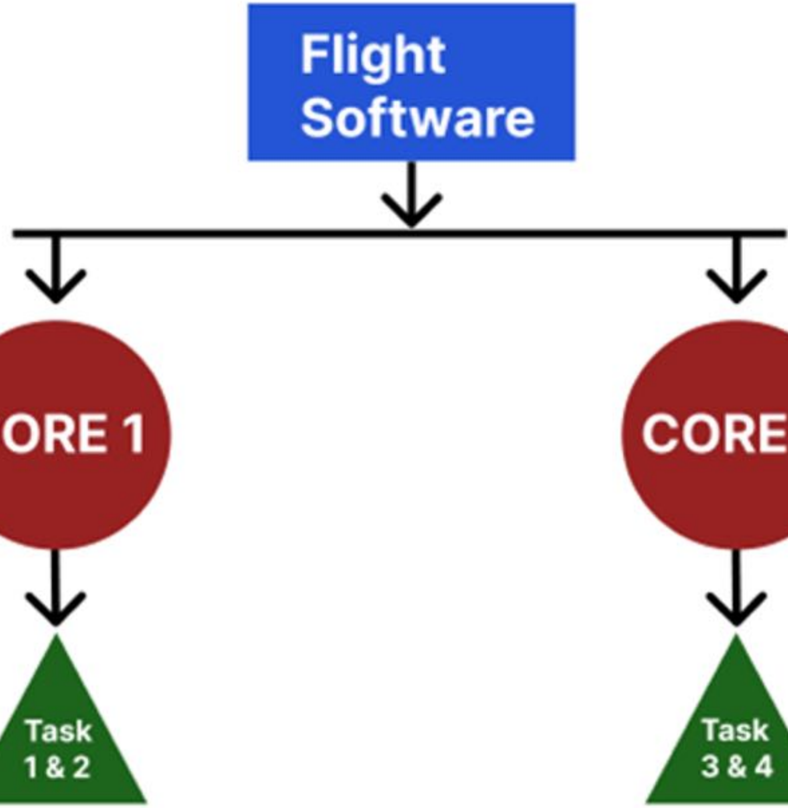
Gain: 5.23dBi



Real Time Operating System (RTOS)



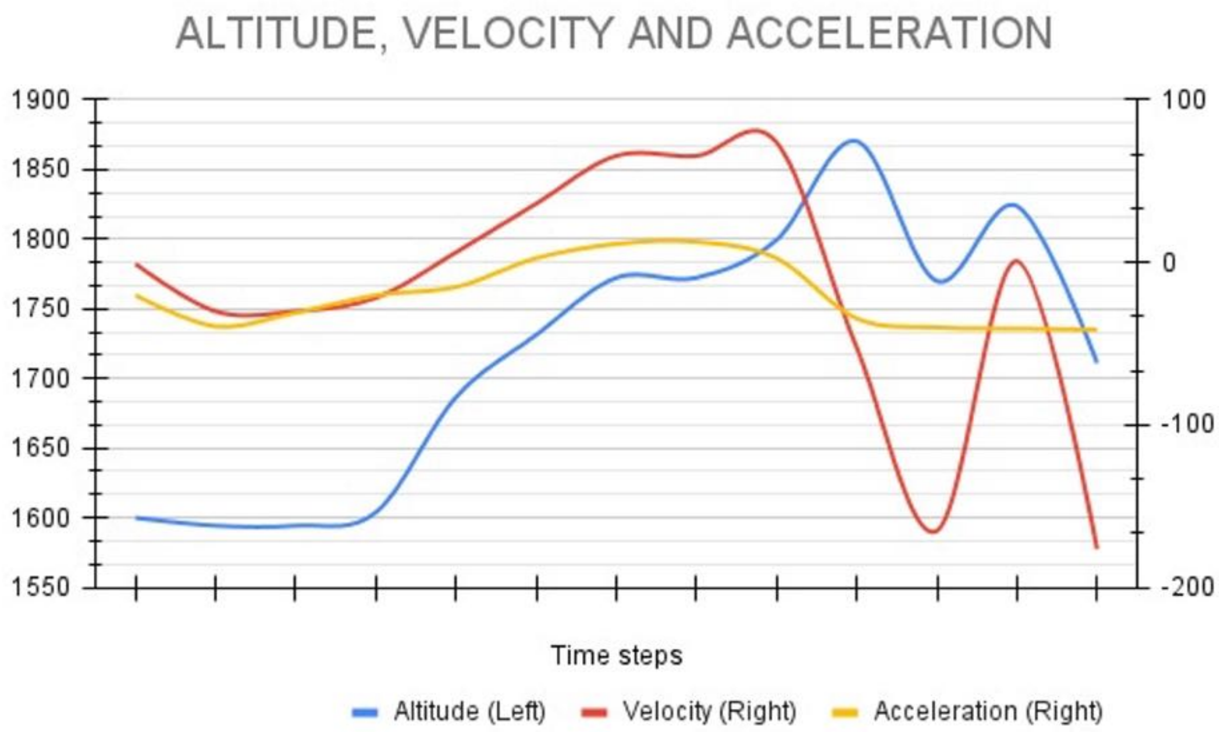
Single core processing



Multi core processing

Successful telemetry communication

We were able to **successfully** transmit data over **LoRa** during the **test flight** that was carried out.

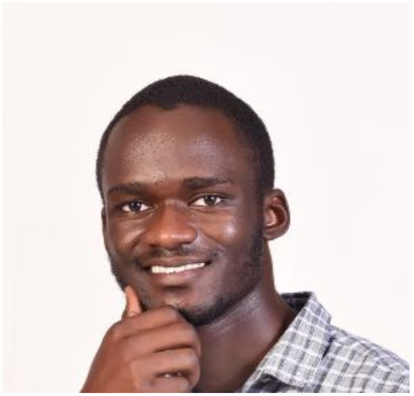


PROPULSION

The propulsion team is made up of 5 members.

Their photos and individual courses are as below.

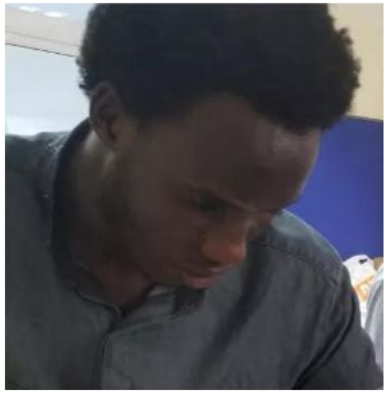
Valerian Nyerere
BSc. TIE



Washington
BSc. Mechatronics

Gichia Maureen
Bsc. Mechatronics

Bryan Nyatwanga
Bsc. ECE



Kennedy
Bsc. Aerospace E.

OBJECTIVES OF THE PROPULSION TEAM

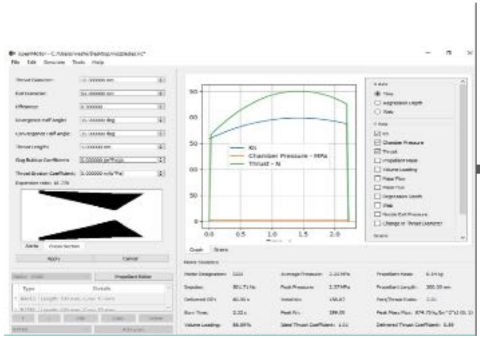
- Development of the **solid rocket propellant**.
- Making the **igniters** and **ejection charge.**
- Design of the **Test-stand**
- Design and fabrication of the **nozzle**, **casing** and **launch pad**.

DEVELOPMENT OF THE SOLID PROPELLANT

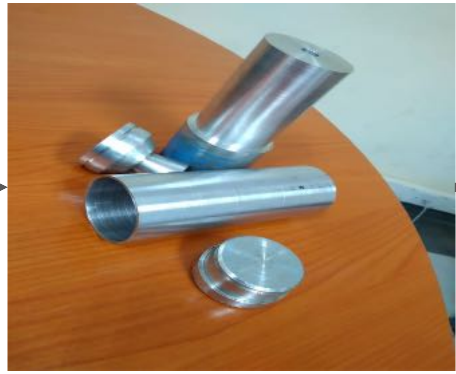
- A propellant is any gas, liquid or solid, the expansion of which can be used to impart motion.
- For the N-2 rocket, we used **Potassium Nitrate(**Oxidizer), **Sorbitol** (fuel)mixture(KNSB) and 1% of **Iron Oxide** which acts as a catalyst to the reaction. A ratio of **67:33** ,oxidizer to fuel was used.

Cured propellant ready for ignition

DEVELOPMENT OF THE SOLID PROPELLANT PROCESS



OpenMotor Simulation



Fabricated nozzle, bulkhead,casing

Curing of casted fuel

Preparation of static firing test

Static firing test

Post-analysis of test

IGNITERS AND EJECTION CHARGE

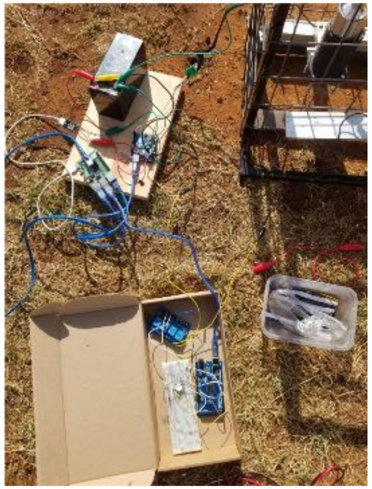
- The **igniters** are responsible for the combustion of the fuel. We made them using **Potassium Nitrate** and **Charcoal** in the ratio 80:20 respectively.
- The **ejection charge** is responsible for parachute ejection after 500m apogee has been achieved. A mixture of **Potassium Nitrate** (6.2g), **Ascorbic Acid** (4.5g), **Iron Oxide** (0.5g) and **hot water** (30ml) was used.

Ignition powder

Prepared ejection charge left to dry

REMOTE IGNITION

- We used remote ignition for safety purposes. Nichrome wire was passed through the igniter, current would flow through it then ignite the powder.
- In the static firing tests, a switch which had a set (10 seconds) delay was used. In the test-launch, we used a relay for ignition which had a set (60 seconds) delay.



The setup for the remote ignition during static tests.

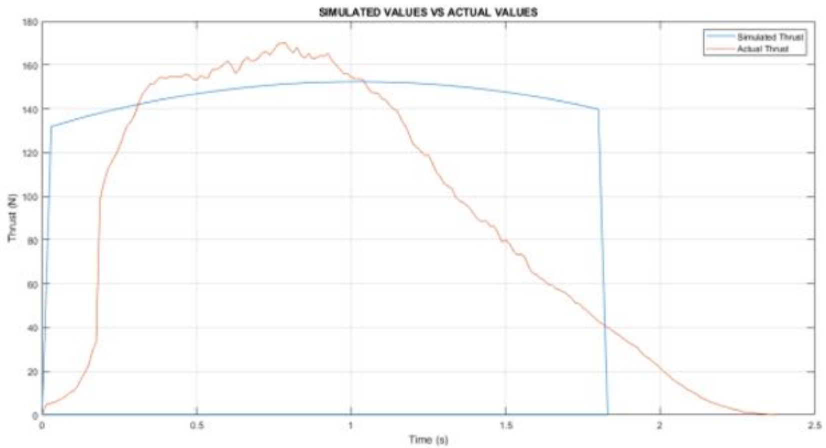
Use of a relay in the test-launch

Use of PCB Failed

STATIC FIRING TESTS

- We carried out **8** static firing tests to complete the KNSB rocket motor before the launch test.

<u>SIMULATED VALUES VS ACTUAL VALUES</u>



Graphical analysis of the 8th static firing test

Value	SIMULATED	ACTUAL
Motor Class	H	H
Total Impulse (Ns)	263.74	214
Specific Impulse (s)	879.15	714.3
Average thrust(N)	141.8	80.87
Peak Thrust (N)	152.2	170
Burn Time (s)	1.83	2.375

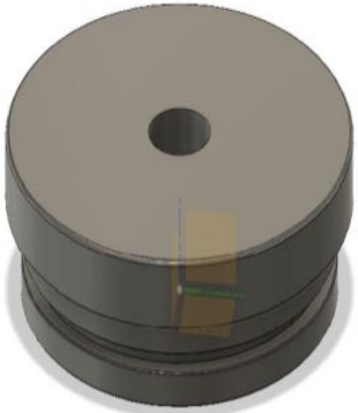
STATIC FIRING TEST

1st attempt

8th attempt

Design and fabrication of solid rocket motor

Bulkhead



Nozzle

Casing

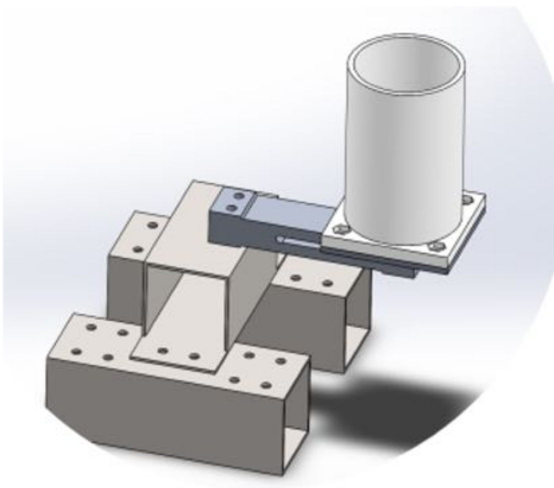
O-rings - used as pressure seals

Snap rings - serve as retainers instead of using bolts

Bulkhead secured within the casing using a snap ring.

DESIGN OF THE TEST STAND

- The N-1 test-stand was revamped to be used in N-2.
- For N-2, one 50kg loadcell was used. Improvement of load cell!!



Test stand design

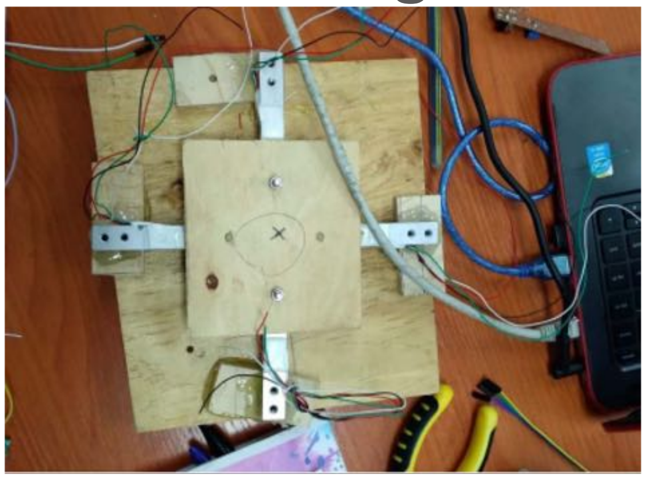
Electronics bay.

Caging as a safety measure

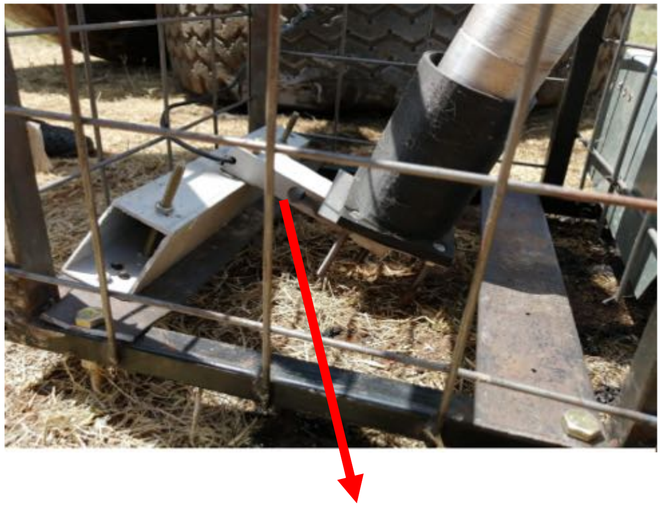
THRUST MEASUREMENT

In N-1, bathroom scales, set-up in a wheatstone bridge design, were used to measure the thrust.

For N-2, **350kg load cells** were incorporated.



Four 5kg loadcells design



50-kg Load cell.

350-kg load cell that replaced the 50-kg load cell.

LAUNCH PAD.

Launchpad designed with an adjustable launch angle of 0-45 degrees.

Launchpad mounted with the rocket ready for N-2 test launch.

CONCLUSION

- Subtractive manufacturing was employed in fabricating the casing.
-We are still looking into new ways of fabricating the casing.

-Ongoing modification of KNSB to KNPSB

Nozzle..Design for pressure.

Material used:Aluminium

Nozzle Failure

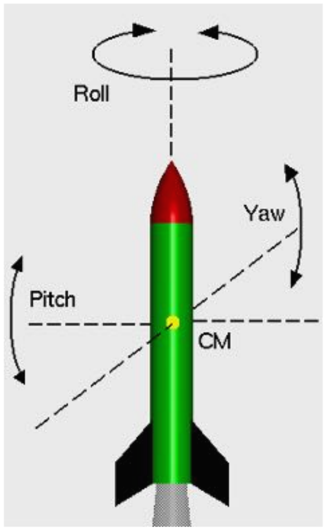
Current design
using Steel.

N2 FLIGHT CONTROL

GOALS:

Motion control of the rocket on:

- Suppress roll axis movement using **reaction wheel**



REACTION WHEEL COMPONENTS

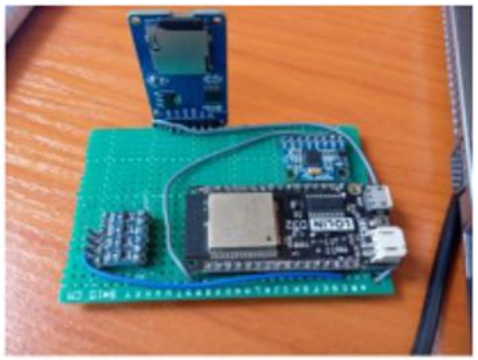
1000KV BLDC motor

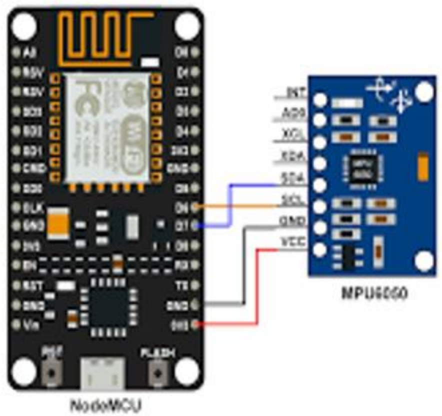
30A Electronic Speed Controller

NodeMCU microcontroller

MPU6050 accelerometer+gyroscope

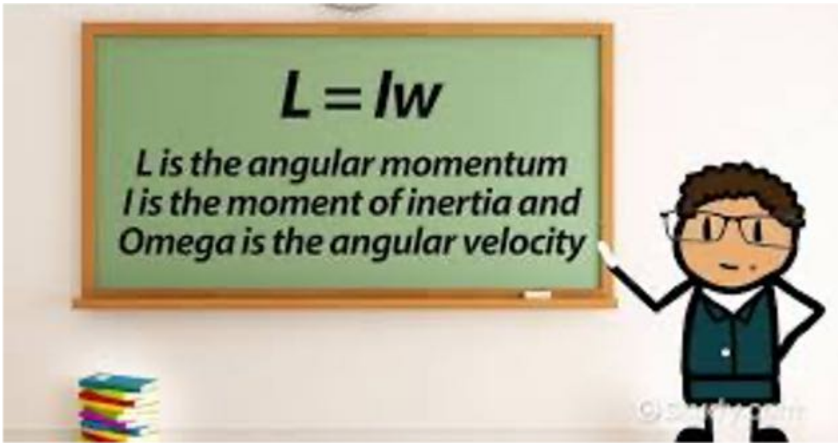
EN8 mild steel wheel





How reaction wheel works

- The reaction wheel works under the principle of conservation of **angular momentum.**



- The law of conservation of angular momentum states that **when no external torque acts on an object, no change of angular momentum will occur**.

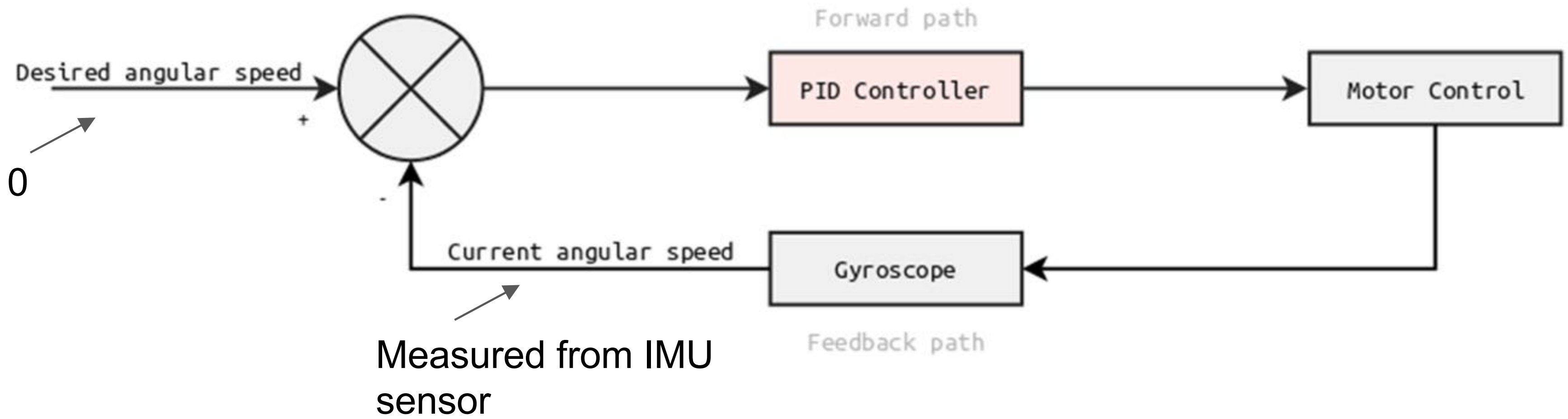
How reaction wheel works

REACTION WHEEL CONTROL MECHANISM

•Based on conservation of angular momentum, reaction wheel rotation causes rocket body to counter-rotate proportionately.

$$I_{flywheel} \cdot \omega_{flywheel} + I_{sat} \cdot \omega_{sat} = k \ (\text{constant})$$

PD control (mathematical error correction):



Developed Reaction Wheel

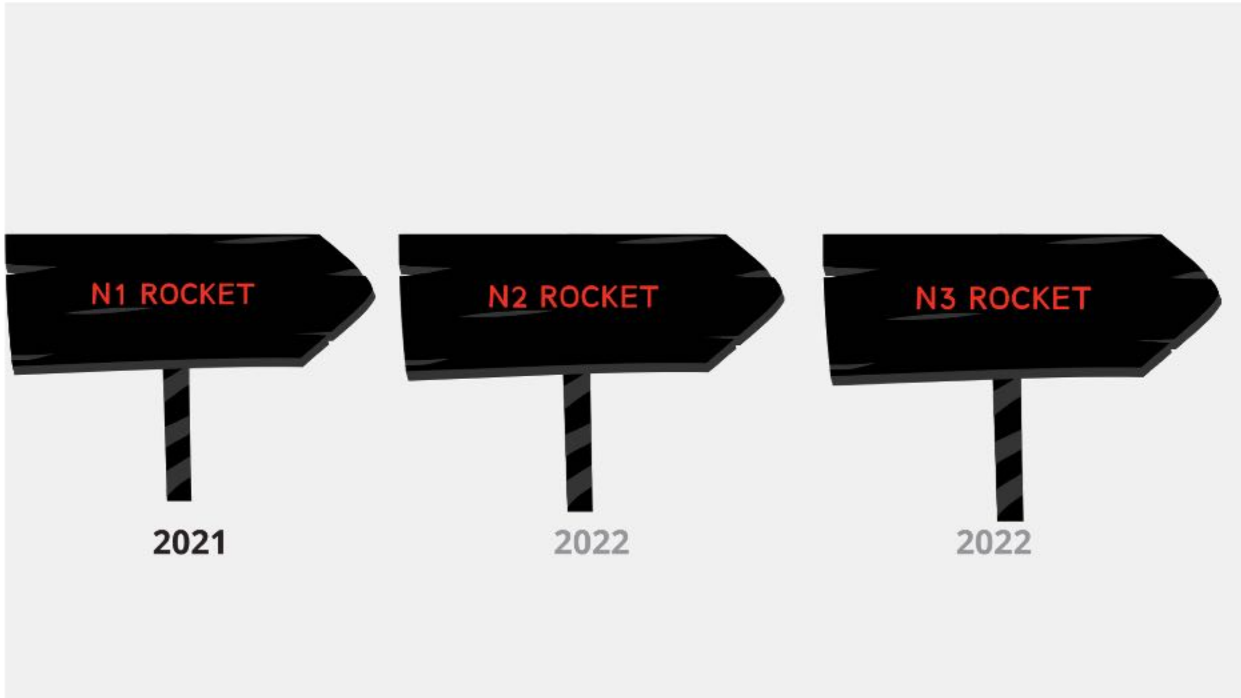
CHALLENGES

- Wheel rotation overshoots and undershoots

  To curb this PD tuning is to be adjusted for the best float Proportional and Derivative values

- Unavailability/limited information on reaction wheel during research.

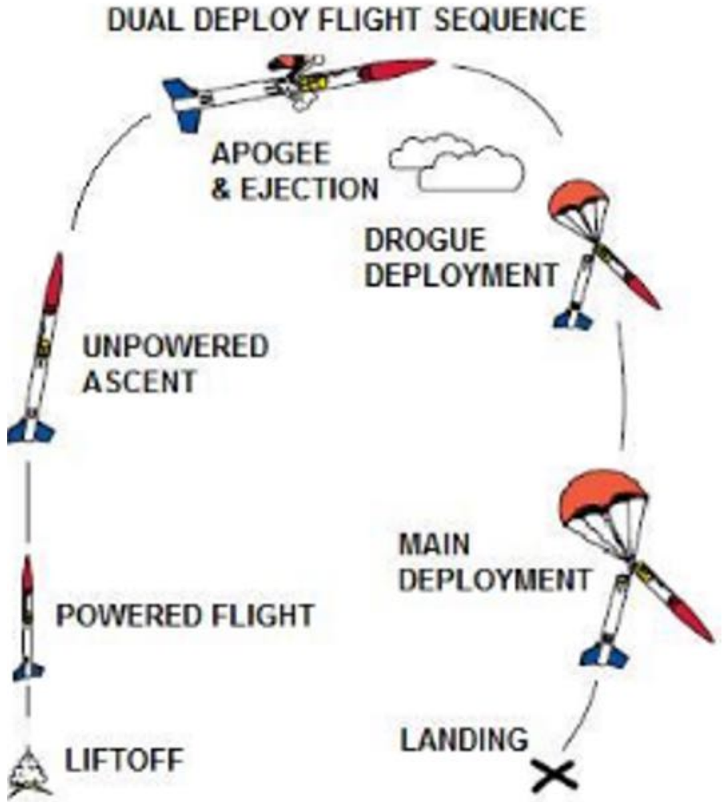
WAY FORWARD?



Airframe

Dual Parachute Deployment

- First Parachute (Drogue chute)
- Second Parachute(main chute) gets deployed midway down



Propulsion

Static firing test 150mm APCP grain

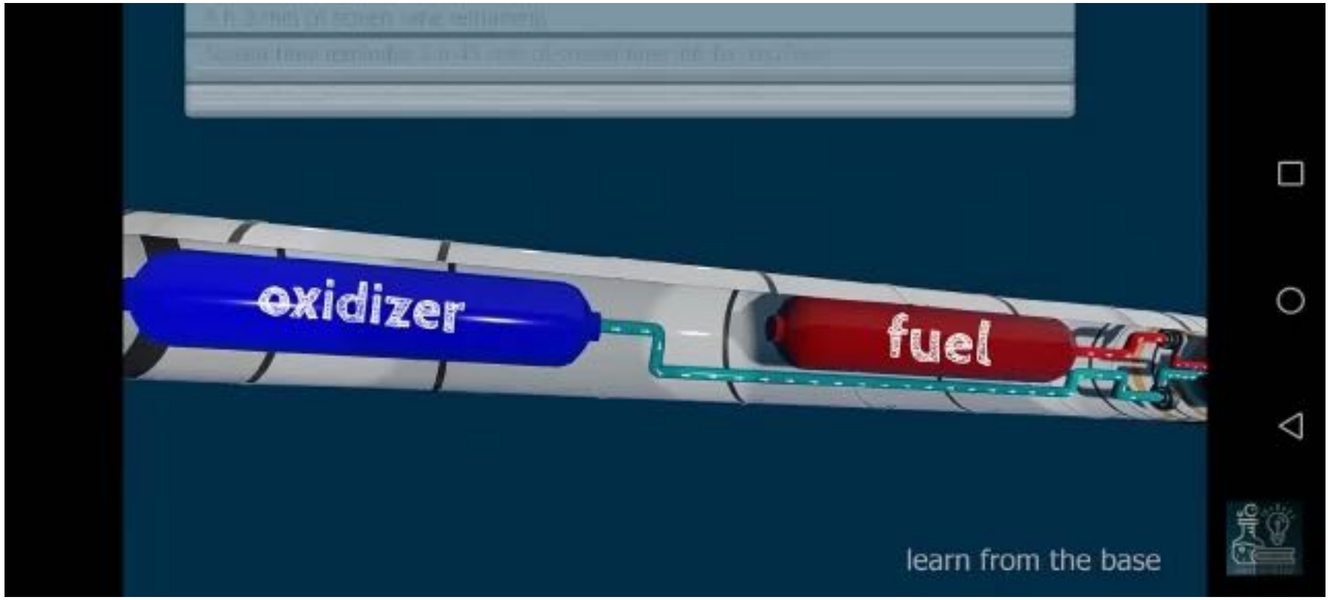
Solid Propellant

APCP Solid propellant with better thrust and larger impulse

Propulsion

Liquid Propellant

Development of liquid propellant test stand is still in conceptual stage



Liquid Propellant Working Principle

Telemetry

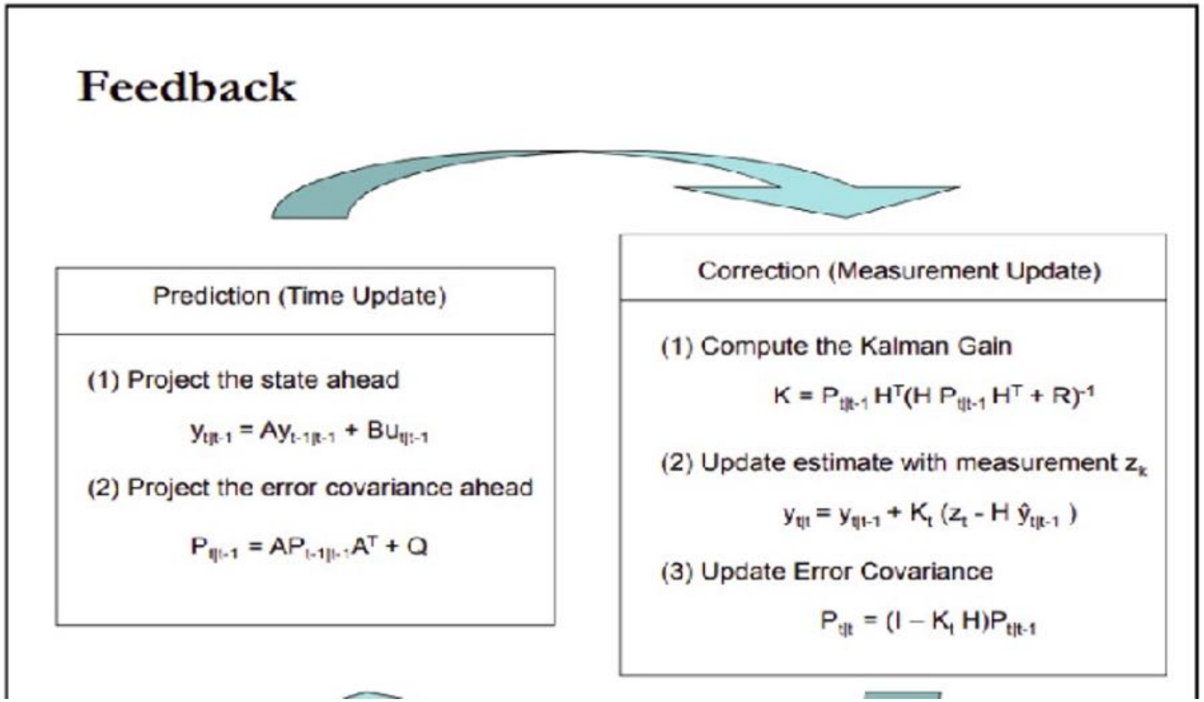
- Live video transmission during flight
- Telemetry data visualization software

Space X Telemetry and video feed Sentinel-6

Avionics

Extended Kalman Filter

Better noise filtering systems, better sensor readings, better software decisions



Extended Kalman Filter

Avionics

Remote Mission Control

Ground station system overrides

- Parachute ejection
- Self-Destruct
- Remote Ignition

Flight Control

Thrust Vector Control

- TVC gimbal to replace the reaction wheel system to control stability and orientation
- Eliminates the need for fins

Thrust Vector Control in Action

NAKUJA Team

Team consists JKUAT and PAUSTI students and lecturers

Interns have completed attachment, some will continue with N-3 Rocket

Expecting new interns every year

Nakuja and Nano-Sat teams at Broglio Space Centre, 2022

Appreciation

- **JICA** for supporting the project
- **KSA** and **ASI** for their involvement - Visit to Broglio Space Centre
- Supervisors from **JKUAT** and **PAUSTI**
- JKUAT - **iPIC** facility
- Team leaders
- Student **Interns** from JKUAT and KSA