Helion Dynamics: Project Lumina

Eric Chen, Felix Chen, Abigail Wang, Laura Wang, Emerson Yu

25 April 2025

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1. Introduction

1.1 Team Organisation and Roles

Mr. Larkin is a humanities and social studies teacher at our school, and is representing Fraser Heights Secondary. Our team consists of 5 members: Eric Chen, Emerson Yu, Laura Wang, Abigail Wang, and Felix Chen.

Eric Chen (Grade 11):
Background - Fair knowledge of programming, CAD, drafting, physics, and electronics. Executive of the Mechatronics Club at school.
Roles -

- Project Management
    - Orders parts needed for CanSat design
    - Ensures project components meet deadlines
    - Delegates tasks and areas of the project to members
- Mechanical Engineer & Designer
    - 3D drafting of prototypes
    - Wires and constructs internal electrical components
    - Builds CanSat shell and internal structure
- Finance Executives
    - Manage funds

Expected Workload - Heavy
Hours dedicated at school - 4 hrs/week
Hours dedicated outside of school - 8 hrs/week

Emerson Yu (Grade 11):
Background - Fair knowledge of programming, drafting, physics, and electronics. Executive of Mechatronics Club at school.
Role -

- Project Management
    - Order the parts and materials needed for the CanSat design
    - Ensures project components meet deadlines
    - Delegates tasks and areas of the project to members
- Software Engineer & Designer
    - Plans and designs software
    - Designs and develops software displaying a user interface and processed data
    - Program the ground station
- Finance Executive

    - Manages funds

Expected Workload - Heavy
Hours dedicated at school - 4 hrs/week
Hours dedicated outside of school - 8 hrs/week

Laura Wang (Grade 11):
Background - Fair knowledge of physics, project management, biology, and environmental sciences. Experience in leadership programs in school, business case competitions, and marketing.
Role -

- Project Management
    - Manages tasks, issues, and timeline of the project
    - Delegates tasks and areas of the project to the members
    - Oversees outreach programs
- Social Media & Outreach
    - Manage the Instagram account
    - Manage outreach programs

Expected Workload - moderate to heavy
Hours dedicated at school - 3 hrs/week
Hours dedicated outside of school - 8 hrs/week

Abigail Wang (Grade 11):
Background - Fair knowledge of physics, biology, project management, and environmental sciences. Experience in leading school clubs, marketing, and Model United Nations conferences.
Roles -

- Social Media
    - Manage the Instagram account
- Project Designer & Planner
    - Grows algae for our secondary mission
- Outreach
    - Elementary presentation planner and designer
    - Junior High School class presentation planner and designer
    - General audience presentation planner and designer

Expected Workload - moderate to heavy
Hours dedicated at school - 2 hrs/week
Hours dedicated outside of school - 8 hrs/week

Felix Chen (Grade 10):
Background - Fair knowledge of biology, environmental sciences, project management, aviation, and electronics. Experience in leadership-based extracurriculars and Model United Nations.
Roles -

- Social media
  - Manage the Instagram account
- Outreach
  - Elementary presentation planner & designer
  - Junior High School class presentation planner and designer
  - General audience presentation planner and designer
  - Outreach activity planner and designer
- PDR Manager:
  - Delegates PDR completion tasks

Expected Workload - moderate to heavy
Hours dedicated at school - 3 hrs/week
Hours dedicated outside of school - 8 hrs/week

1.2 Mission Objectives

Mission Objectives

The objective of Lumina is to test the stresses on microalgae during rocket launch and descent. As the human race aims to move onto different planets, we must bring our plants and animals with us, as the other planets are rather lifeless. A rocket launch presents a unique challenge for plants, and we must understand the effects of such stresses on the plants we are bringing millions of kilometres away. If we send some plants to another planet and they are all dead on arrival, that would be a calamity.

The goal of this CanSat mission is to see how algae handle a rocket launch and descent for future reference in other space launches.

In order to determine the algae's survivability against the stress of rocket launch and descent, which Lumina will undergo, we have decided to collect data on fluorescence levels.

This mission would be successful if Lumina transmits all data in real time to the ground station, properly processes the data, and displays the results. Additionally, this mission would be deemed successful if we yield significant results. As the mission will be conducted upon Earth's surface, the expectations are the following values:

Secondary Mission Specifications:

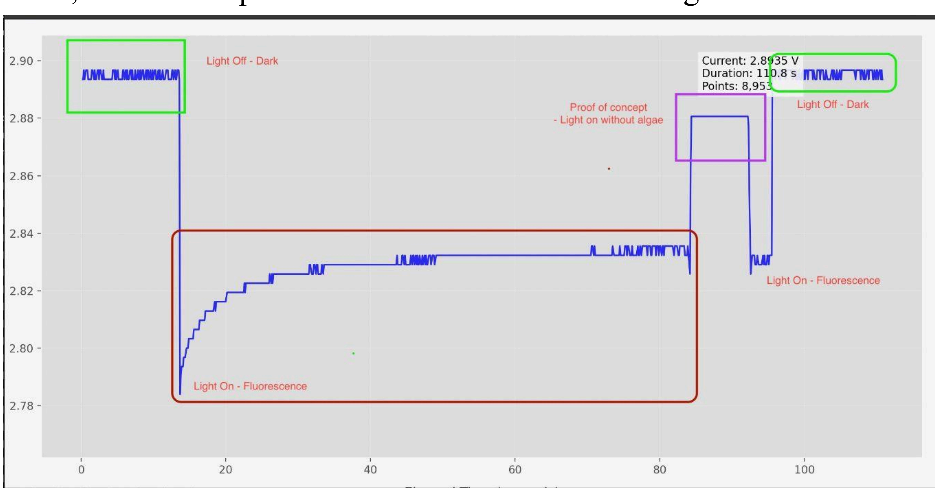
The chlorophyll viability will be tested with an onboard fluorometer.

During photosynthesis, chlorophyll absorbs light energy, primarily in red and blue wavelengths of light. These photons excite chlorophyll molecules in algae, causing electrons to jump to a higher energy state. Typically, this energy is sent through to the electron transport chain to produce ATP and NADPH. However, when the energy is used inefficiently, the excited electron releases energy as light energy, releasing as fluorescence, typically in wavelengths of ~695 nm, or red light. Light energy will be provided by a blue light inside our CanSat.

Light must be given to the sample of algae for it to excite the electrons and re-emit light. This means that a simple photodiode would not be sufficient to measure the re-emitted light from the chlorophyll sample. Chlorophyll A and Chlorophyll B have different fluorescent wavelengths.

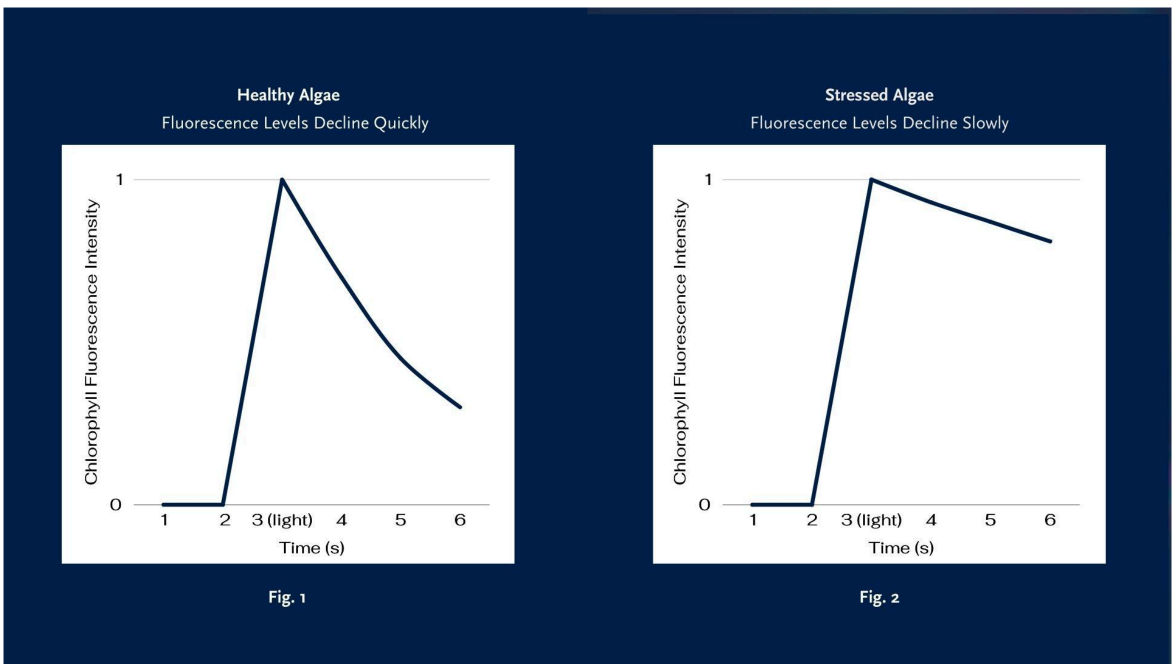
In short, fluorescence levels rise as the algae's ability to photosynthesize and use energy efficiently is decreased. To compare fluorescence levels, we will be testing fluorescence levels on the ground and while the CanSat is in the air. By comparing fluorescence levels, we can observe the impact of stress while the CanSat is moving in the air. If the algae are impacted by stress, we expect to see a large amount of fluorescence energy compared to the fluorescence levels observed during normal conditions (no stress) released when algae are exposed to light. This means the algae can no longer photosynthesize efficiently.

Our first method of collecting data will be to turn the blue light on for 30 seconds, then off for 10 seconds. In this time, we expect to see a curve similar to the one below. Using this curve, we can compare the fluorescence levels of the ground state to the CanSat.



There is also an additional method to observe algae's health after it has endured stress. By Kautsky's effect, there is an initial sharp rise in fluorescence when plants are exposed to light. In a healthy plant, the system takes over quickly, and fluorescence levels drop as energy is used to photosynthesize instead of being released. However, in a stressed plant, the system struggles to photosynthesize and fluorescence levels stay high or decline at a slower rate. We plan to test this effect by closing the light inside our CanSat when it is 180 meters above the ground. Then, when it reaches 5 meters above the ground, we plan to turn the light back on to observe how the plant utilizes the light energy it has just been exposed to.

Below are graphs of the relative fluorescence levels we expect to see in a healthy vs stressed organism based on the Kautsky effect.



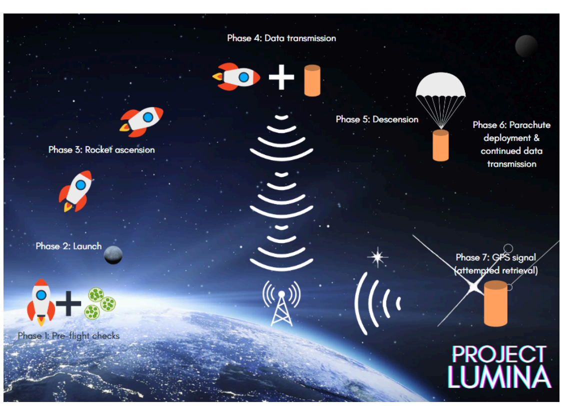
To measure fluorescence levels, we will be using a fluorometer. A fluorometer is a custom module made to collect chlorophyll fluorescence levels. It reads voltage using a photodiode module, whose values are inverse to fluorescence levels.

2. Mission Overview
2.1 Mission Introduction

After heavy consideration, our team has come up with the name Project Lumina. We've decided on Project Lumina for several reasons: symbolism, ties to space exploration, and alignment with our mission's purpose. "Lumina" is the Latin word for light or illumination. The symbolism connects to 2 key ideas: light, which is essential for growth, and illumination, which represents knowledge and discovery, shedding light on algae's response to spaceflight conditions. Project Lumina also ties back to outer space exploration as light is a fundamental element of space, the Sun's energy, which is essential to sustain life. Additionally, just as light enables life, our CanSat project seeks to enable life in space by understanding how algae endure launch stresses. We hope our project inspires and suggests hope and sustainability for long-term space exploration.

The Project Lumina will be conducted with the following procedure:

1. Load cuvette with concentrated microalgae suspended in medium.
2. Place the cuvette in secondary mission containment, and secure the primary and secondary mission layers.
3. Inspect all wiring, sensor mounts, and connections to ensure they are secure.
4. Turn Lumina on.
5. The blue light inside our can will turn on for 30 seconds, then turn off for 30 seconds.
6. Establish a radio connection with the ground station and Lumina.
7. Begin data recording.
8. Monitor telemetry from the onboard fluorometer and primary mission sensors; the onboard fluorometer will take and report data once every 5 seconds.
9. When altitude begins decreasing, deploy the parachute. Primary and secondary sensors will continue sending data.
10. When CanSat is 180m above ground level, turn the blue light off.
11. CanSat will land and turn the blue light back on.
12. GPS signal, attempt to retrieve



f3. Mechanical Overview

3.1 Mechanical Design

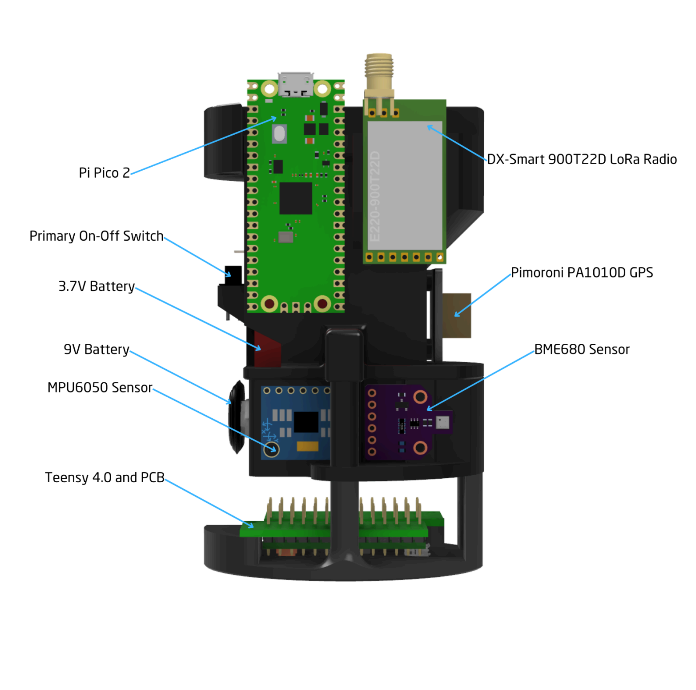


Fig. 3.1

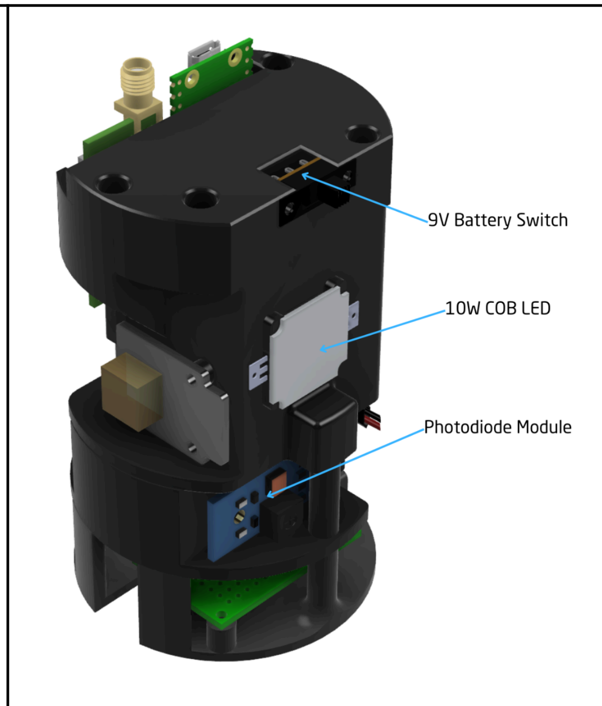


Fig. 3.2

3.2 Bill of Materials

Item	Cost (CAD)	Description
Primary Mission		
Teensy 4.0	29.95	Mainboard for CanSat
Raspberry Pi Pico	13.95	Secondary Board to send data
BME680 Sensor	10.18	Digital Temperature and Humidity Sensor
PA1010D GPS Module	14.66	For location tracking and recovery
MPU6050 Gyroscope	7.99	Orientation and Acceleration

Various Wires	8.99	Wires to connect the electronics
Solderable PCB	4.99	Connect all sensors and modules
DX-Smart LR02-900T22D	16.59	LoRa Radio Module
On-off Switches	2.99	Power control
Secondary Mission		
Cuvette	14.49	Housing algae solution
LED (10W)	10.99	Stable source of light for photosynthesis
Photodiode	4.66	Sensor to detect photosynthesis
Acrylic Mirror	3.99	Reflect light into the sensor from algae
Transistor	1.00	Turn on and off the LED
Mechanical Assembly		
Bambu Lab ABS Glass-Fill Filament	28.99	For the housing and plates for the can
Various Hardware	20.00	Nuts, bolts, and standoffs to hold everything together
Summary		
Total	194.41	Total Price of CanSat

3.3 Materials, Design, and Assembly Process

Our CanSat is composed of various materials to support our primary and secondary missions. The printed portions, such as the shell, mounts, and component housing of our CanSat, are made from ABS with glass fibres. ABS with glass fibres was chosen for its high toughness, immense stiffness, and high heat resistance. For our secondary mission, the fluorometer is made of acrylic mirrors, and the cuvette houses our algae.

Lumina is designed with modularity in mind. The design relies on three stacks of components, with each stack being able to be adjusted without affecting the others. Starting from the bottom and working upwards, the first stack houses the mainboard and its PCB. The middle stack has a variety of sensors along with the nine-volt battery. Finally, the utmost section stores the fluorometer, radio, secondary microcontroller, and 3.7-volt battery.

The design of Lumina tried to make it as easy as possible for it to be assembled. First, each component is secured into its designated mount. After each module is fastened, the wiring is connected and cleaned up in preparation for the case to be fitted. Before the case can be fitted, the parachute must be tied down to its four tie-down points. After the parachute is attached, two bolts go in through the case to secure the whole CanSat together.

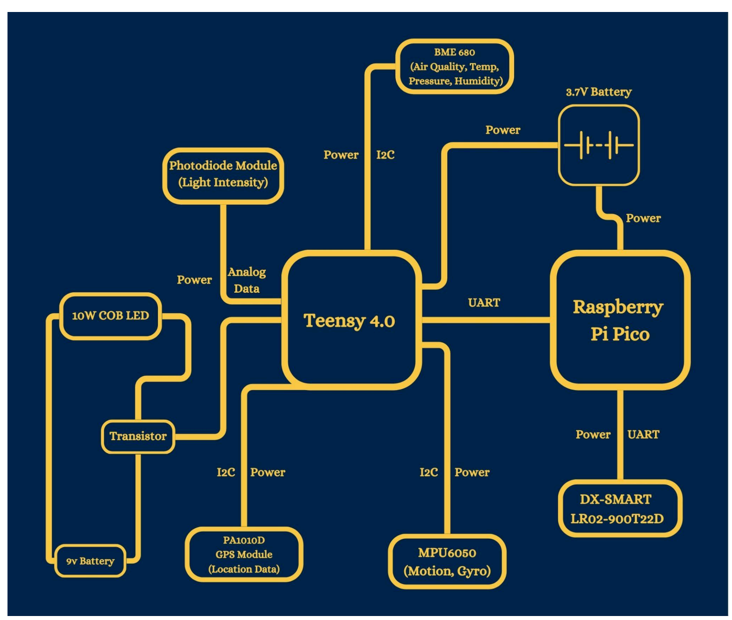
4. Electrical Overview

4.1 Electrical Design

The **CanSat electrical design** consists of a 3.7v battery connected to two mainboards: The Teensy 4.0 and the Raspberry Pi Pico, which connect to different modules.

Modules connected to Teensy 4.0:

- **Photodiode Module** for light intensity (analog input)
- **BME680** sensor (via I2C) for air quality, temperature, pressure, and humidity
- **PA1010D GPS Module** (via I2C and power) for location tracking
- **MPU6050** (via I2C and power) for motion and gyroscope data
- **Transistor** turns the blue light on and off inside our CanSat



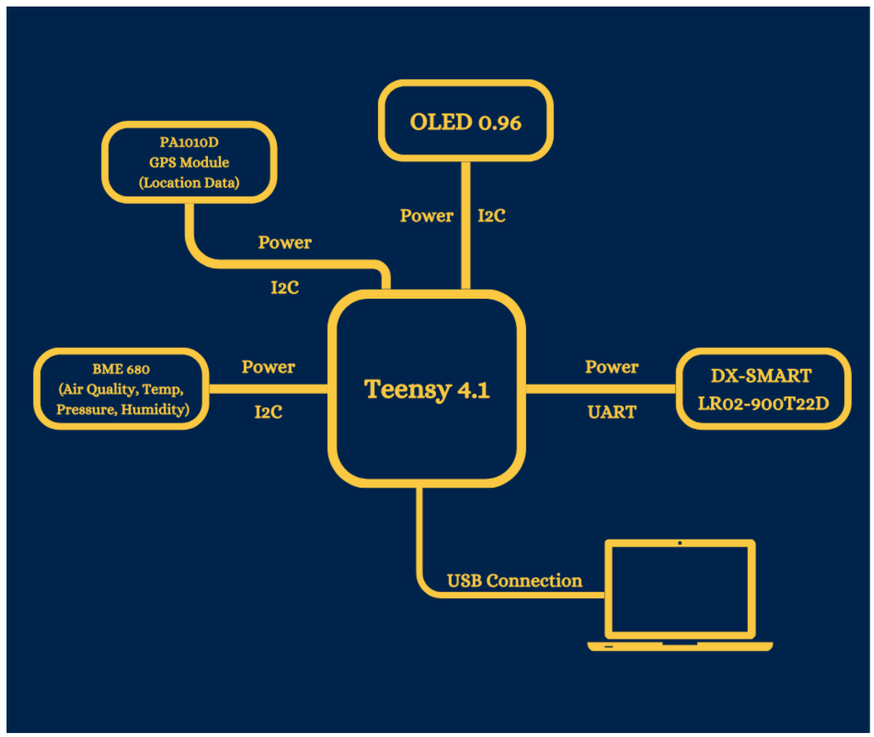
Modules connected to Raspberry Pi Pico:

- **DX-SMART LR02-900T22D** (via UART and power) serves as the radio module for the CanSat

The **Ground Station electrical design** consists of a mainboard (Teensy 4.1) powered by an external source, which is connected to different modules. Teensy 4.1 receives transmitted data and displays it.

Modules connected to the Teensy 4.1:

- **DX-SMART LR02-900T22D** LoRa module for wireless communication with the CANSAT
- **BME680** for local environmental readings
- **PA1010D GPS Module** for local positioning
- **OLED 0.96" Display** to show real-time data



4.2 Power Budget

Module	Current (mA)	Power (W)	Power (mW)
Teensy 4.0	100	0.330	330
Pi Pico 2	90	0.297	297
DX-LR02-900T22D	80	0.264	264
MPU6050	4	0.014	14
BME680	6	0.020	20
Photodiode Module	4	0.014	14
LED Indicator	10	0.033	33
Total	294	0.972 W	972 mW

Main Battery - 3.7V 2000 mAh

LED Battery - 9V 692 mAh

3.7V Battery Life = $\frac{Battery\ Capacity\ (mAh)}{Current\ (mA)} = \frac{2000\ mAh}{294\ mA} = 6.8$ hours (6 hrs 48 min)

9V Battery Life= $\frac{Battery\ Capacity\ (mAh)}{Current\ (mA)} = \frac{692\ mAh}{339\ mA} = 2.04$ hours (2 hrs 4 min)

5. Software Overview

5.1 Software Design

1. Introduction

The Environmental Data Collection and Transmission System is a robust solution for real-time monitoring, implemented through four Python modules: Data_Collector.py, Data_Sender.py, Ground_Station.py, and SerialReading.py. Designed to collect sensor data, transmit it via LoRa, display metrics on an OLED screen, and visualize data on a host computer, the system uses standardized interfaces (UART, LoRa, JSON) for modularity and reliability.

2. Data Collector Module

The Data Collector operates on a Raspberry Pi Pico, interfacing via I2C with a BME680 sensor (temperature, pressure, altitude), a GPS module (latitude, longitude), an MPU6050 (three-axis acceleration), and an analog input (A2). Every 0.1 seconds, it compiles these metrics into a JSON array, including a timestamp and relative altitude calibrated after a 5-second startup. A blue light toggles based on altitude thresholds (on below 5m, off above 180m), and an LED blinks to confirm data transmission. Data is sent via UART at 115200 baud to the Data Sender.

3. Data Sender Module

The Data Sender receives JSON data via UART (GP0/GP1, 115200 baud) and transmits it using a DX-LR02 LoRa module (GP4/GP5, 9600 baud). It configures the LoRa module with AT commands to set transparent mode, a spreading factor of 6 (SF6) for faster data rates, and channel 82, retrying up to three times for critical operations like entering AT mode. After validating JSON, it sends data with a 0.25-second delay to prevent congestion. Console-logged errors ensure reliable transmission.

4. Ground Station Module

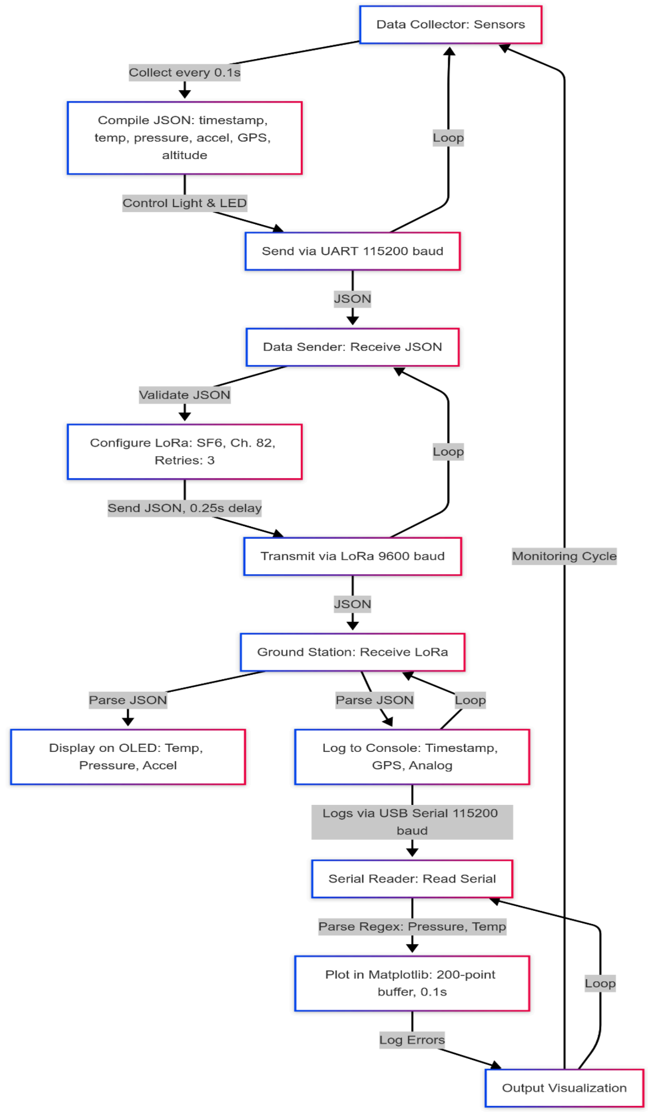
The Ground Station receives LoRa data through a second DX-LR02 module (TX7/RX7, 9600 baud), configured to match the Data Sender's settings. It parses JSON and displays temperature, pressure, and acceleration on a 128x64 SSD1306 OLED via I2C (SCL2/SDA2). Detailed data, including timestamps, GPS coordinates, and analog readings, is logged to the console for monitoring or forwarding via USB serial.

5. Serial Reader Module

The Serial Reader, running on a host computer, processes console logs from the Data Collector or Ground Station via USB serial (115200 baud). It uses regex to extract pressure and temperature, storing them in 200-point deques for real-time Matplotlib plotting. Two subplots update every 0.1 seconds with auto-scaling axes, and users can exit by pressing 'q' or Ctrl+C. A robust error-handling decorator manages serial, parsing, and unexpected errors, with automatic reconnection after failures. Logs are saved to sensor_monitor.log.

6. System Architecture and Integration

The system follows a pipeline architecture with a loop-like structure: Data Collector → UART → Data Sender → LoRa → Ground Station → UART → Serial Reader, with the Serial Reader's visualization feeding back into the monitoring cycle. Hardware includes RP2040-based microcontrollers, DX-LR02 LoRa modules, sensors, and an OLED. Interfaces like UART (115200/9600 baud), LoRa (SF6, channel 82), and JSON ensure modularity, allowing independent module updates. The software process is displayed in the flowchart on the right-hand side.



6. Radio Overview

6.1 Radio Design

The radio design leverages the DX-LR02 LoRa module in the 900 MHz band (902-928 MHz) for long-range, low-power communication, optimized for environmental monitoring.

- **Module Selection**: DX-LR02 variant for 900 MHz, using the ASR6601 SoC with a Sub-1GHz RF transceiver, supporting +22 dBm transmit power and -138 dBm sensitivity for a line-of-sight range up to 8 km.

- **Configuration**:
  - **Operating Mode**: Transparent transmission mode (AT+MODE0) for direct JSON data transfer.
  - **RF Parameters**: Spreading Factor 6 (AT+SF6) for a balance of data rate (7812 bps) and range (~4.5 km outdoor), Bandwidth 125 kHz (AT+BW0), Coding Rate 4/6 (AT+CR2), CRC disabled (AT+CRC0) to maximize throughput.
  - **Channel**: Channel 82 (AT+CHANNEL82, 915 MHz) to comply with regional regulations and minimize interference.
  - **Power**: Transmit power set to 22 dBm (AT+POWER22) for maximum range, with high-efficiency mode (AT+SLEEP2) for continuous receive readiness.

7. Test Plans

March 22nd - First Prototype

- We tested the BME680 sensors by ensuring data was being collected accurately by connecting the sensors to a laptop and ensuring data was being sent.
- We tested the radio by sending data wirelessly from the BME680 sensors to a ground station up to 800m away.
- We then tested the fluorometer, ensuring that readings were accurate and matched what was expected by turning the blue light on and off.
- After we had finished our first prototype of the CanSat, we measured all dimensions from our Fusion file, ensuring we were within range of the requirements.
- Lastly, we calculated our operational duration based on battery capacity and total current drawn.

April 6th - Second Prototype

- We tested everything similarly to March 15th.
- This time, we tested the deployment of the parachute as well, making adjustments as needed.
- We aimed to ensure the parachute deployed fully and that no sides stayed closed.

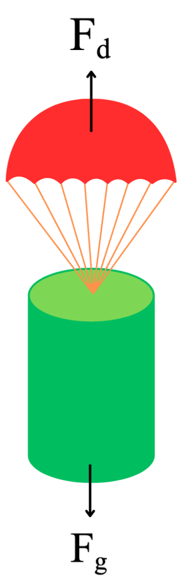
April 17th - Final Test

- We flew a drone carrying our CanSat as high up as possible, ensuring that data was still being transmitted wirelessly.
- Then, we dropped the CanSat, ensuring that the parachute deployed well and the CanSat fell as expected.

8. Recovery System

8.1 Recovery Description

Lumina's descent to the ground is covered by a parachute. In order to calculate the frontal area (the face of the parachute facing towards the ground) of the parachute, the force of drag and gravity must equal each other at a decent rate of around 6 m/s. The calculations are below:

Free Body Diagram	Calculations
 	**Variables/Constants:** F_d = Force of Drag F_g = Force of Gravity m = mass of CanSat g = constant for acceleration of gravity C = drag coefficient (0.60 for a cross shape) p = *constant for the density of air* A = frontal area v = *velocity relative to the air* **Formulas:** $F_d = \frac{1}{2} C\rho A v^2$ $F_g = mg$ **Calculations:** $C = 0.70$ p = 1.225kg/m^3

	v = 6m/s m = 0.310kg F_g = 3.038N $F_g = F_d$ A = 0.24 M^2

We chose to use a cross parachute as it has a large drag coefficient, and we wanted to aim for a slower descent rate to allow maximum time for data collection. Our recovery system uses a cross parachute that is constructed from neon green ripstop nylon fabric and has micro nylon cords strung through it. The micro nylon cords are held in place by a snake knot. The micro nylon cords will be attached to the lid of our CanSat at 4 attachment points.

Assuming we are dropping our can from 1000m elevation, the flight time is approximately 2 mins and 50 seconds at a decent rate of 6m/s.

8.2 Location Tracking

The location tracking system for Lumina is designed to ensure efficient and reliable retrieval of our CanSat. This will be done through a GPS sensor and radio communication. The GPS sensor is connected to the mainboard and will continuously stream latitude, longitude, and altitude coordinates. These will be processed and transmitted to the ground station through the onboard radio. The system will broadcast Lumina's location every ten seconds along with the other data that needs to be sent. After touchdown, the coordinates can be entered into a map, and Lumina can be recovered.

9. Requirements Verification

Characteristics	**Value**
Height	115mm
Mass	310g
Diameter	65.5mm

Flight Time Scheduled	2mins 50s
Calculated Descent Rate	6m/s
Operational duration when ON	6 hrs 48 min
Total Cost	191.42 CAD

10. Outreach Programs

Our outreach program focuses on a combination of engaging youth in science and displaying our project initiative and the promises it may hold for future space exploration. We focused on reaching out to youth to engage them in STEM and further their passions. In order to do that, we conducted outreach at multiple levels.

We established outreach initiatives with different communities:

- Elementary Students: Taught informational lessons and conducted hands-on learning workshops with youth.
- Junior High School Students: Engaged junior science classes with STEM opportunities in hopes that they will also participate in future CanSat competitions. Showcased our project and the progress we have made, along with answering questions.
- General Public/Community: Connected with our community through youth showcases held at City Hall.
- Other: Established a social media platform to document our progress and journey throughout preparation for the CanSat competition.
- Social Media Account: https://www.instagram.com/helion_dynamics/

Below is a timeline we followed for our outreach programs along with photos:

11. External Support

We would like to thank our sponsors below for helping us with costs and providing support:

We would also like to thank Mr. Larkin for sponsoring our club and providing us with support on our CanSat throughout the last few months.

Works Cited

LICHTENTHALER, Hartmut K. and Botanisches Institut II (Plant Physiology and Plant Biochemistry), University of Karlsruhe. *IN VIVO CHLOROPHYLL FLUORESCENCE AS A TOOL FOR STRESS DETECTION IN PLANTS*. 1988.

Bates, Harvey, et al. "A Guide to Open-JIP, a Low-cost Open-source Chlorophyll Fluorometer." *Photosynthesis Research*, vol. 142, no. 3, Sept. 2019, pp. 361–68, doi:10.1007/s11120-019-00673-2.