CanSat 2025
Post Flight Review (PFR)
Outline

Team #3114
Robotics for Space eXploration (UofT)

Presentation Outline

Section	Presenter	Slides
Systems Overview	Arthur Goetzke-Coburn, Gianluca Ceccaci	4-7
Concept of Operations and Sequence of Events	Alexey Albert, Angelique Liao	8-11
Flight Data Analysis	Luke Watson, Daniel Yu, Alexey Albert	12-26
Failure Analysis	Adam Kabbara	27-29
Lessons Learned	Arthur Goetzke-Coburn, Gianluca Ceccacci	30-31
Conclusion	Adam Kabbara	32

Team Organization

Adam Kabbara
CanSat Team Lead
2nd Year EngSci

Dr. Jonathan Kelly
Faculty Advisor
Professor @ UTIAS

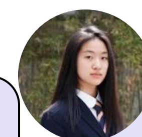
Arthur Goetzke-Coburn
Mechanical Team Lead
4th Year Robotics Eng.

Daniel Yu
Electrical Team Lead
4th Year Computer Eng.

Luke Watson
Software Team Lead
4th Year Computer Eng.

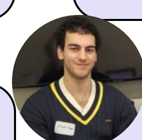
Gianluca Ceccacci
Mechanical Team Member
2nd Year EngSci

Nour Barsoum
Electrical Team Member
4th Year Robotics Eng.



Angelique Liao
Software Team Member
1st Year Electrical Eng.

Alexey Albert
Mechanical Team Member
1st Year Mathematics

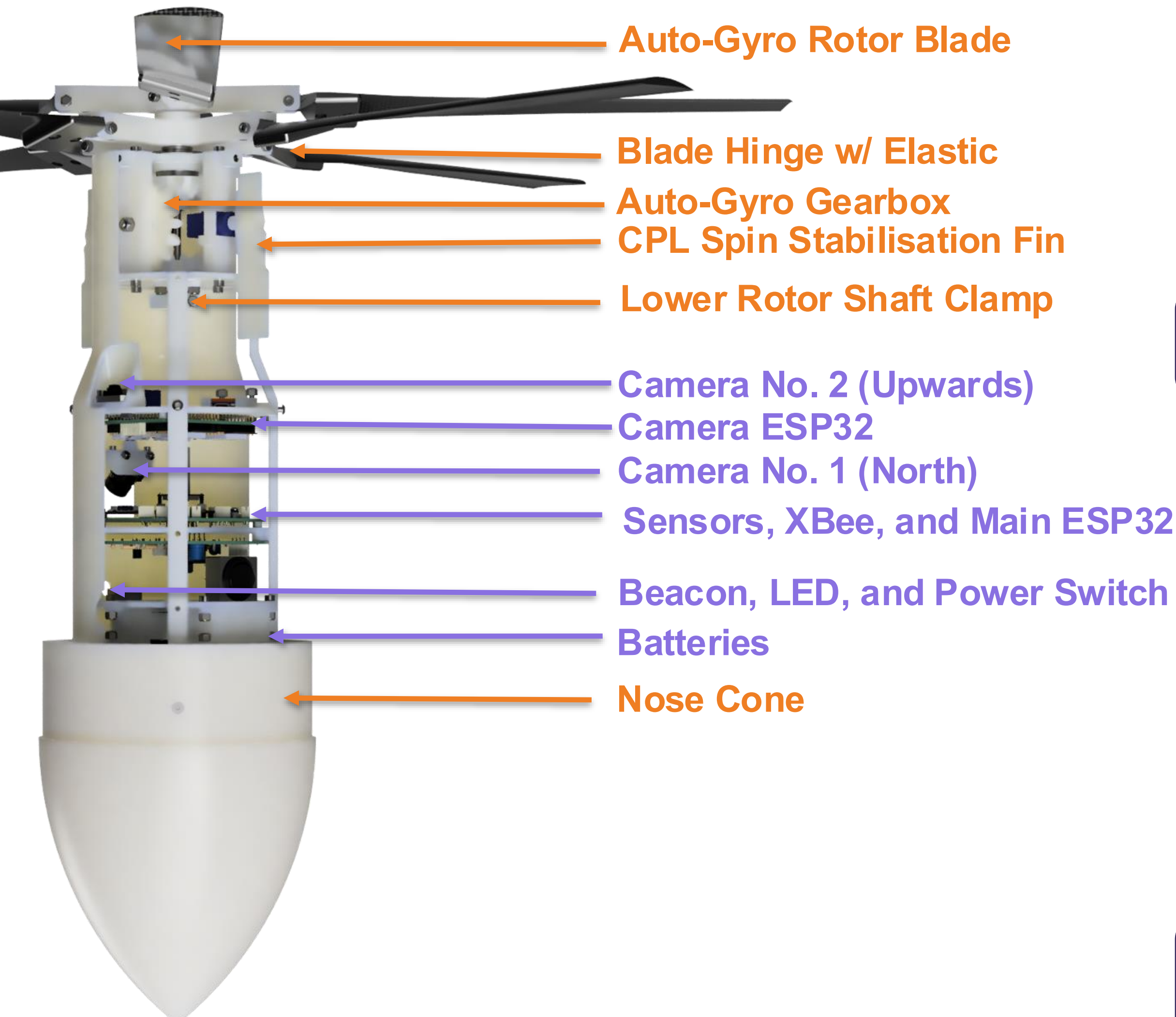


Robert Saab
Electrical Team Member
2nd Year Electrical Eng.

Systems Overview

Arthur Goetzke-Coburn & Gianluca Ceccacci

Payload Design Description (1/2)



XBee communicates sensor data, powered by a Li-ion battrey to the ground station, informing release. Cameras commence recording and Beacon is powered on.

↓

Payload releases from the CC using the release mechanism

↓

Elastics at the hinges and air resistance lift rotor blades to the horizontal

↓

Auto-Gyro gearbox with a 1:1 ratio, regulating descent

↓

Sensors continuously send data to GS. Cameras continuously record. Beacon is used to locate payload.

Payload Design Description (2/2)

Type	Air Pressure and Temperature	Battery Voltage	GPS	Hall Effect	IMU	Magnetometer	Camera 1 (Release)	Camera 2 (Ground)
Model	BME280	ESP32 ADC Pin	NEO-6M	A3144EU	BNO085	LIS3MDL	OV5640AF	OV5640

Power Management Board

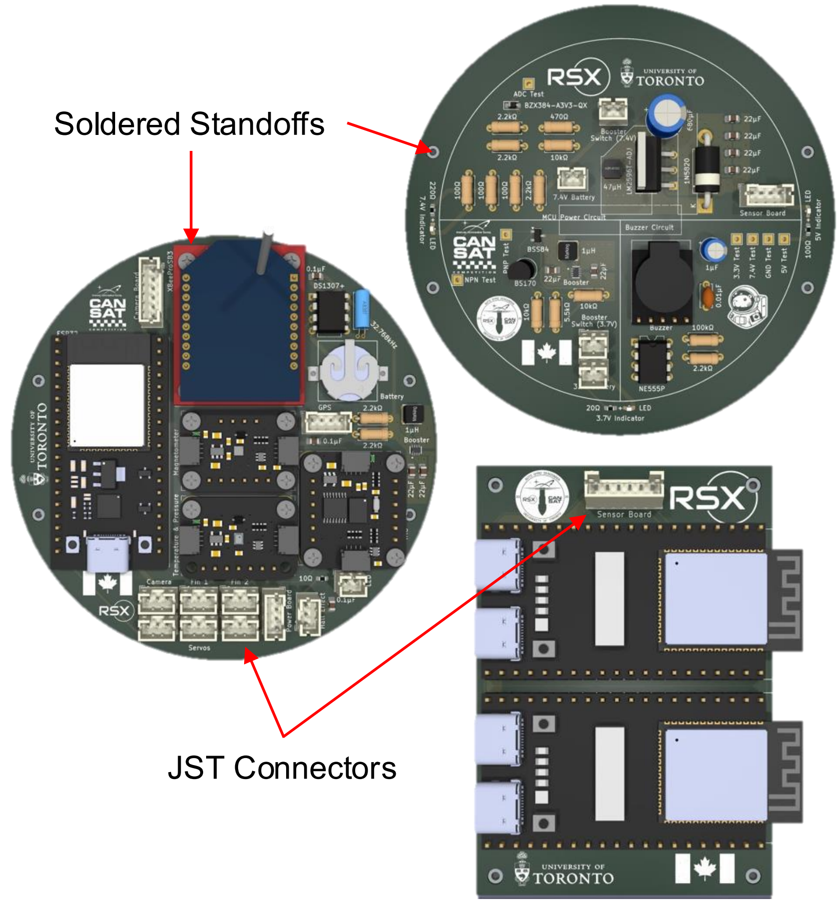
- Distributes 7.4 V from the battery to the camera and main boards, powers servos directly, and steps it down to 3.3 V for XBee and high-current sensors to reduce load on the ESP32.
- Converts 7.4 V to 3.3 V via a voltage divider for ADC input to the ESP32, and boosts a 3.7 V battery to 5 V for the buzzer circuit.
- Includes a self-sustaining timer circuit that remains active across system restarts.

Main Board

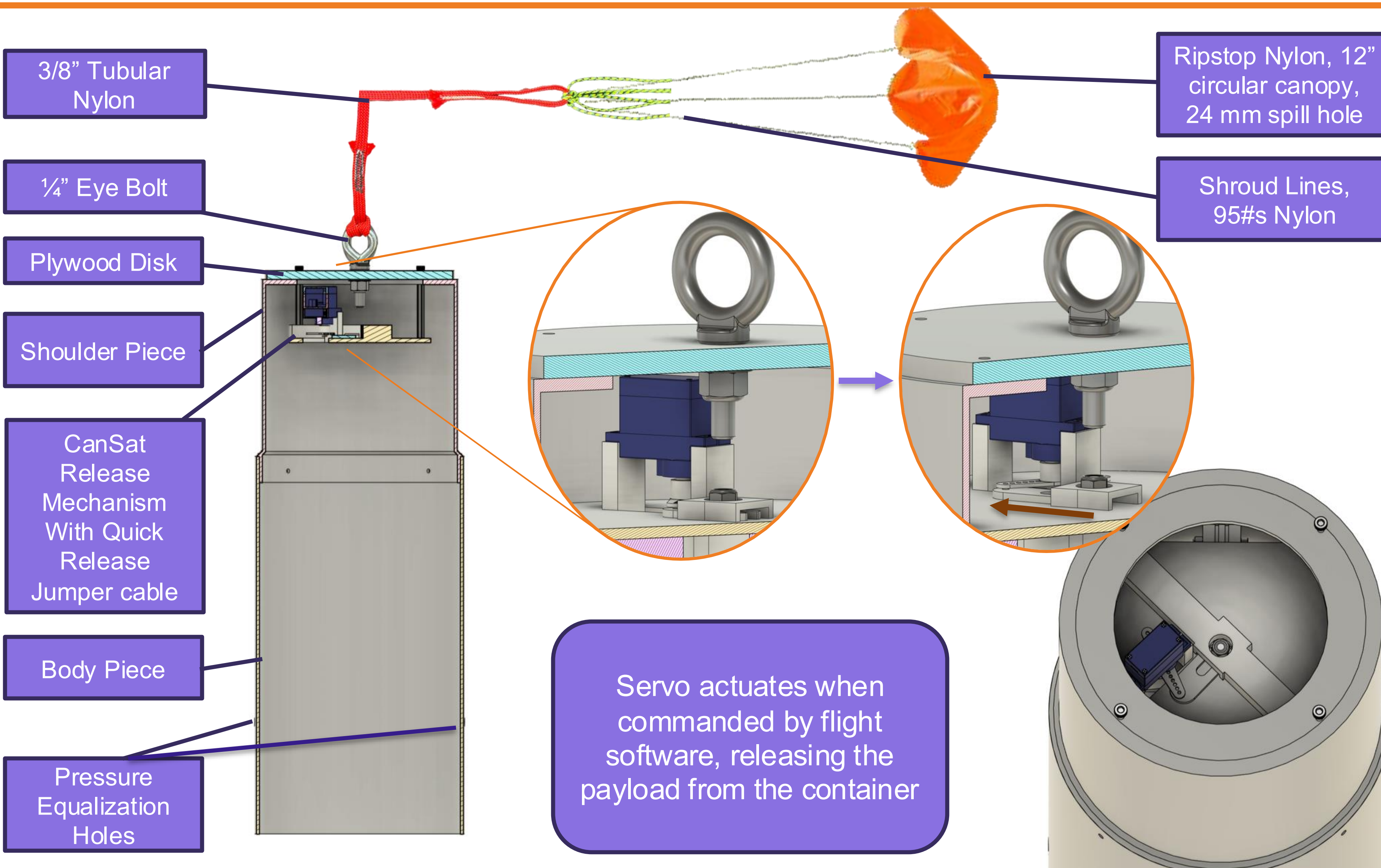
- Hosts an ESP32 that steps down 7.4 V to 3.3 V using its onboard buck converter.
- Powers digital sensors with the ESP32's regulated 3.3 V to ensure clean and stable signals.
- Central controller for managing digital sensor inputs and overall system control.

Camera Board

- Contains two ESP32s, each equipped with its own SD card slot.
- Each ESP32 uses its onboard buck converter to step down 7.4 V to 3.3 V for stable camera operation.
- Handles camera control and data logging independently from the main board.



Container Design Description



Concept of Operations and Sequence of Events

Alexey Albert & Angelique Liao

Comparison of Planned and Actual CONOPS

<table>
<tr><th>Pre-launch</th><th>Launch</th><th>Post-launch</th></tr>
<tr><td>Set up the ground station, including the GUI and the hand-held communication antenna.</td><td>Rocket launch while still transmitting telemetry and recording video.</td><td rowspan="2">The recovery team scouts for the CanSat using the last known GPS coordinates and the buzzer sound.</td></tr>
<tr><td>Switch on the CanSat (CPL) and the buzzer.</td><td rowspan="2">Apogee is reached around ~740 m (assuming J425 engine).
CC is deployed and descends with its parachute. Rocket descends and lands with its own parachute.</td></tr>
<tr><td>Ensure XBee enters running as intended.</td><td>The telemetry data received by the GS and the on board CanSat footage are retrieved</td></tr>
<tr><td>Instruct CanSat crew to integrate the CanSat into the rocket.</td><td rowspan="2">At 75% apogee (~555 m) CC will deploy the CPL which will descend using the auto-gyro system while CC continues to decent and land with its parachute.</td><td rowspan="2">A thumb drive with the telemetry data is prepared and presented to the GS judges.</td></tr>
<tr><td>Calibrate and zero the onboard flight system values, including barometric altitude and roll-pitch-yaw IMU values.</td></tr>
<tr><td>CanSat continuously collects and sends telemetry data at 1 Hz.</td><td rowspan="2">CPL lands and telemetry data streaming and video footage are stopped while the buzzer keeps beeping.</td><td rowspan="2">PFR (includes flight footage) preparation and presentation.</td></tr>
<tr><td>CanSat starts recording and storing video footage from both cameras.</td></tr>
</table>

1. CC is released but does not descend using parachute.
2. All telemetry is transmitted but not all sensors sent valid data.
3. The cameras stopped working mid mission due to over heating.

Comparison of Planned and Actual SOE (1/2)

1. Arrival, Ground Station, and Antenna Setup	2. CanSat Assembly and System Validation	3. Pre-Launch Checklist
Arriving at the launching site	Battery Charge Level Check	Positioning Ground Control Station
Check and fix any potential damage could happened in the transportation	CanSat Assembly Final Integration and System Check	CanSat Integration Check
Ground Control System Assembly	Communication and Sensor Functionality Check	CanSat + GCS Communication Verification
Antenna Assembly	Weight & Size Compliance Verification	Sensor Calibration: Adjust and verify sensor accuracy and turn on cameras
	Final Inspection Submission	Final Safety Inspection

4. Launch Execution	5. Post-Landing Recovery	6. Post-Landing Evaluation and Cleanup
Initiating Launch Procedures	Deploy team to locate and recover the CanSat	Return to check-in for final assessment
Monitor CanSat during flight	Retrieve the onboard storage device MicroSD	Clear the Ground Station area
CanSat Recovery after landing	Flight data backup after recovery	Process and interpret collected flight data
Submit flight data via USB stick to the judge		

Comparison of Planned and Actual SOE (2/2)

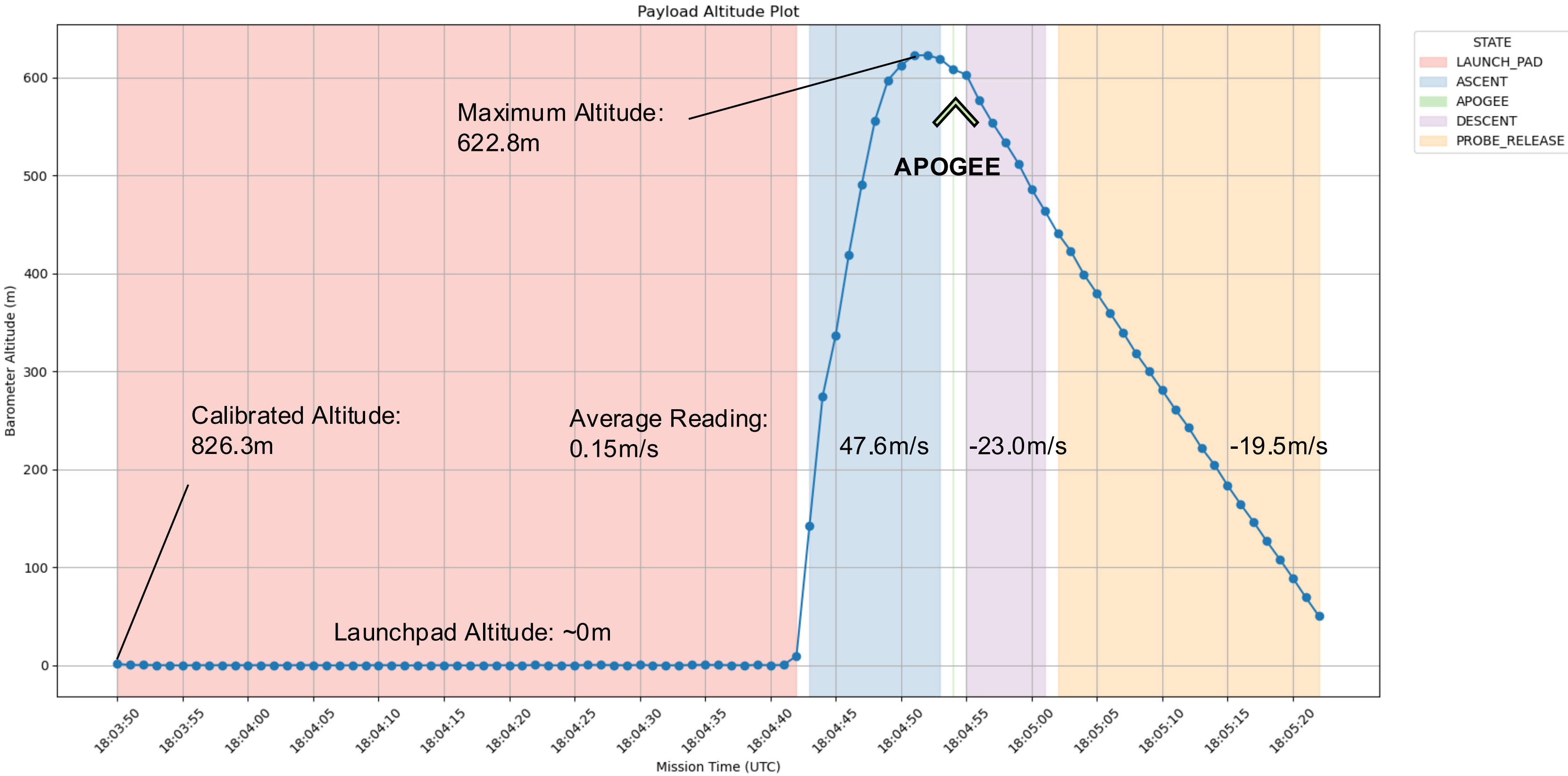
Role	Members	Responsibilities	Events
Mission Control Officer (MCO)	Adam Kabbara	Oversees countdown and readiness.	**Launch Check & Control**
Ground Station Crew (GSC)	Luke Watson, Angelique Liao, and (Nour Barsoum) Arthur Goetzke-Coburn	Monitors telemetry and commands.	**Ground Station Configuration**
Recovery Crew (RC)	Gianluca Ceccacci, (Robert Saab) Daniel Yu, and Alexy Albert	Tracks and retrieves CanSat	**Post-Landing Recovery**
CanSat Crew (CCR)	Arthur Goetzke-Coburn, Alexy Albert, Daniel Yu	CanSat preparation and rocket integration team	**CanSat Preparation & CanSat Integration**

Two of our members could not make it to launch day so the roles had to be moved around.

Flight Data Analysis

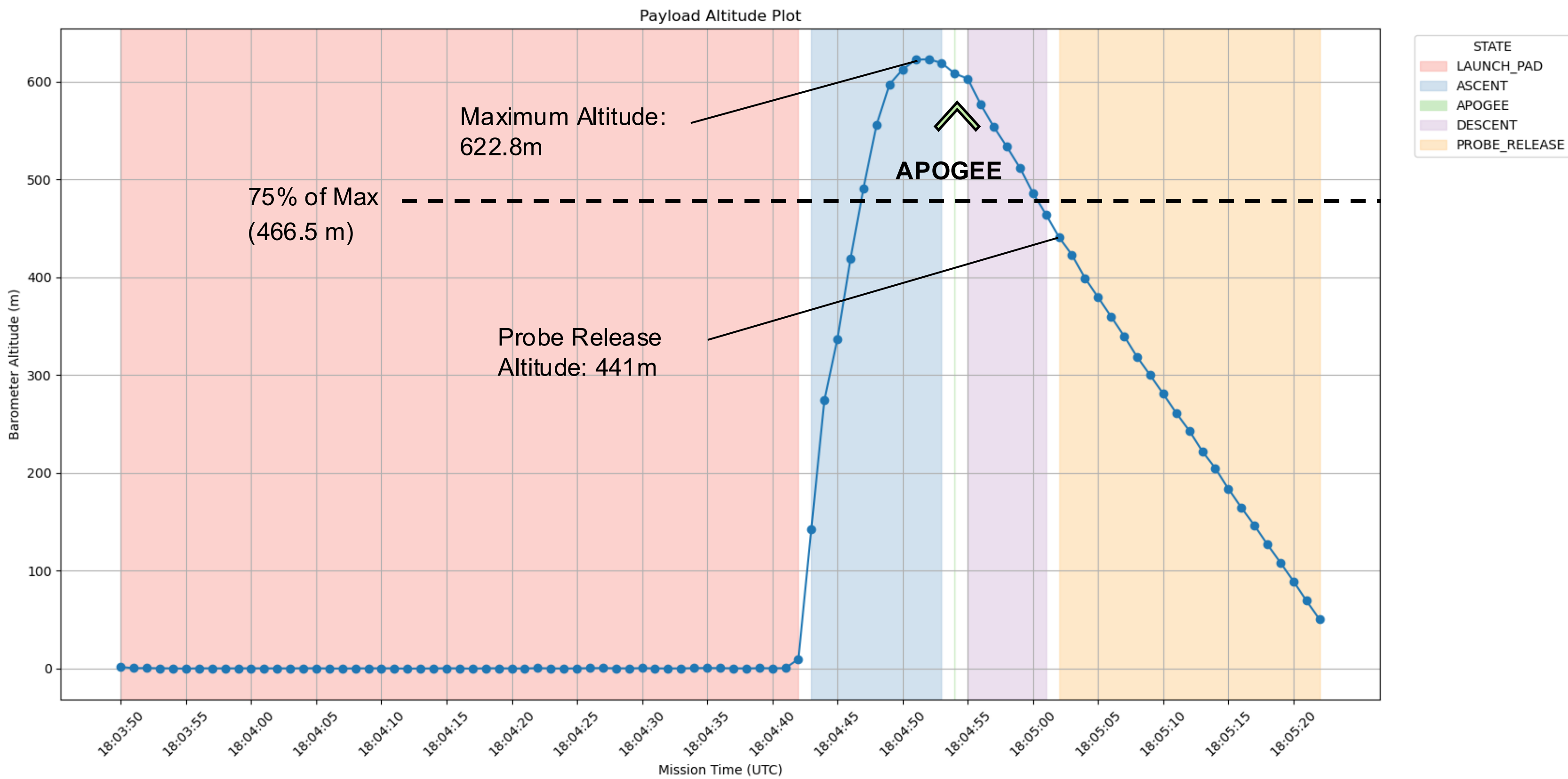
Luke Watson, Daniel Yu, & Alexey Albert

Payload Altitude Plot



The ground station received all packets sent by the CanSat until 18:05:20 UTC, where the XBee was dislodged from the adapter upon ground impact.
Note that we were able to reach the required descent velocity despite the parachute failure.

Probe Release at 75% (1/2)



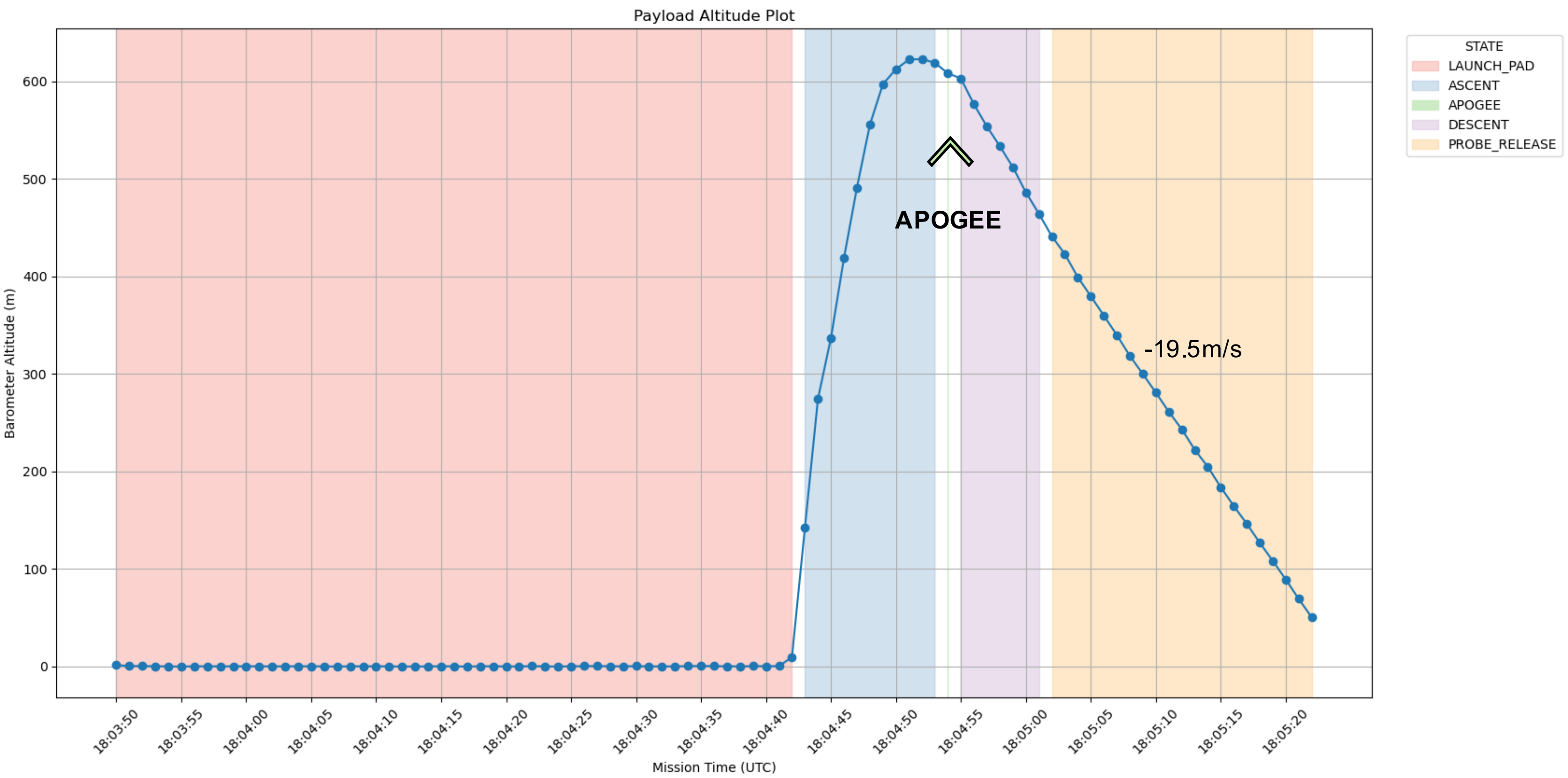
From telemetry data, we can see a transition to the PROBE_RELEASE state at 441m, which is ~70% of the maximum altitude.

Probe Release at 75% (2/2)

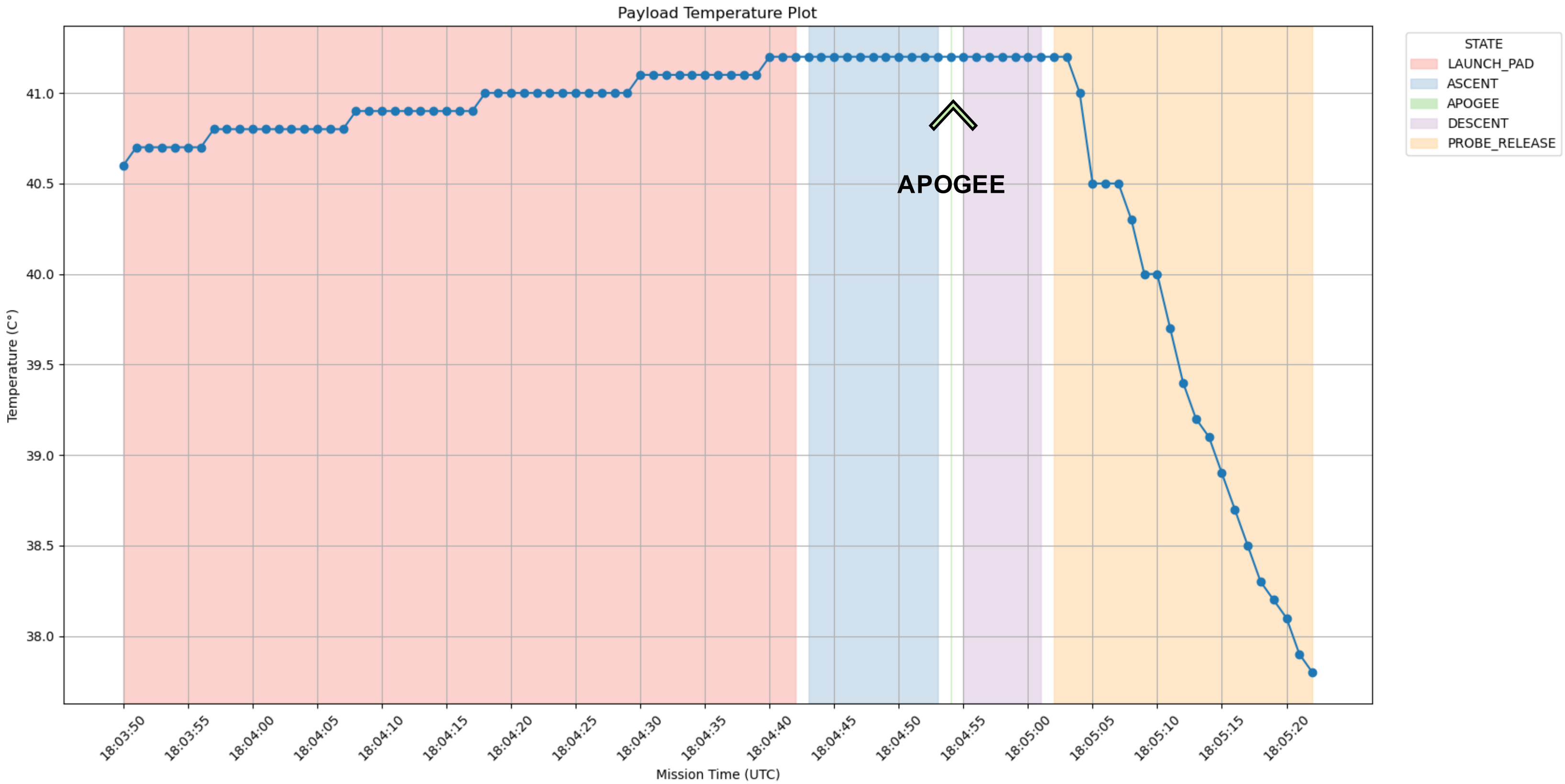
The FSW was able to successfully separate the payload and container at this time, as shown below:

Auto-Gyro Descent Rate at 5 m/s

The auto-gyro did not properly deploy as it was in an unstable tumble because of the container parachute failure. As such, the payload tumbled to the ground at an average speed of 19.5m/s.

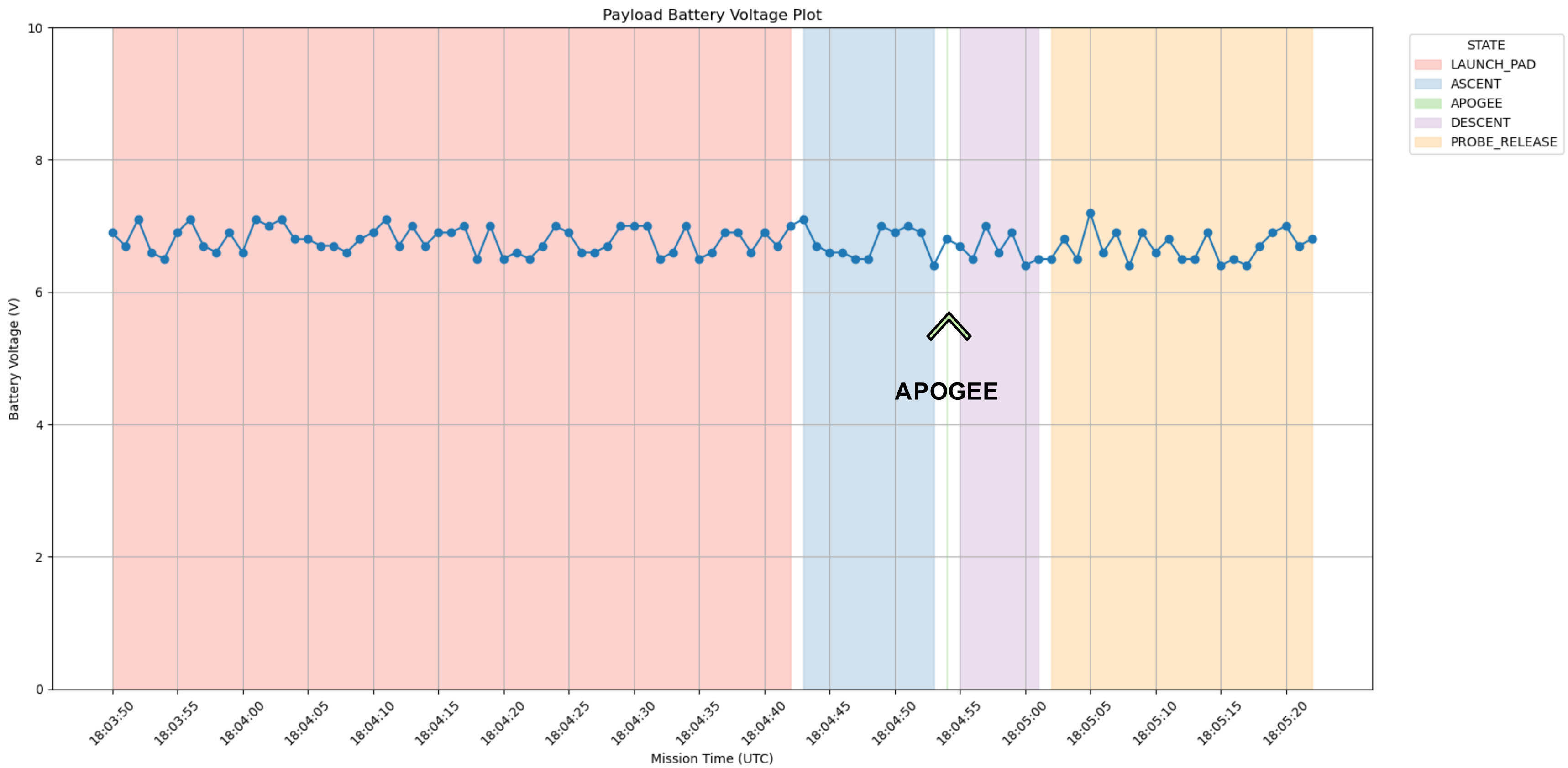


Payload Temperature Sensor Plot



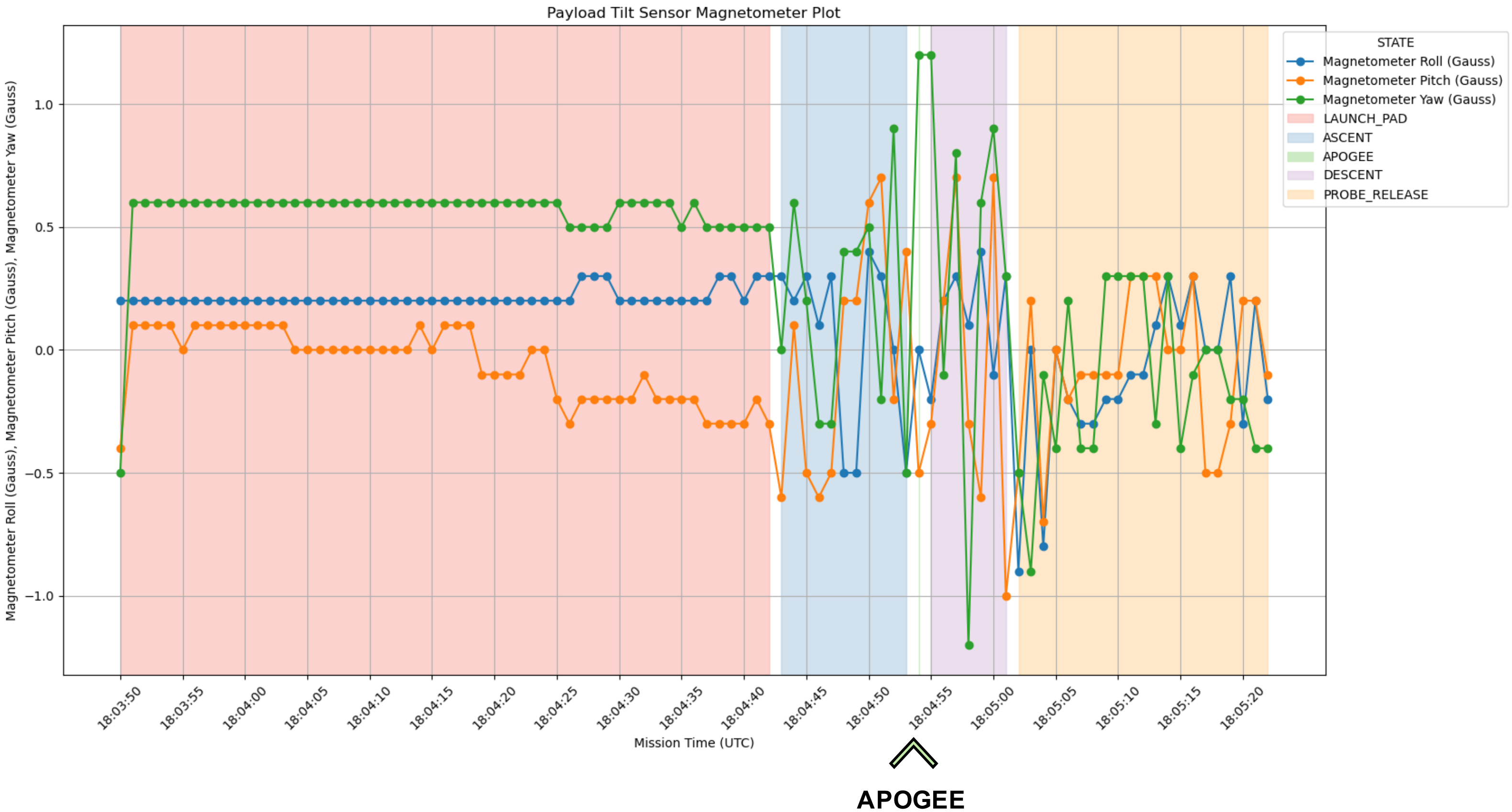
The payload was heating up while waiting on the launch pad. As soon as the payload was ejected from the container, the airflow through the shroud cooled the payload down.

Payload Battery Voltage Plot



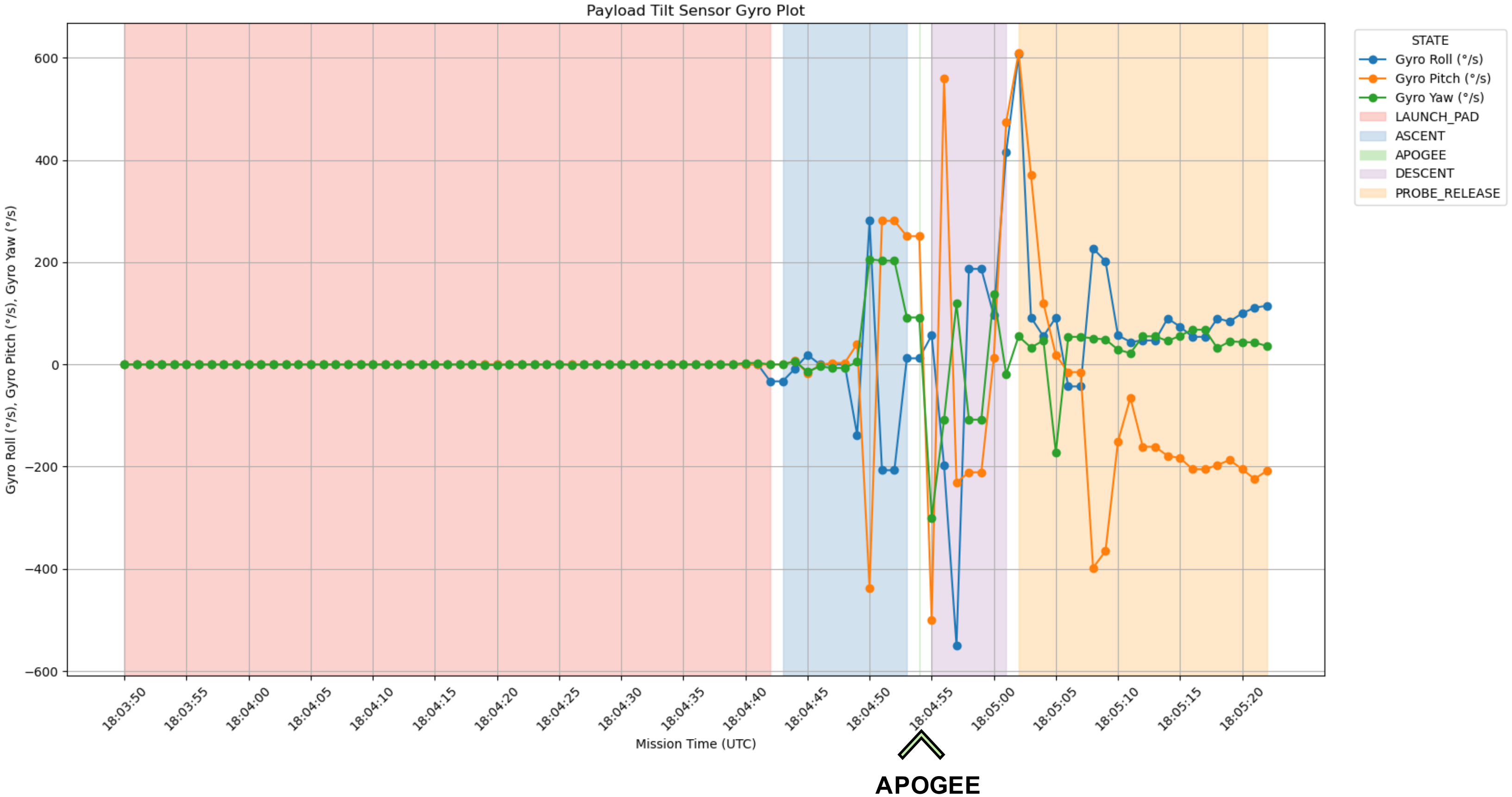
The voltage data was consistent at around 7V, however, some noise due to the pin connections and processing of analog values on the ESP32 allowed for the variations of the voltage value as seen here in the plot.

Payload Tilt Sensor Plots/Ground Camera Stability (1/3)



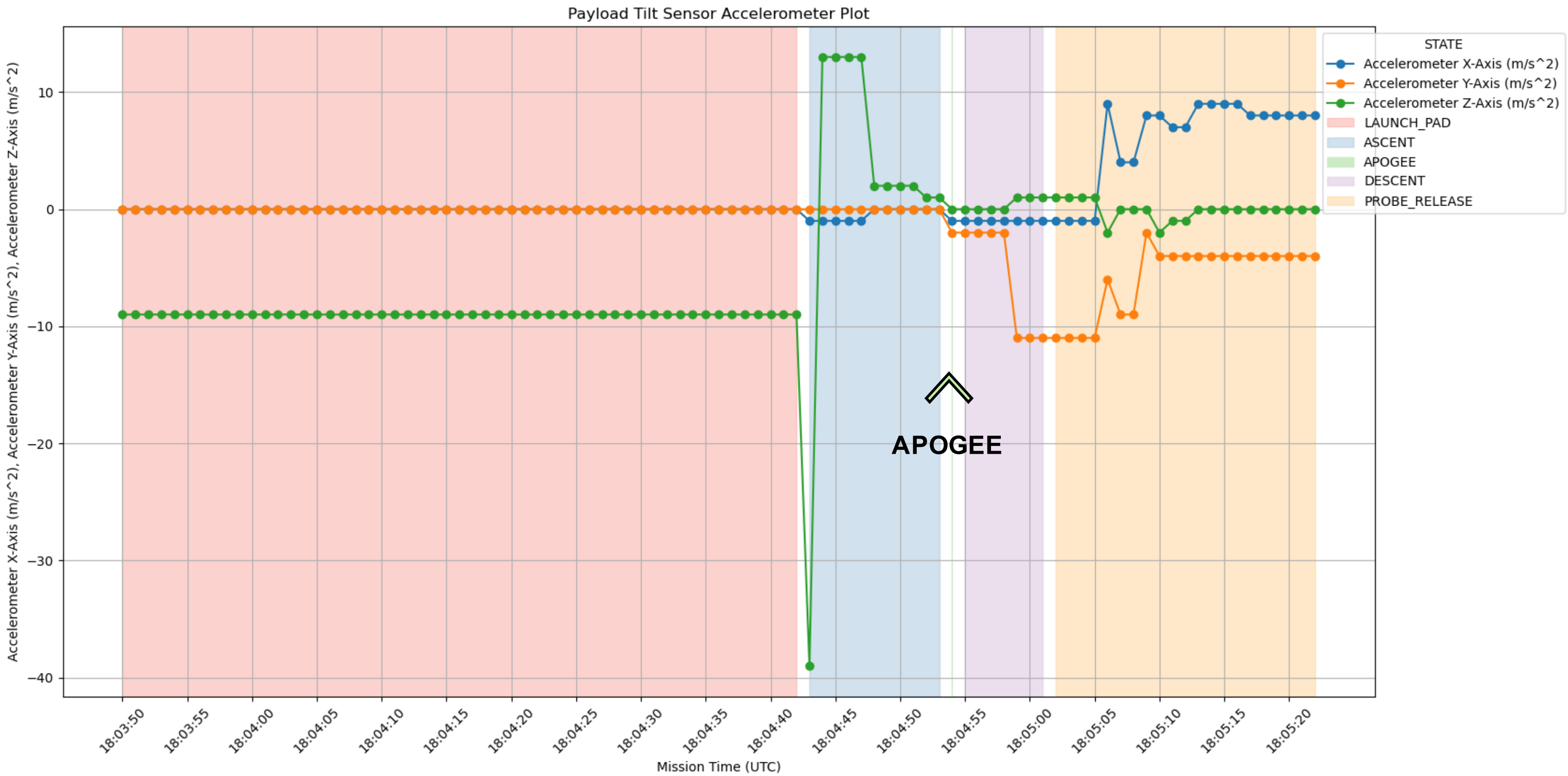
Magnetometer readings are stable at the launch pad. Increasing movement is seen during ascent, apogee, and descent, with less chaotic movements during probe release.

Payload Tilt Sensor Plots/Ground Camera Stability (2/3)



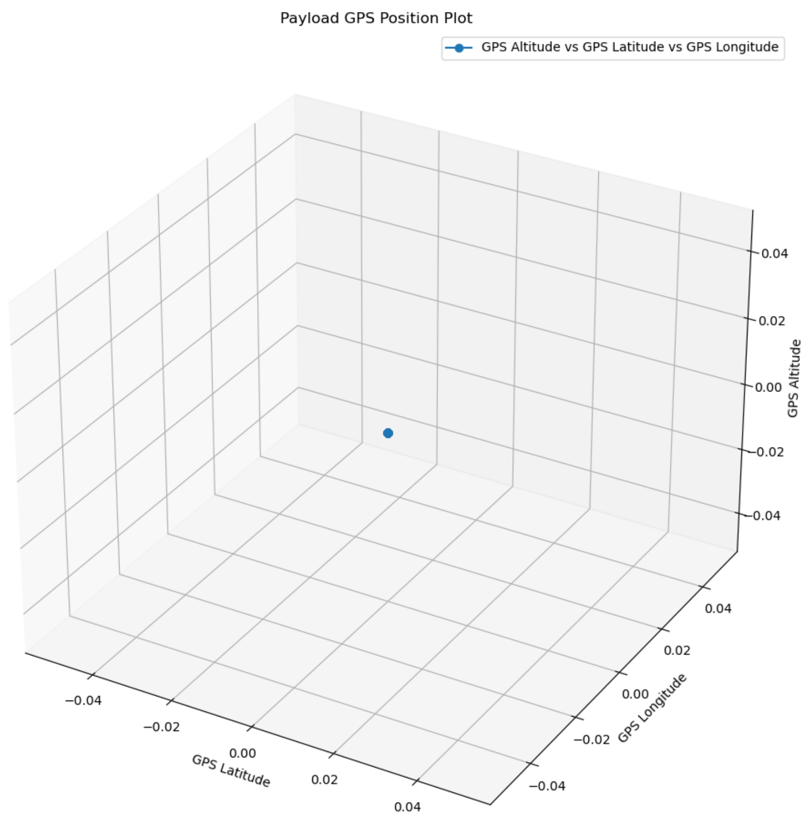
During the launch pad phase, we see all readings are 0. We see activity increase in ascent with huge spikes in descent and probe release. This is an accurate reflection of the tumbling we observed during the flight.

Payload Tilt Sensor Plots/Ground Camera Stability (3/3)



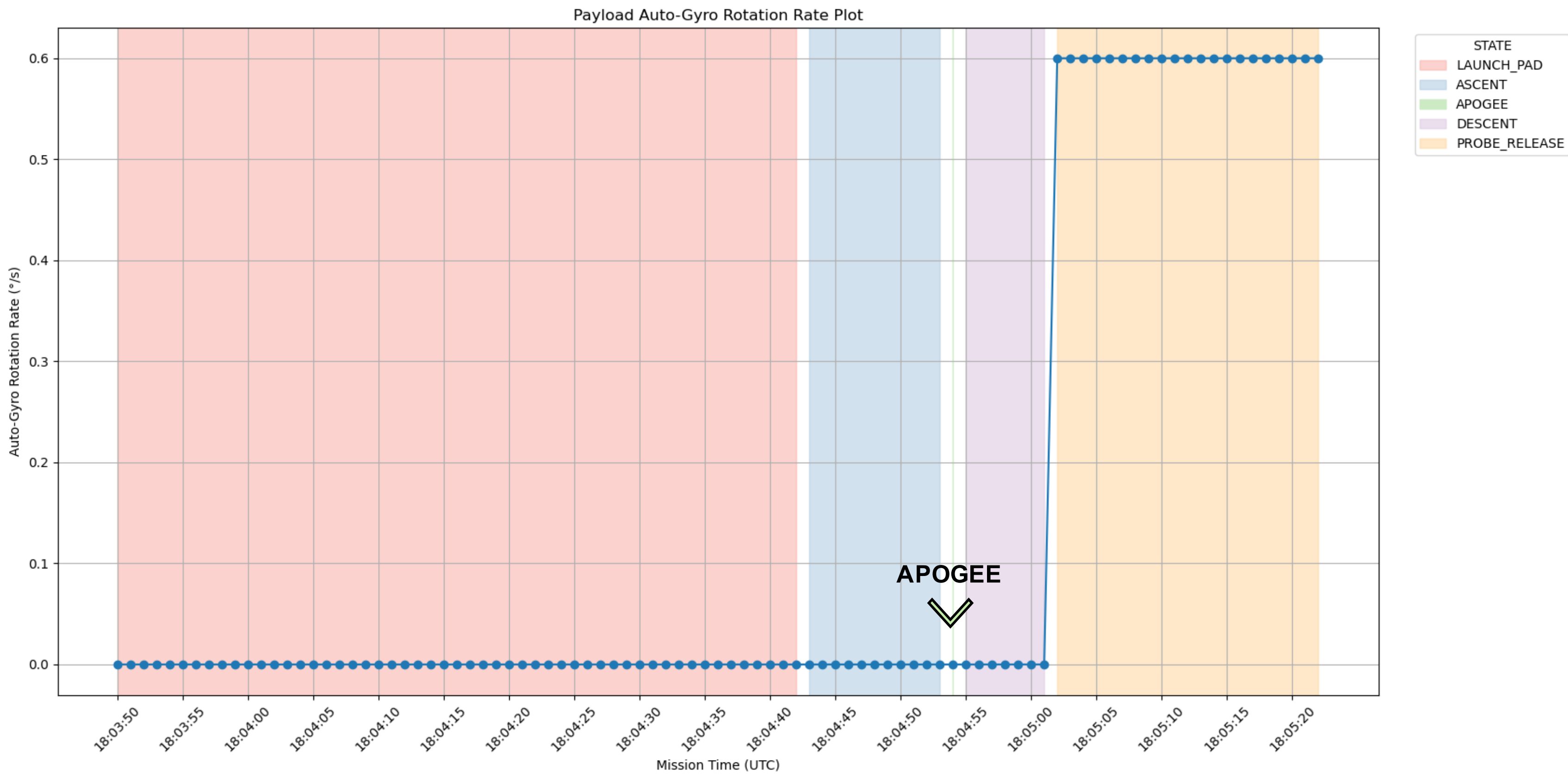
We see a consistent reading of ~9m/s^2 due to gravity on the Z-Axis on the launch pad, then consistent positive acceleration during ascent, dropping towards zero/negative during descent/probe release.

Payload GPS Position Plot



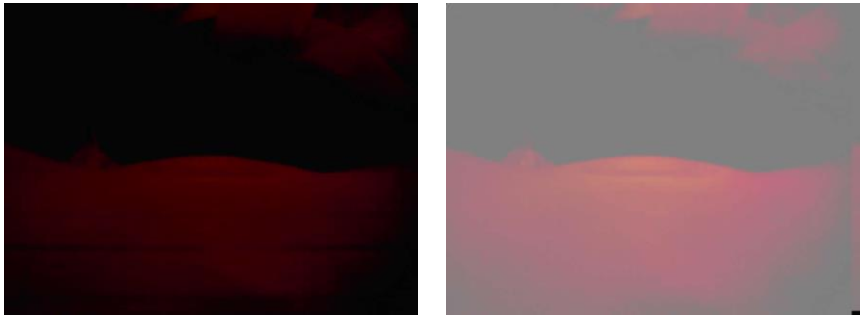
Due to a last-minute failure of our BN-220 GPS module, we had to integrate a NEO-6M GPS module donated to us by the University of Hawai'i CanSat team. Unfortunately, this GPS did not receive a single fix on any satellites throughout the entirety of the launch even though it did during testing

Auto-Gyro Rotation Rate Plot

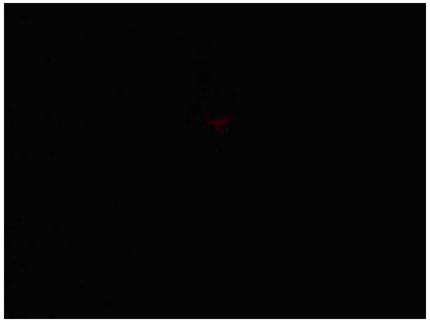


Accurately represents what was physically observed as after probe release, the rotor blades jam and essentially stopped spinning due to the lack of stabilization from a missing parachute. Although some spinning was observed, the magnet likely passed by the hall sensor one single time – an artificial measurement of the rotation rate.

Payload Release Camera Video



Struggling camera sensor during CanSat integration (black lines on screen, bright flashes):
https://drive.google.com/file/d/1yr0GdckrrTrf2QQrKLBeiR2vzp16YpVA/view?usp=sharing



The camera likely seconds before crashing for the final time (only a small splotch of red/data):
https://drive.google.com/file/d/1SEHR9c_Iuld-7ti87NWoYEFy61v4EapE/view?usp=sharing

Unfortunately, our camera sensors failed to record videos. Our assessment is that due to the extreme air temperature of ~40ºC in the CanSat Payload, the already thermally stressed sensors overheated, resulting in the destruction of the Payload Release Camera, as well as the Ground Camera to crash. This is supported by the steep decline in recording quality during testing as seen in the two recordings attached as well as the significantly worse camera quality in the Ground Camera footage, further discussed in the next slide.

Ground Camera Video

Likely the most recently recorded frames before the sensor permanently failed: https://drive.google.com/file/d/1IrfCSjjWt9cMLMz9yvkIMIQQvBz5fMV1/view?usp=sharing

Signs of eminent sensor failure were present when conducting a postmortem of launch day: https://drive.google.com/file/d/10pqGMasy4BveemrgkuoYIrZsPExTgofy/view?usp=sharing

The appearance of footage recorded with the Ground Camera prior to launch day for reference: https://drive.google.com/file/d/1SapZ7BgK9RTjxkdH8Ko7na3ef_32PFTB/view?usp=sharing

As you can see, the images captured on and after launch day with the camera are extremely dark and are primarily only red or blue—in stark contrast to footage recorded prior to the extreme heat of launch day.

Failure Analysis

Adam Kabbara

Identification of Failures, Root Causes, Corrective Actions

1. Failed to retain parachute

2. Failed to hold all rotors

3. Failed to point cams north

4. Cams failed mid mission

Ejection charge wrongly timed possibly due to slow motor start-up. This caused an early ejection at high speed

The parachute was exposed to much greater loads than expected, causing the parachute cord to rip through its attachment points and separate the parachute from the container

This caused the container to rapidly tumble causing the payload to tumble as well and not deploy all rotors correctly

During the flight, our ground station was ready to send a command to manually release the payload in case of a problem with the flight software. This did not end up being needed.

Launch Video:
https://drive.google.com/file/d/1cjAtmRTXh1Y_zpiC4DniZekwGRUozfjr/view?usp=drivesdk

Identification of Corrective Actions

Upgrade Parachute Strength and Testing Procedures
- Select a more robust parachute capable of withstanding higher-than-expected loads at apogee.
- Conduct stress testing beyond nominal conditions to simulate worst-case deployment scenarios.

Improve Thermal Management and Environmental Testing
- Implement active or more effective passive cooling systems instead of relying solely on airflow during descent and limited runtime.
- Conduct full environmental testing on all systems, including thermal testing of components such as onboard cameras.
- Note: Camera thermal testing was omitted due to incomplete test specifications; this must be addressed in future protocols.

Reduce Payload Mass from internal Shroud Usage
- Consider using a lighter shroud or removing it entirely.
- While the shroud offers aerodynamic benefits and helps protect the electronics, the added mass negatively impacts payload efficiency and system performance.

Secure Sensor Mounting and Improve Mechanical Integration
- Avoid relying on header pins for securing electronics, especially for critical components like the XBee.
- Sensors with mounting holes should continue using standoffs; however, for modules without mounting features, design and implement 3D-printed enclosures or brackets to ensure mechanical stability.
- Bolting down all sensors improves durability, reliability, and resistance to vibration/shock during flight.

Lessons Learned

Arthur Goetzke-Coburn, Gianluca Ceccacci, & Adam Kabbara

Discussion of What Worked and What Didn't

What Worked:

Custom-Built Antenna successfully communicated with the XBee on the payload and was easily hand-held.

Custom PCBs were effective, yielding good space utilization.

Altitude data was accurate, and the logic was correct. This lead to the Auto-Gyro successfully decoupling from the CC at 75% of apogee where the rotor blades successfully lifted as anticipated after a proper quick release.

The fiber glass composite rotor blades were very strong and survived impact.

Altitude, Magnetometer, Hall Effect, and temperature data was accurate.

Buzzer survived impact with the ground – JST connectors are effective.

The internal structure of the payload survived impact with relatively minimal damage, protecting the sensors from damage.

What Didn't Work:

ESP32s were unreliable microcontrollers, making them difficult to work with and requiring frequent replacement.

Lightweight ASA was difficult to print and weak (poor layer adhesion and brittleness). It should not have been used for small prints that require increased structural integrity such as our gearbox supports.

Fiber glass layup rotor blades are ineffective at the hinges of the rotor system, requiring 3D printed attachments for proper integration.

FDM 3D printed gears should be replaced by either metallic gears or potentially resin printed ones.

The cameras failed mid mission -- this demonstrates need for better thermal management and better overall cameras.

The Auto-Gyro system was slow to assemble and needed to be assembled in a specific order, making modifications and testing to certain parts difficult, showing a strong need for better design for assembly.

Conclusion

This year, University of Toronto's RSX made a proud return to CanSat after 9 years of absence. We achieved 2 of our 4 external objectives and successfully launched a payload with custom 15g fiberglass layuped rotors.

Though we faced challenges, including a parachute failure and mid-mission camera loss, we collected valuable data and learned a lot. We also had an amazing time meeting teams from around the world and sharing learning from each other.

Special thanks to the University of Hawai'i team for lending us a GPS last-minute, and to the CanSat organizers and judges for making this a great experience. See you next year!