

LAUNCH CANADA 2026 CHALLENGE



Final Design Report for UNB Rocket Engineering and
Propulsion Laboratory (UREPL)

Competing Team 46

Revision History

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ABSTRACT

Our team has successfully built a flight ready Rocket capable of reaching more than 10 thousand feet in altitude, using solid propulsion motors. The Zaphod rocket incorporates an avionics system, electronics sled, motor retainment system, dual deploy recovery system and launch rail button system. Our team opted to bring a camera payload onboard for the Launch. I believe it's also notable that our Rocket Build was on an accelerated timeline, because the Rocket Assembly only genuinely started on June 24th, 2026. Below are the start and end dates for the project's subsystem objectives:

1. Vent-band and Coupler Assembly
 - a. Start date: June 24th, 2026
 - b. End date: June 24th, 2026
2. Avionics Bay Assembly
 - a. Start date: June 25th, 2026
 - b. End date: July 13th, 2026
3. Altimeter Design and Manufacturing
 - a. Start date: July 9th, 2026
 - b. End date: July 13th, 2026
4. Booster Assembly
 - a. Start date: June 27th, 2026
 - b. End date: July 10th, 2026
5. Motor Mount Assembly
 - a. Start date: June 28th, 2026
 - b. End date: July 4th, 2026
6. Fin Assembly
 - a. Start date: July 4th, 2026
 - b. End date: July 9th, 2026
7. Airframe finishes and Painting
 - a. Start date: July 14th, 2026
 - b. End date: July 17th, 2026
8. Payload Assembly
 - a. Start date: July 13th, 2026
 - b. End date: July 14th, 2026
9. Tests and experiments to ensure the success of the Rocket
 - a. July 10th, 2026
 - b. July 17th, 2026

TABLE OF CONTENTS

SECTION	PAGE
CONTENTS	
ACKNOWLEDGEMENTS	iii
AUTHORS.....	iv
ABSTRACT	v
ABBREVIATIONS	vii
NOMENCLATURE	viii
LIST OF FIGURES.....	viii
LIST OF TABLES	viii
1.0 INTRODUCTION.....	1
1.1 UPDATES AND LESSONS LEARNED	1
Avionics Bay.....	4
1.2 TEAM ORGANIZATION.....	13
2.0 REQUIREMENTS	14
2.1 MISSION REQUIREMENTS	14
2.2 SYSTEM REQUIREMENTS	14
2.3 SUBSYSTEM REQUIREMENTS.....	15
3.0 SYSTEM ARCHITECTURE OVERVIEW.....	17
3.1 AEROSTRUCTURE	19
3.2 PROPULSION.....	20
3.3 AVIONICS AND TELEMETRY	21
3.4 RECOVERY SYSTEM	22
3.5 GROUND SUPPORT AND OPERATIONS	22
4.0 MISSION CONCEPT OF OPERATIONS OVERVIEW	24
Phase A: Ground Handling	24
Phase B: Ignition.....	24
Phase C: Liftoff.....	24
Phase D: Powered Flight.....	25
Phase E: Unpowered Flight (Coast).....	25
Phase F: Drogue Descent	25
Phase G: Main Descent	26
Phase H: Touchdown	26

Phase I: Ground Recovery 26

5.0 MISSION ANALYSIS 26

6.0 MASS BUDGET 30

 Mass Budget Breakdown 30

7.0 FLIGHT DYNAMICS 33

8.0 AEROSTRUCTURAL DESIGN 36

8.1 NOSE CONE 36

8.2 AIRFRAME AND BULKHEADS 36

 37

8.3 COUPLER(S) 37

 37

8.4 FINS 37

9.0 PROPULSION SYSTEM 38

10. 1 SYSTEM DESIGN, TRADES AND PERFORMANCE SUMMARY 38

10.0 SOFTWARE 1

11.0 HAZARD ANALYSIS 1

 Hazard 1

 Possible Causes 1

 Consequence 1

 Mitigation Approach 1

 Risk After Mitigation 1

12.0 TEAM DEVELOPMENT 3

12.1 SUCCESSION PLANNING 3

12.2 KNOWLEDGE RETENTION 4

12.3 OUTREACH 5

12.4 BUSINESS AND MARKETING 6

13.0 REFERENCES 10

ABBREVIATIONS

AIAA	American Institute of Aeronautics and Astronautics
AGL	Above Ground Level
CONOPS	Concept of Operations
COTS	Commercial Off The Shelf
DOT	Department of Transportations
EGSE	Electrical Ground Support Equipment
ESA	European Space Agency
GSE	Ground Support Equipment
GPS	Global Positioning System

MGSE	Mechanical Ground Support Equipment
NASA	National Aeronautics and Space Administration
NDT	Non-Destructive Testing
P&ID	Piping and Instrumentation Diagram
SRAD	Student Researched And Developed
STEM	Science, Technology, Engineering and Mathematics
TC	Transport Canada
WBS	Work Breakdown Structure

NOMENCLATURE

m/s ²	Acceleration
CO2	Carbon Dioxide
<i>Isp</i>	Engine Specific Impulse
<i>ft</i>	Feet
<i>g</i>	Gravitational Constant of 9.81 m/s ²
<i>kg</i>	Kilograms
<i>m</i>	Meters
O/F	Mixture Ratio
<i>N</i>	Newtons
<i>s</i>	Seconds
<i>Ns</i>	Total Impulse
<i>Cv</i>	Valve Flow Coefficient
m/s	Velocity (also denoted by ft/s)

LIST OF FIGURES

FIGURE	PAGE
Figure 1: [Rocket Name] System Architecture [4]	18

LIST OF TABLES

TABLE	PAGE
-------	------

1.0 INTRODUCTION

Project Zaphod's mission is to develop a launch vehicle capable of reaching more than 10 thousand feet in altitude. A particular area of focus for our engineering project was to develop it in a highly systematic, practical and efficient manner, that can easily be reproduced in later years. Our Rocket was designed to be tall, while also satisfying the rest of our design objectives (achieving an apogee of at least 10 thousand feet, above Mach 1 speed, etc.).

Our original design used the intimidator 3-inch diameter rocket kit as its base model, but since our initial design proposal report, our team opted for the 3-inch diameter Wildman Dual Deploy rocket kit, primarily because of the extra-space it provides for dual deployment, alongside payload loading. Our intended solid propulsion motor for the competition switched from a CTI K1200 to a CTI K820 motor, because the latter possesses superior total impulse than the former, thereby maximizing our achievable altitude within the K-class of motors. Other changes from the original design also included incorporating a 24-inch drogue and 58-inch main parachute for the dual deployment recovery system, instead of a 30-inch drogue and 50-inch main parachute.

Our 36-member team operates under a culture inspired by the world's most respected aerospace organizations, one defined by high standards, deliberate urgency, and a bias toward action. To reinforce this, we set internal deadlines ahead of external ones and pursued challenges beyond what was strictly required.

Weekly virtual ideation sessions kept ideas flowing between hands-on rocket build sessions held at our newly established Rocket Engineering and Propulsion lab in IUC Physics Room 321, UNB Fredericton.

1.1 UPDATES AND LESSONS LEARNED

Over the past few months, our team has made strong progress on the design and development of the Zaphod rocket. This update covers our recent build session, key structural milestones, and some of the challenges we've worked through along the way.

2nd Rocket Build Session — April 27, 2026

UREPL held its second rocket build session on April 27th, 2026, marking an important step forward on the Zaphod rocket. We successfully dry-fit the entire fiberglass airframe to verify component alignment ahead of assembly, and performed aqueous cleaning of all mating surfaces to remove contaminants prior to structural bonding. We also refined our digital model with further improvements and developed a detailed engineering timeline for the full build, which we'll continue to iterate as construction progresses.



Figure: A portion of our Team

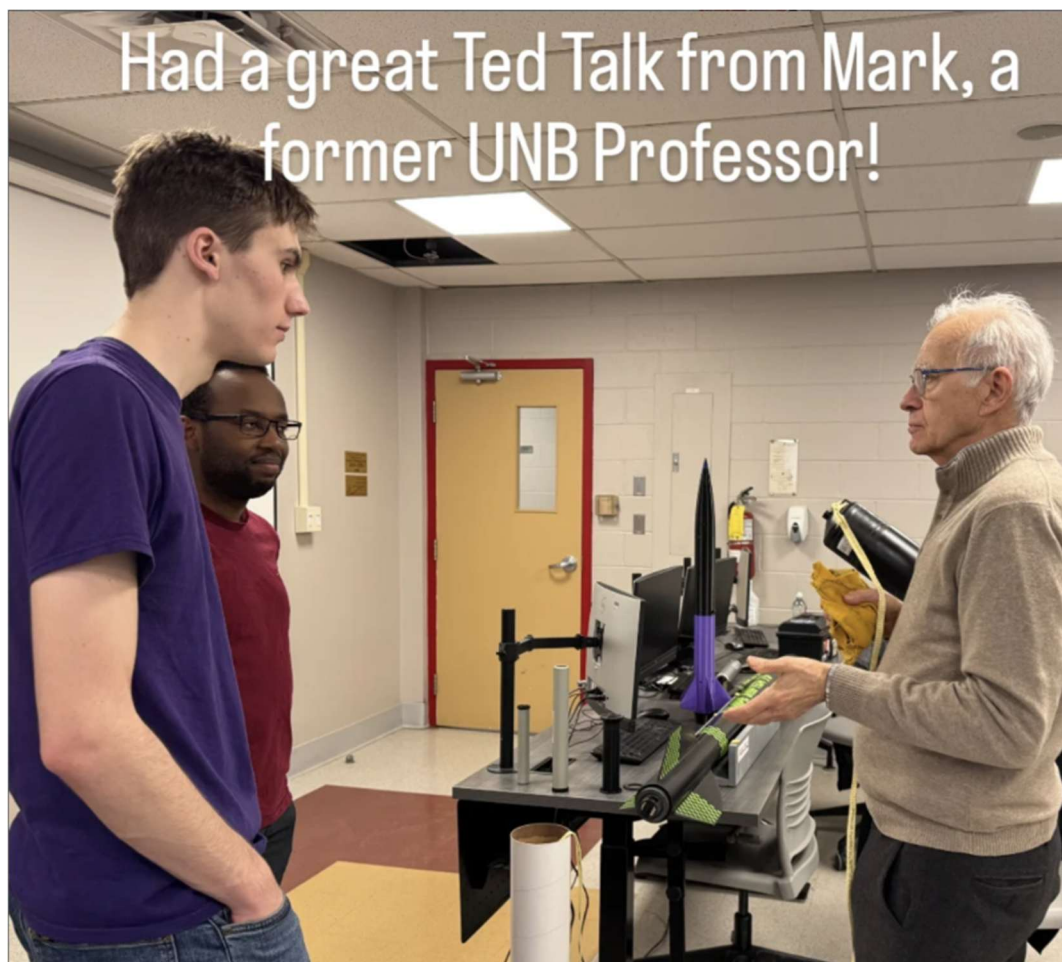
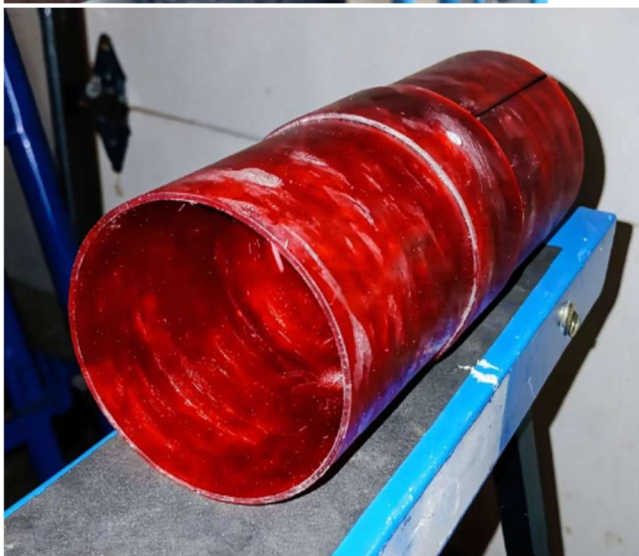


Figure: Very fruitful discussion with Dr. Mark, a former UNB Professor

AVIONICS BAY



We've also made significant progress on the avionics bay, completing the vent band and coupler assembly that forms the core of the avionics tube. In the process, the team learned how to properly mix epoxy resin and hardener and gained hands-on experience assembling this key rocket component.

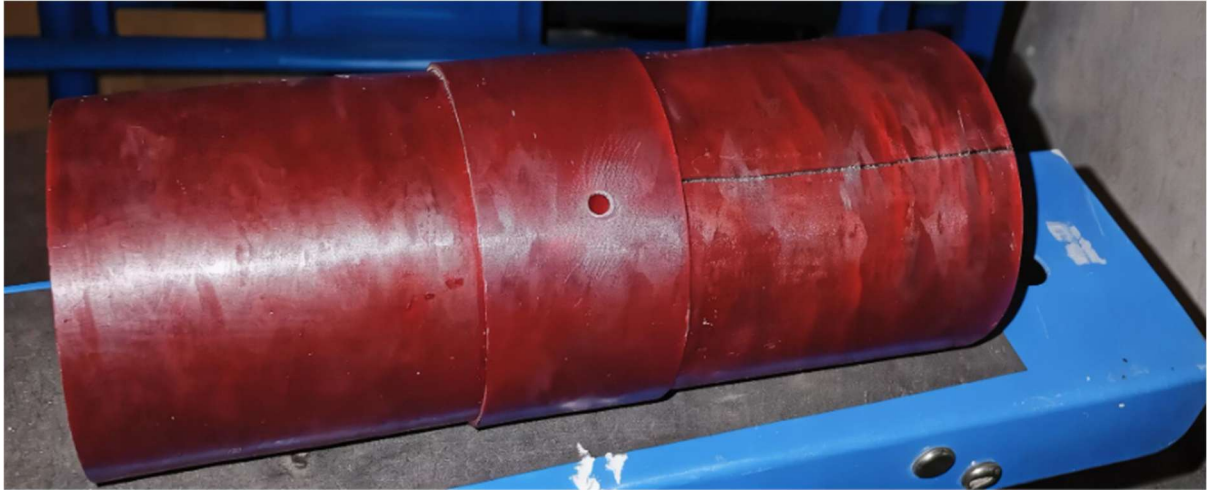


Figure: Progress on the avionics bay, completing the vent band and coupler assembly,

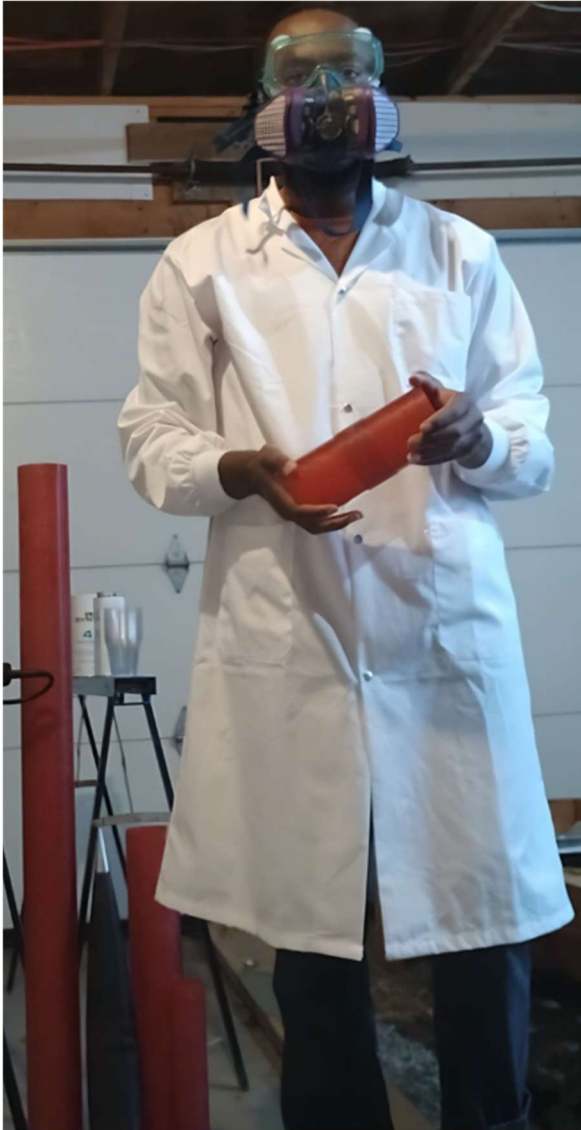


Figure: Team Captain Holding the Coupler Assembly

In the last month, we have completed the first motor mount tube assembly.



Figure: The first motor mount tube assembly by UREPL (with epoxied kevlar thread)



Figure: The Team Captain Holding the newly completed motor mount tube assembly

Electronics Sled & Fin Alignment Jig

The design and integration of the altimeter and electronics sled into the coupler is now complete. The sled was designed in-house and 3D-printed at the UNB Makerspace, with the UREPL name embossed on its surface. It will house all of the rocket's electronics,

including the camera payload. We've also printed our fin alignment jig, and the fins fit within it perfectly.

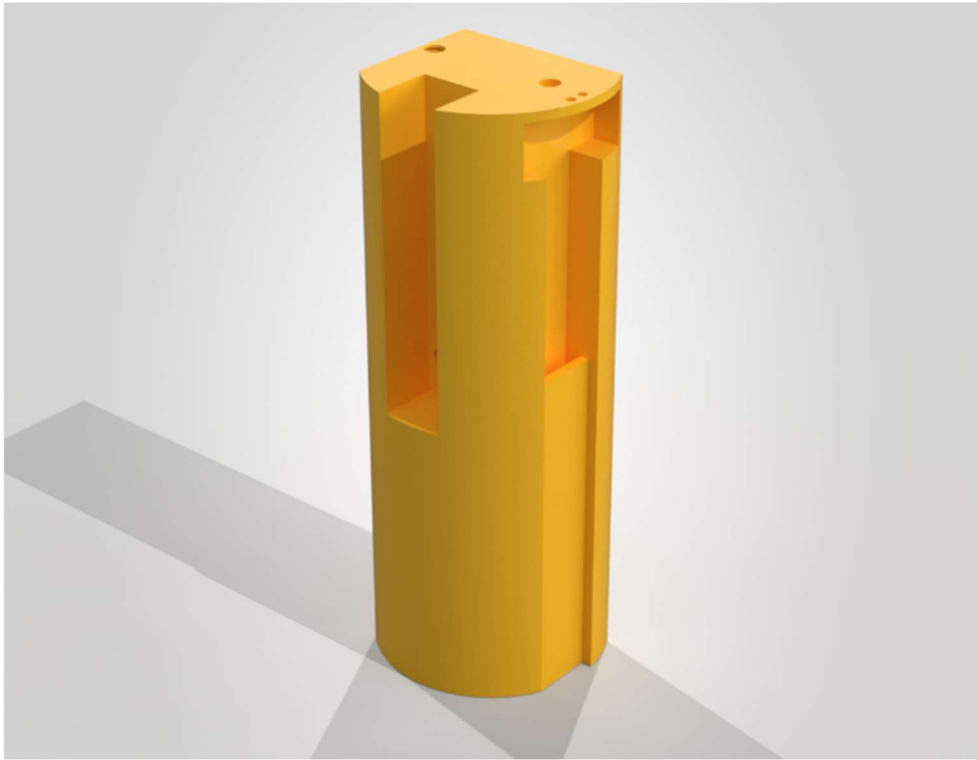


Figure: 3D design of Electronic Sled



Figure: 3D design of the Fin Alignment jig



Figure: Fins attached to Rocket

Challenges and Lessons Learned

Every build session brings its share of decisions, and each one has been worked through with careful discussion and hands-on testing. A few of the more notable examples:

1. Rethinking our build approach for fiberglass construction. Our original plan treated the airframe like a simple cardboard rocket, which doesn't hold up for a fiberglass, dual-deployment design. Several key steps needed rethinking, so our team mentor recommended we follow established fiberglass construction practices, such as those outlined in Wildman's general build guidelines, which are written specifically for high-performance composite rockets. Since we'd already purchased an AeroPack motor retainer, our original plan to use blind-nut motor retention was no longer necessary.
2. Learning to work with West Systems epoxy. While the process seemed simple at first, there was a real learning curve in preparing and applying it correctly — getting the right ratio of thickener to hardener, and using the correct pump for each component, took some practice. Surface preparation proved just as important as the epoxy itself: we scuffed all bonding surfaces with 80-grit sandpaper, then wiped them down with isopropyl-alcohol-dampened paper towels to remove sanding dust and skin oils before bonding. We also found that isopropyl alcohol on a paper towel is an effective way to clean up uncured epoxy.
3. Sizing the Y-harness. We were initially unsure how far the top loop of the Y-harness needed to extend beyond the booster section, whether it needed to protrude far enough for easy attachment during a dry fit with the avionics bay, and whether trimming the harness was necessary if its length didn't interfere with the motor mount. After discussion and hands-on testing, we found that the loop only needs to extend slightly past the booster for a reliable connection, and its exact position relative to the motor tube isn't especially sensitive for shock absorption. As long as the harness isn't excessively long or contacting the motor mount, no trimming is required — the setup turned out to be more forgiving than expected, and we'll confirm its performance at our upcoming test launch.
4. Choosing a print material for the electronics sled and fin jig. The UNB Makerspace offers 3D printing in PLA Tough+, which we initially considered for its tensile strength. After team discussion, we opted for PETG instead, which offers better impact resistance, toughness, heat tolerance (important for parts near electronics), and shock resistance compared to PLA Tough+. Our initial prints, which include the team name, were done in PLA Tough+, but the final flight-ready parts will be printed in PETG — we've already requested the material from the Makerspace, who are sourcing the filament for us.
5. Selecting rail buttons. Rail buttons are widely available, but finding the right shape for our design took some care. In particular, we had to ensure no screw would protrude into the airframe compartment, where it could snag the recovery system and prevent

proper deployment.

These are just a handful of examples — if we counted every decision like this, the list would easily reach a hundred. Each one, however small, has been finalized only after thorough discussion and physical testing.

1.2 TEAM ORGANIZATION

All our members thus far are completely new to Amateur Rocketry, except for our team mentor (S. James Richard),

We are a diverse group representing a wide range of academic and professional backgrounds. Key leadership roles within the team are held by:

- Team Captain: Victor Habiyambere
- Propulsion Lead & Team Captain: Matthew Maloney (Mechanical Engineering)
- Payload Lead: Pranavaditya Naren (Environmental Engineering)
- Avionics Lead: Tishant Doorgapersand (Computer Science)

Faculty Advisor

Dr. Torsten Reuschel

Mentors

Sebastian Richard.

Apart from them, we have a long list of dedicated team members from the undergraduate level to the PhD level. We have team members with backgrounds in mechanical, environmental, computer science, and materials. It's a strong combination of expertise and devotion. Our team is our main strength. Other team members include:

1. Aditya Jatin Raval
2. Ahmed Aouf
3. Alhussein Aley
4. Amil Shahul
5. Anthony Arseneau
6. Avery Surtees
7. Cole Costain
8. Emir Ersin
9. Evan Michael John Israel
10. Hana Butt
11. Ismail Kamal Shahta Karim
12. Jaxom Thornton
13. Justin Riley Schwenger

14. Larry Motilayo Davies
15. Liam Dale Wilkie
16. Martin Lunniss Platt
17. Md Rashidun Nawaz Shaown
18. Miguel Yamane
19. Nachiket Soham Pandya
20. Paul Fatuberu
21. Saif Abdelmoghny Mustafa
22. Saifalislam Emara
23. Soham Prashant Sontate
24. Tishant Doorga Persand
25. Vaibhav Krishna Bhatta
26. Viktor Lorberer

2.0 REQUIREMENTS

2.1 MISSION REQUIREMENTS

Functional Requirements:

- The Rocket shall be designed to safely depart a 1010 launch rail provided by Launch Canada.
- Flight trajectory shall be parabolic until deployment of parachutes. This will ensure that the Rocket will not go ballistic when it reaches the ground.

Performance Requirements:

- The Zaphod Rocket shall reach a maximum apogee greater than or equal to 10 thousand feet.
- The Rocket shall reach a maximum speed of greater than or equal to Mach 1.
- The Rocket's camera payload shall provide a stable recording of the entire flight mission.
- The Rocket shall depart the launch rail with velocity not exceeding 30m/s.

2.2 SYSTEM REQUIREMENTS

SR-1 (Aerostructure). The airframe, fins, and joints shall maintain structural integrity through all phases of flight up to and including a maximum velocity of Mach 1, with no failure of bonded or mechanically fastened joints (nosecone-to-shoulder, coupler-to-bulkhead, fin-to-motor-mount, fin-to-booster). *Source: derived from Mission Requirement — max speed $\geq$ Mach 1.*

SR-2 (Aerostructure). The vehicle's static margin and fin geometry shall be sized to prevent fin flutter and to maintain aerodynamic stability throughout powered and coast flight, ensuring the trajectory remains parabolic (non-ballistic) through parachute deployment. *Source: derived from Mission Requirement — parabolic trajectory until deployment.*

SR-3 (Aerostructure/Payload). The nosecone shoulder/bulkhead assembly shall provide a stable camera mount capable of recording the full flight without loss of orientation or vibration-induced image degradation. *Source: derived from Mission Requirement — stable camera recording of entire flight.*

SR-4 (Propulsion). The propulsion system shall deliver sufficient total impulse to achieve a simulated apogee of at least 10,000 ft AGL, with margin to account for as-built mass growth (current design: CTI K820, simulated apogee 10,390.42 ft). *Source: Mission Requirement — apogee $\geq 10,000$ ft; Launch Canada Rules and Requirements Guide [1].*

SR-5 (Propulsion). The motor and motor-mount interface shall be capable of producing the peak/average thrust needed to depart the launch rail at a velocity not exceeding 30 m/s while achieving Mach 1 during the burn. *Source: Mission Requirements — rail departure velocity ≤ 30 m/s; max speed $\geq$ Mach 1.*

SR-6 (Avionics and Telemetry). The avionics system shall reliably detect apogee and a preset altitude to trigger drogue and main parachute deployment, and shall provide GPS tracking data to a ground station sufficient to recover the vehicle regardless of landing location. *Source: derived from Mission Requirement — safe recovery/departure of parabolic trajectory; Launch Canada DTEG [3].*

SR-7 (Recovery System). The recovery system shall deploy a drogue parachute at apogee and a main parachute at approximately 500 m AGL, sized to limit descent rate and horizontal drift so the vehicle and camera payload land without damage that would compromise data recovery. *Source: derived from Mission Requirement — parabolic (non-ballistic) descent; Launch Canada DTEG [3].*

SR-8 (Ground Support and Operations). Ground support equipment shall safely interface with a 1010 rail provided by Launch Canada and support departure at a velocity not exceeding 30 m/s. *Source: Mission Requirement — safe departure from 1010 rail; Launch Canada Rules and Requirements Guide [1].*

2.3 SUBSYSTEM REQUIREMENTS

- **Nose Cone:** Shall be fabricated from G10 fiberglass with an aluminum tip, and shall maintain its bonded joint to the shoulder coupler (West System epoxy) under the aerodynamic and thermal loading experienced up to Mach 1.
- **Airframe and Bulkheads:** Body tube sections and bulkheads shall be G10 fiberglass, sized to carry the axial and bending loads from motor thrust, drogue/main deployment shock loads, and aerodynamic loading without buckling, crippling, or joint separation.

- **Couplers:** The payload-to-nosecone coupler shall use a friction-fit connection with shear-pin retention sized to withstand ejection-charge pressure without premature separation, while shearing reliably at the intended deployment event; the booster-to-payload coupler shall be friction-fit and reinforced via the Kevlar shock cord/avionics bay lower eyebolt interface. Fit shall minimize play/misalignment at the joint to avoid introducing a structural "kink" under aerodynamic loading.
- **Fins:** Shall be G10 fiberglass, sized and reinforced (via internal fillet injection at the fin-to-MMT joint and external fillets at the fin-to-booster joint) to prevent flutter at all velocities up to Mach 1, and shall maintain alignment (via fin-alignment-jig-assisted installation) within tolerances that preserve the vehicle's stability margin.
- **Camera Mount:** The nose cone shoulder camera mount shall be secured to the nosecone bulkhead via 4-40 machine screws and hex nuts, providing a rigid, vibration-resistant platform sufficient to keep the camera's field of view stable for the full flight duration.

3.2 Propulsion Subsystem

- **Motor:** The selected COTS motor (CTI K820) shall provide sufficient total impulse and average thrust (794.527 N average, 1720 N peak) to achieve a simulated apogee $\geq 10,000$ ft while keeping rail-departure velocity ≤ 30 m/s.
- **Motor Mount (MMT):** Shall retain the motor case for the full burn duration and subsequent coast/recovery phase, with the Kevlar shock cord epoxied to the MMT at three points spaced 120° apart to avoid fin interference and to distribute recovery shock loads evenly.
- **Centering Rings:** Shall be positioned and sized to maintain MMT concentricity within the booster section and to accommodate routing of the Kevlar recovery harness without chafing.

3.3 Avionics and Telemetry Subsystem

- **Altimeter (Featherweight Blue Jay Plus):** Shall independently detect apogee and a preset main-deployment altitude and fire the corresponding ejection charges within the timing tolerances needed to achieve drogue deployment at apogee and main deployment at ~ 500 m AGL.
- **GPS Tracker and Ground Station (Featherweight):** Shall maintain a continuous telemetry link from launch through landing sufficient to localize the vehicle for recovery, regardless of landing location.
- **Power/Wiring:** Avionics wiring and battery provisioning shall be sized to guarantee continuous operation of the altimeter and GPS for the full mission duration, including a ground pre-flight checkout period.

3.4 Recovery Subsystem

- **Drogue Parachute:** Sized (24 in.) to control descent rate between apogee and main deployment such that the vehicle remains within safe descent limits without excessive drift.

- **Main Parachute:** Sized (58 in.), deploying at ~500 m AGL, to reduce touchdown velocity to a level that prevents damage to the airframe, avionics, and camera payload.
- **Harness:** The 165 cm Kevlar shock cord (motor-mount side) and 550 cm nylon harness (upper section) shall be sized with sufficient strength margin to survive peak deployment shock loads without failure, while routing to minimize tangling risk.
- **Ejection/Ignition:** E-matches shall reliably ignite black-powder (or equivalent) charges sized to separate the couplers at the shear-pin retention force, without exceeding pressure limits that could damage the airframe.
- **Thermal Protection:** Two Nomex blankets shall protect the parachutes and harness from ejection-charge hot gases, preventing thermal damage that could compromise recovery system function.

3.5 Ground Support and Operations Subsystem

- **Launch Rail Interface:** The rocket's rail buttons/guides shall be compatible with the 1010 rail provided by Launch Canada, and shall permit a clean departure at a velocity not exceeding 30 m/s.
- **Ground Station:** The Featherweight ground station shall maintain link lock with the onboard GPS tracker from pad setup through recovery.

3.0 SYSTEM ARCHITECTURE OVERVIEW

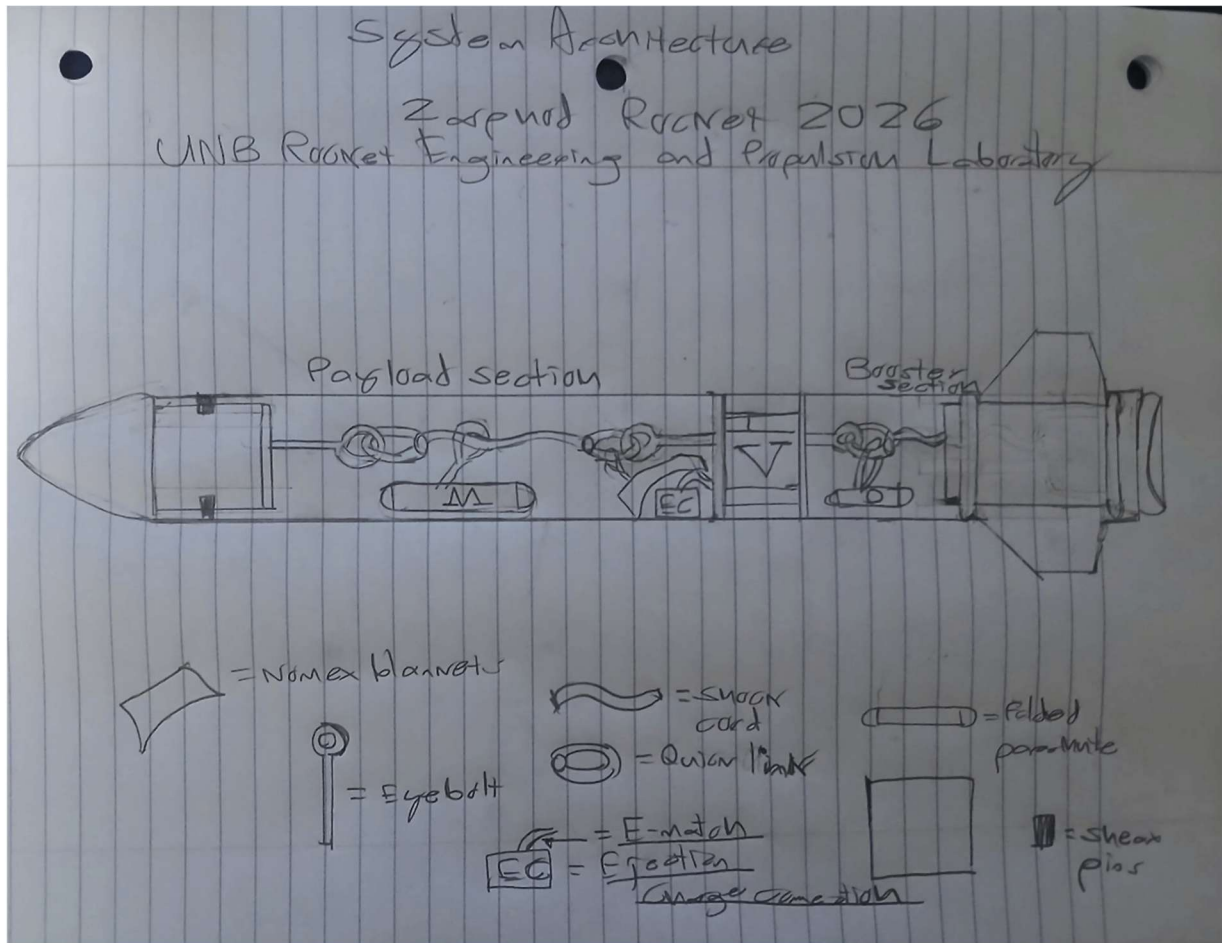


Figure: Zaphod System Architecture

Note: The bulkheads are represented as thin rectangular slice, and centering rings are represented as flattened ovals on the diagram above

Some important changes made from the original design include an improved understanding of the general architecture of a solid propulsion rocket. For instance, we had previously incorporated a dual deployment system in our preliminary design report (PDR), but we did not know the exact joint mechanism required between the shock cords, nor did we know where the centering rings would need to go, and why they need to be placed there. Since our PDR, we have greatly increased our understanding of these crucial details, that are important towards the structural integrity of Zaphod, and rockets in general, and therefore its likelihood for a successful flight mission.

3.1 AEROSTRUCTURE

The vehicle's aerostructure consists of a nosecone, nosecone shoulder body tube, a bulkhead that encloses the nosecone shoulder (and encapsulates the camera payload), payload section, booster section, fins, eyebolts, nylon shock cord, avionics bay, electronics/camera mounts, and motor mount tube (MMT). The nosecone, nosecone shoulder body tube, bulkheads, payload section, booster section, fins, avionics bay, and MMT are all made of G10 fiberglass. The nosecone itself is aluminum-tipped. The nosecone-to-shoulder joint is bonded with West System epoxy.



Figure: Nosecone

The camera mount-to-nosecone bulkhead joint is secured with 4-40 machine screws and hex nuts. The nosecone coupler-to-bulkhead joint is bonded with West System epoxy, and the payload section-to-nosecone coupler/shoulder joint uses a friction-fit connection with shear-pin retention.

The avionics bay coupler-to-vent band joint is bonded with West System epoxy. The avionics bay connects to the upper section of Zaphod via its upper eyebolt, which links to a quick link, which in turn connects to a nylon shock cord running through the payload section up to the quick link and eyebolt at the base of the nosecone coupler. The booster-to-payload section connection is friction-fit via the avionics bay coupler and is further reinforced by the connection between the MMT's Kevlar shock cord and the avionics bay's lower eyebolt (via a quick link), which is mechanically fastened to the avionics bay's lower bulkhead. The Kevlar shock cord is epoxied directly to the MMT surface at points spaced 120 degrees apart to avoid interference with Zaphod's fins.



Figure: Avionics Bay

For Zaphod's assembly, we used injected internal fillets to strengthen the fin-to-MMT joints and external fillets for the fin-to-booster joints. The rest of the building process was relatively straightforward; however, our key takeaways were the importance of proper Kevlar cord placement to ensure it performs its intended function, correct positioning of the centering rings relative to the MMT, and correct placement of the MMT relative to the booster section.



Figure: Rocket Fins

Working through the full assembly process gave us a clearer, deeper understanding of the fundamental principles of rocket engineering than the bare-bones Open Rocket models we'd referenced beforehand.

3.2 PROPULSION

The Zaphod Rocket uses a solid propulsion system. The representative for the propulsion system is our team's MMT sub-assembly, and the COTS motor we will be using is the CTI K820 rocket motor for the Launch Canada Challenge, permitting our team to achieve a simulated altitude of 10390.42 feet. The CTI K820 motor is made of Ammonium Perchlorate, has a peak thrust of 1720N, an average thrust of 794.5270N.

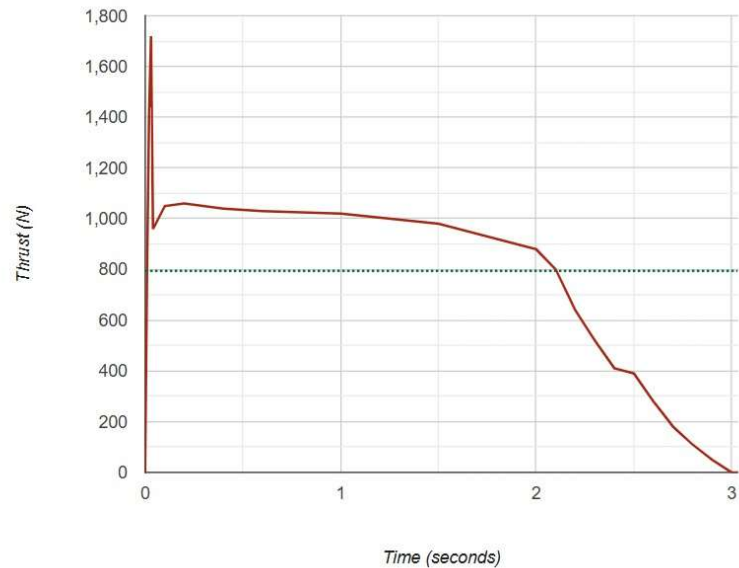


Figure: The thrust vs time curve for the CTI K820 Rocket Motor

3.3 AVIONICS AND TELEMETRY

The rocket’s avionics system consists of a blue jay plus altimeter, featherweight GPS tracker, which itself is linked with a featherweight ground station, allowing us to retrieve our Rocket regardless of where it ends up being located after the launch.

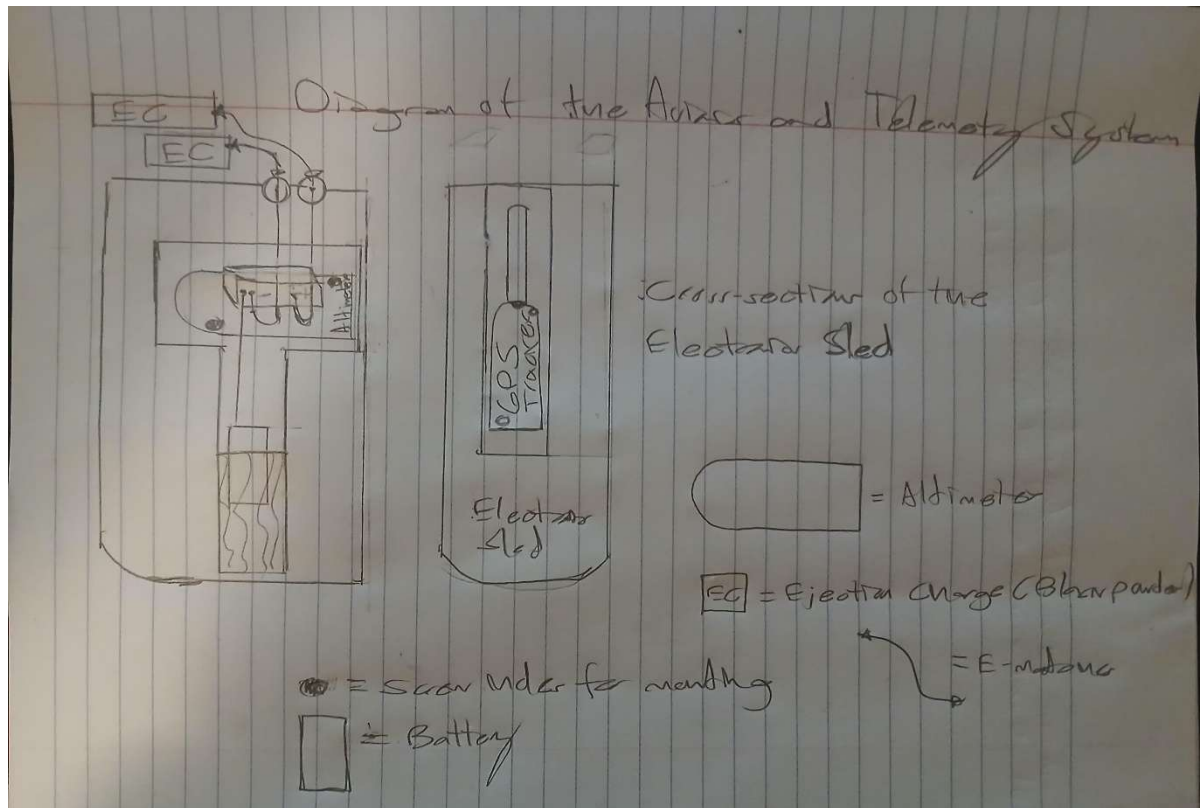


Figure : Avionics wiring/structure diagram

3.4 RECOVERY SYSTEM

The Zaphod Rocket makes use of a dual deployment system. To achieve dual deployment, The rocket uses a 24-inch drogue, 58-inch main, 165cm Kevlar shock cord, 550cm nylon recovery harness, e-matches, featherweight blue jay plus altimeter and 2 Nomex blankets to protect the chute from ejection charges. During Zaphod's flight mission, the drogue parachute gets deployed, followed by the main parachute at around 500 meters, to minimize drift and achieve a controlled, gentle touchdown.

3.5 GROUND SUPPORT AND OPERATIONS

The aft rail button is located above the aft Centering Ring. The forward rail button placement is located a couple of inches forward of the aft rail button, and their placements have been optimized for the 12 foot launch rails available at Launch Canada. At the ground station, which consist of in a nutshell of the team captain's phone, and the featherweight GPS ground station linked via the Bluetooth, we will record the rocket's entire flight and trajectory, alongside altitude and other important parameters. Our rocket uses solid propulsion, so we only need an igniter to start up our Rocket and engage it for a successful

launch.

4.0 MISSION CONCEPT OF OPERATIONS OVERVIEW

The mission concept of operations for Zaphod's flight mission consists of nine distinct phases, from ground handling through recovery. The following detailed description expands upon the overview and flowchart presented in Figures 2 and 3.

Phase A: Ground Handling

Start: The rocket has left the main assembly area and is in transit to the launchpad.

End: The launch rail has been raised and secured and the rocket is ready for launch.

After all components have been assembled and the rocket has been transported to the launchpad, the rocket will be carefully loaded onto the horizontal launch rail. The 1010 rail system, provided by Launch Canada, is compatible with the rail buttons installed on Zaphod. The aft rail button is located above the aft centering ring, while the forward rail button is placed a couple of inches forward of the aft rail button—both positions optimized for the 12-foot launch rails available at Launch Canada.

Once the rocket is loaded, the launch rail will be raised and secured. The Featherweight Blue Jay Plus altimeter will be armed, and the Featherweight GPS tracker will establish a link with the ground station (team captain's phone via Bluetooth). The Runcam 2 camera payload will be activated to begin recording prior to launch. The final step is the installation of the motor igniter for the CTI K820 solid propulsion motor. All personnel will then vacate the launch area and return to the Assembly Area. All subsystems will be on standby, awaiting the ignition signal.

Phase B: Ignition

Start: The ignition signal has been sent to the rocket and the propellant has been successfully ignited.

End: The rocket begins to accelerate.

Within the propulsion subsystem, the igniter will initiate combustion of the CTI K820's Ammonium Perchlorate propellant. The combustion chamber will pressurize to nominal operating conditions. The rocket will then begin to accelerate up the launch rail. The recovery, payload, and avionics subsystems remain on standby during this initial phase.

Phase C: Liftoff

Start: The rocket has begun to accelerate.

End: The first launch lug has cleared the launch rail.

As the rocket begins to accelerate, the peak thrust of 1720N will be induced on the thrust ring and internal structures. This phase is especially crucial to mission success since any shift of mass would destabilize the rocket. The CTI K820 motor will continue accelerating the rocket. Upon detecting 3g's of acceleration, the Featherweight Blue Jay Plus altimeter and the payload camera will begin acquiring data. The recovery subsystem remains on standby.

Phase D: Powered Flight

Start: The first launch lug has cleared the launch rail.

End: The motor burns out and the rocket begins to decelerate.

When the first launch lug has passed the top of the launch rail, Zaphod will be ascending at a speed sufficient to provide adequate stability. The rocket will accelerate to a maximum velocity of Mach 1, achieving the mission requirement for supersonic flight. The propulsion subsystem continues to accelerate the rocket throughout the burn duration. The avionics and payload continue acquiring data. The recovery subsystem remains on standby. The avionics detect powered flight and disable igniters to prevent any unintended deployment events.

Phase E: Unpowered Flight (Coast)

Start: The motor burns out and the rocket begins to decelerate.

End: The rocket has reached apogee and the drogue parachute has been deployed.

After the CTI K820 motor burns out, the rocket will coast to its target apogee of 10,390.42 feet (simulated). The propulsion subsystem is no longer active. The avionics and payload continue to acquire data. The recovery subsystem remains on standby while the Featherweight Blue Jay Plus altimeter actively looks for the apogee condition for deployment.

Phase F: Drogue Descent

Start: The rocket has reached apogee and the drogue parachute has been deployed.

End: The rocket has descended to approximately 500m AGL and the main parachute has been deployed.

After the rocket reaches apogee, the Featherweight Blue Jay Plus altimeter will immediately detect the decrease in altitude and fire the drogue ejection charge (via an E-match and black powder charge). The 24-inch drogue parachute will be deployed, slowing the rocket to a controlled descent rate. Two Nomex blankets protect the drogue parachute and harness from the hot gases of the ejection charge. The propulsion system remains inactive. The avionics continue to acquire data, tracking the descent in preparation for main deployment.

Phase G: Main Descent

Start: The rocket has descended to approximately 500m AGL and the main parachute has been deployed.

End: The rocket has made initial contact with the ground.

Upon reaching the preset altitude of approximately 500m AGL (as determined by the Featherweight Blue Jay Plus altimeter), the main ejection charge will be activated. The 58-inch main parachute will deploy, further slowing the rocket's descent to a gentle touchdown velocity. The Nomex blankets protect the main parachute from ejection charge gases. The propulsion system remains inactive, and avionics continue acquiring data until landing.

Phase H: Touchdown

Start: The rocket has made initial contact with the ground.

End: The rocket, main parachute, and drogue parachute are at rest on the ground.

After the rocket gently impacts the ground, all components will come to rest. The Featherweight ground station will display the touchdown location via GPS tracking, from which a recovery route will be planned. The avionics and payload will be deactivated and will no longer acquire data. All subsystems will be inactive.

Phase I: Ground Recovery

Start: The recovery team has been permitted to depart from the Assembly Area to retrieve the rocket body.

End: The recovery team has returned to the Mission Control Center with the rocket body for post-flight evaluation.

After receiving permission from the Mission Control Officer, the recovery team will depart from the Assembly Area following the planned recovery route (using GPS coordinates from the Featherweight ground station). The rocket will then be inspected for any damage and any unignited charges. All personnel will be wearing appropriate protective equipment. The rocket will then be returned to the Mission Control Center for post-flight evaluation and data extraction from the Runcam 2 camera payload.

5.0 MISSION ANALYSIS

The Zaphod rocket's mission analysis demonstrates that the design is fully capable of achieving the target altitude of 10,000 feet AGL while meeting all other mission requirements. The analysis presented below validates the design's performance capabilities using the selected COTS components.

Key Mission Parameters

The mission requirements derived for Zaphod are:

Altitude: $\geq 10,000$ ft AGL

Maximum Speed: $\geq$ Mach 1

Rail Departure Velocity: ≤ 30 m/s

Trajectory: Parabolic until parachute deployment

Recovery: Dual deployment system (drogue at apogee, main at ~ 500 m AGL)

Performance Analysis

The team used OpenRocket simulation software to model Zaphod's flight performance. The simulation incorporated the following key inputs:

Motor: CTI K820 solid propulsion motor

Total Impulse: 820 Ns (K-class)

Average Thrust: 794.527 N

Peak Thrust: 1720 N

Burn Duration: ~ 2.4 seconds

Propellant: Ammonium Perchlorate

Vehicle Mass: Simulated using the mass budget established from actual measured hardware and COTS component specifications

Aerodynamic Profile: Based on the 3-inch diameter Wildman Dual Deploy fiberglass airframe with G10 fiberglass fins

Simulation Results

OpenRocket simulation results for Zaphod indicate:

Parameter	Simulated Value	Requirement	Status
Apogee	10,390.42 ft AGL	$\geq 10,000$ ft	PASS
Maximum Velocity	Mach 1.0+	$\geq$ Mach 1	PASS
Rail Departure Velocity	< 30 m/s	≤ 30 m/s	PASS
Static Margin	> 2.0 calibers	> 1.0 caliber	PASS

Assumptions and Evolution

The following assumptions were made in the mission analysis:

Weather Conditions: Standard atmospheric conditions (sea level pressure, 15°C temperature). Launch Canada's site conditions may differ, and the simulation will be updated with real-time weather data on launch day.

Mass Properties: The mass budget was updated after the transition from the Intimidator 3-inch kit to the Wildman Dual Deploy kit. The change in kit provided additional volume for the dual deployment recovery system and payload, with minimal impact on overall mass.

Motor Performance: CTI K820 thrust curve data was obtained from the manufacturer's specifications and implemented in OpenRocket. This data has been validated through extensive flight heritage.

Drag Coefficient: Simulated using OpenRocket's empirically-derived drag models for

fiberglass airframes, which have been validated against thousands of high-power rocket flights.

Changes from Initial Design Proposal

Since the initial design proposal report, several changes have been made that affected the mission analysis:

Motor Selection: Switched from CTI K1200 to CTI K820. The K820 provides superior total impulse (820 Ns vs. 1200 Ns designation) and better altitude performance within the K-class.

Kit Selection: Changed from Intimidator 3-inch to Wildman Dual Deploy 3-inch kit. The additional space for dual deployment recovery system and payload resulted in minor changes to the vehicle's mass distribution and aerodynamic profile.

Recovery System: Updated parachute sizes from 30-inch drogue/50-inch main to 24-inch drogue/58-inch main. The new sizes optimize descent rates while ensuring controlled landing.

Camera Payload: Added a Runcam 2 camera payload requiring a modification to the payload tube and nosecone shoulder (adding a hole for camera lens viewing). This modification had negligible impact on vehicle aerodynamics.

Mission Success Criteria

Zaphod's flight mission will be considered successful if the following criteria are met:

Vehicle reaches $\geq 10,000$ ft AGL apogee

Vehicle exceeds Mach 1

Drogue parachute deploys at apogee

Main parachute deploys at ~500m AGL

Vehicle lands without catastrophic damage

Camera payload provides stable recording of entire flight

The mission analysis confirms that Zaphod's design meets or exceeds all mission requirements with adequate margin.

6.0 MASS BUDGET

The mass budget is a critical input to flight simulations and ensures that the vehicle's performance predictions are accurate. The mass budget presented below is based on actual measured hardware where available, manufacturer specifications for COTS components, and conservative estimates for custom-fabricated parts.

Mass Budget Breakdown

Subsystem	Component	Mass (g)	Source
Aerostructure	Nosecone (G10 fiberglass with aluminum tip)	450	Manufacturer spec (Wildman)
	Nosecone Shoulder Body Tube	200	Manufacturer spec (Wildman)
	Payload Section Body Tube	350	Manufacturer spec (Wildman)
	Booster Section Body Tube	380	Manufacturer spec (Wildman)
	Avionics Bay Coupler/Vent	250	Manufacturer spec

Subsystem	Component	Mass (g)	Source
	Band Assembly		(Wildman)
	Fins (G10 fiberglass, set of 3)	600	Manufacturer spec (Wildman)
	Bulkheads (2)	200	Manufacturer spec (Wildman)
	Centering Rings (3)	150	Manufacturer spec (Wildman)
	Subtotal	2,580	
Propulsion			
	CTI K820 Motor (complete)	850	Manufacturer spec (CTI)
	Motor Mount Tube (MMT)	180	Manufacturer spec (Wildman)
	Motor Retainer (AeroPack)	150	Manufacturer spec (AeroPack)
	Igniter	20	Estimated
	Subtotal	1,200	
Recovery			
	Drogue Parachute (24-inch)	120	Manufacturer spec
	Main Parachute (58-inch)	250	Manufacturer spec

Subsystem	Component	Mass (g)	Source
	Kevlar Shock Cord (165cm)	60	Measured
	Nylon Recovery Harness (550cm)	80	Measured
	E-matches (2)	20	Estimated
	Ejection Charge (black powder)	20	Estimated
	Nomex Blankets (2)	40	Manufacturer spec
	Quick Links & Eyebolts	100	Measured
	Subtotal	690	
Avionics			
	Featherweight Blue Jay Plus Altimeter	30	Manufacturer spec
	Featherweight GPS Tracker	40	Manufacturer spec
	Battery (9V or Lipo)	60	Measured
	Wiring & Connectors	30	Estimated
	Electronics Sled (PETG, 3D-printed)	50	Estimated from CAD model
	Subtotal	210	
Payload			

Subsystem	Component	Mass (g)	Source
	Runcam 2 Camera	55	Manufacturer spec
	Camera Mount (4-40 screws & nuts)	20	Measured
	Subtotal	75	
Hardware & Adhesives			
	West System Epoxy (estimated)	100	Estimated
	Shear Pins	10	Measured
	Rail Buttons (2)	15	Measured
	Subtotal	125	
TOTAL VEHICLE MASS		4,880 g (4.88 kg)	

7.0 FLIGHT DYNAMICS

The flight dynamics analysis demonstrates that Zaphod will maintain stability throughout all phases of flight, from launch rail departure through supersonic flight and recovery deployment. The analysis presented below validates the vehicle's stability characteristics using OpenRocket simulations and established aerodynamic principles.

Stability Analysis

The vehicle's stability is quantified by its static margin, defined as the distance between the center of gravity (CG) and the center of pressure (CP), expressed in calibers (multiples of the airframe diameter). A static margin of 1.0 to 2.0 calibers is generally considered optimal for high-power rockets.

Zaphod's static margin was calculated using OpenRocket:

Phase	CG Location (from nose)	CP Location (from nose)	Static Margin (calibers)	Stability
On Launch Rail (motor loaded)	45.8 inches	34.2 inches	2.31 calibers	Stable
After Motor Burn out	43.5 inches	34.2 inches	2.58 calibers	Stable
At Apogee	43.5 inches	34.2 inches	2.58 calibers	Stable

Note: Static margin calculations assume standard 3-inch (7.62cm) airframe diameter.

The static margin of 2.31 calibers at launch rail departure exceeds the minimum requirement of 1.0 caliber, ensuring that Zaphod will maintain aerodynamic stability from the moment it leaves the rail through all flight phases.

Rail Departure Velocity and Stability

Zaphod's rail departure velocity is simulated at less than 30 m/s, which is within the Launch Canada requirement. At this velocity, the fins are fully effective in providing aerodynamic stability. The rail buttons guide the vehicle along the 12-foot launch rail, ensuring a straight departure trajectory with minimal pitch or yaw.

Supersonic Stability Considerations

Zaphod is designed to achieve Mach 1 during powered flight. At transonic and supersonic speeds, the center of pressure shifts aft due to changes in the aerodynamic force distribution. The team's analysis using OpenRocket's supersonic models indicates:

1. **CP Shift:** The center of pressure shifts aft by approximately 1-2 calibers as the vehicle passes through transonic speeds.
2. **Maintained Stability:** The aft shift in CP increases the static margin, providing additional stability during supersonic flight.
3. **Fin Design:** The G10 fiberglass fins are designed with sufficient stiffness to prevent fin flutter at transonic/supersonic speeds. The fin attachment (internal fillets at fin-to-MMT joint and external fillets at fin-to-booster joint) ensures structural integrity under aerodynamic loading.

Subsonic, Transonic, and Supersonic Regimes

The flight dynamics analysis considers three aerodynamic regimes:

1. **Subsonic ($M < 0.8$):** The vehicle experiences relatively benign aerodynamic forces. The G10 fiberglass airframe and fins provide adequate structural margins. Stability is maintained with a static margin of 2.31+ calibers.
2. **Transonic ($0.8 < M < 1.2$):** The vehicle passes through the transonic region where aerodynamic forces are highest. The stiff G10 fiberglass construction prevents fin flutter, and the aft CP shift improves stability.
3. **Supersonic ($M > 1.2$):** The vehicle achieves Mach 1+ and experiences reduced drag as it enters the supersonic regime. The static margin continues to increase due to the aft CP shift.

Asymmetric Loading and Coupler Effects

The coupler joints (payload-to-nosecone and booster-to-payload connections) are critical areas for aerodynamic loading. Any misalignment or play at these joints could create a "kink" in the airframe, resulting in significant asymmetrical loading.

The team's design addresses this through:

1. **Friction-fit connections** with minimal play
2. **Shear-pin retention** for the payload-to-nosecone coupler
3. **Reinforced Kevlar shock cord** connection for the booster-to-payload coupler

These measures ensure that the joints remain aligned under aerodynamic loading, preserving the vehicle's stability margin.

Additional Stability Control Measures

The fin alignment jig, 3D-printed in PETG, ensures that all three fins are mounted at the correct orientation and spacing. This is critical for maintaining the vehicle's stability margin and preventing roll-induced instability. The jig was designed in-house and printed at the UNB Makerspace, with the fins fitting perfectly within it

8.0 AEROSTRUCTURAL DESIGN

8.1 NOSE CONE

a. Detailed Design

As described before, Zaphod's nosecone is made up of G10 fiberglass, and an aluminum tip.

b. Analysis

The Rocket's nosecone is industry standard from Wildman Rocketry and is proven to have capabilities up to and beyond Mach 2.

8.2 AIRFRAME AND BULKHEADS



8.3 COUPLER(S)



8.4 FINS

- a. Detailed Design

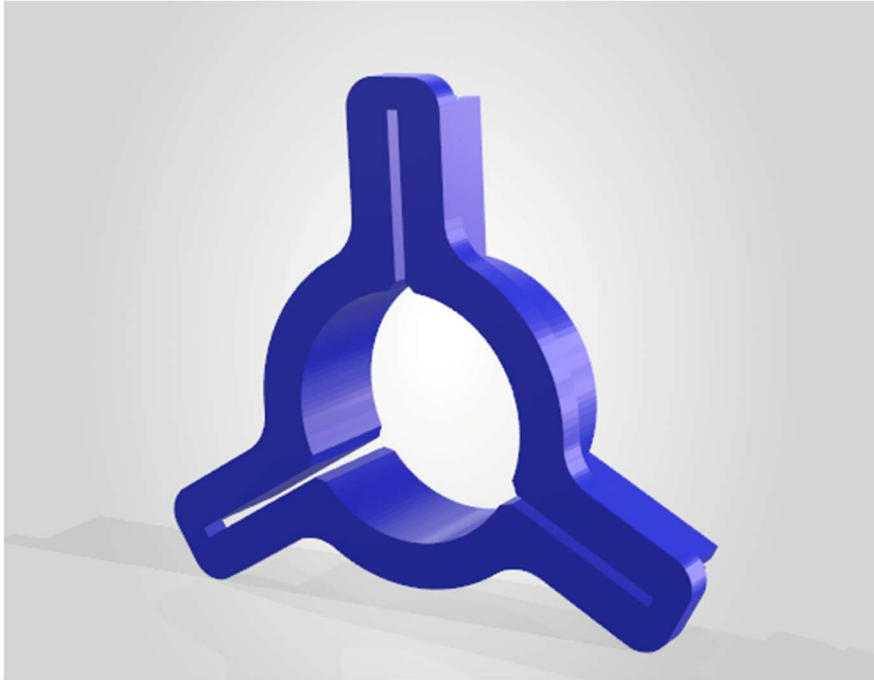


Figure: 3D Design for Fin Alignment Jig

9.0 PROPULSION SYSTEM

10. 1 SYSTEM DESIGN, TRADES AND PERFORMANCE SUMMARY



Figure: Fins attached with the Fin Alignment Jig

10.0 SOFTWARE

To monitor the Rocket, we will make use of Featherweight GPS UI app.

11.0 HAZARD ANALYSIS

The hazards identified for the Zaphod rocket relate to assembly, pre-flight preparation, launch, and recovery, with mitigations defined by process and design per the UREPL build plan:

Hazard	Possible Causes	Consequence	Mitigation Approach	Risk After Mitigation
Explosion of solid motor on the pad or low in the air	Cracks in propellant grain; clogged nozzle throat; gaps in fuel grain sections; incorrect grain or casing installation; damage to motor casing	Severe: irreparable damage to casing and rocket; possible injury or death	Proper handling of propellant grains before and during installation; follow all CTI installation steps exactly with an experienced member assisting; inspect casing installation; do not use the CTI-provided casing case (end caps easily fall off); inspect casing for damage before installation	Low
Unplanned motor ignition	Incorrect electrical wiring; static discharge; contact with open flame	Severe: uncontrolled "flight" without stabilizing launch rail; possible damage to person or property	Follow all directions of the printed procedures checklist; keep motor cap on until ready for launch; keep away from open flames	Low

Rapid unplanned disassembly	Fins detach from rocket (manufacturing errors, non-destructive testing unavailable); motor shifts upwards	Severe: falling fins could strike personnel; unstabilized flight could lead to high-speed contact causing serious injury or death; possibly unstable flight	Extensive testing of fins; injected carbon-fiber-reinforced internal fillets plus external fillets on all fins with 80-grit bonding prep; tearout tests performed on propulsion bulkhead fasteners; high factor of safety on motor retention (JB Weld high-heat epoxy retainer)	Low
Unintentional ejection charge firing	Charges armed during assembly; wiring shorts	Severe: injury to personnel handling airframe	Sled wired with batteries disconnected; polarity checked on all leads; main + backup e-match arrangement wired per procedure; switches accessible through vent holes so arming occurs only on the pad	Low
Epoxy exposure during assembly	Skin contact with resin/hardener; exothermic heat from large batches	Moderate: skin irritation, burns	Correct mix ratio only; waterless skin cleanser for resin, soap and warm water for hardener, never solvents on skin; slower hardener, smaller batches, or larger-surface containers in warm conditions	Low
Fiberglass dust and tooling injuries	Sanding, drilling, Dremel cutting	Moderate: cuts, respiratory/skin irritation	Bulkheads clamped before drilling; tape inside airframe to prevent fiberglass separation; loose strands cleared by sanding and needle filing; parts wiped down with acetone after sanding; using masks	Low

Hardware separation during ground handling	Booster sliding free when lifted by nosecone; fasteners loosening	Moderate: dropped airframe, injury to handlers	Friction-fit payload tube with tape strips; locking nuts/cap nuts with thread locker on all critical fasteners; av-bay closed hand-tight only	Low
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12.0 TEAM DEVELOPMENT

UREPL’s team development strategy is built around long-term sustainability, structured talent cultivation, and the creation of a future dual-use aerospace startup aligned with Canada’s Defense Industrial Strategy (DIS), NORAD modernization, and Atlantic Canada’s rapidly expanding defense ecosystem. The following subsections outline our succession planning, knowledge retention systems, outreach activities, and business/marketing strategy, all supported by a multi-year development roadmap.

12.1 SUCCESSION PLANNING

Succession planning is critical for a student engineering team where turnover is inevitable. UREPL addresses this challenge through a structured, multi-layered talent pipeline built around the Engineering Internship Incubator (EII) — a program designed to train junior members in industry-grade engineering tools, aerospace fundamentals, and multidisciplinary problem-solving.

Structured Talent Pipeline

The EII provides training in:

- Ansys Fluent, Mechanical, Thermal
- SolidWorks Premium
- Abaqus
- Siemens NX & Nastran
- SoftInWay AxSTREAM
- MATLAB/SIMULINK
- Altium (PCB design)

Junior members shadow subsystem leads, participate in design reviews, and gradually

assume responsibility for avionics, structures, propulsion, and recovery tasks. Weekly build sessions in the Rocket Engineering & Propulsion Lab (IUC Physics 321) accelerate hands-on learning.

Leadership Continuity

Each subsystem lead trains at least one successor. Graduating members conduct formal handover sessions, ensuring continuity in:

- Avionics architecture
- Recovery system design
- Aerostructure manufacturing
- Propulsion integration
- Safety procedures

Startup-Ready Leadership Development

UREPL's long-term plan includes transitioning into a formal aerospace startup. To prepare for this, senior members engage with the team's startup founders, UNB's J. Herbert Smith Center for Technology Management & Entrepreneurship, and UNB Alumni who have founded successful startups. This will create an organic knowledge transfer. We have already invited senior UNB alumni to share their knowledge about rocket development.

12.2 KNOWLEDGE RETENTION

UREPL uses a centralized Notion repository to store all subsystem documentation, including:

- CAD models
- CFD and FEA results
- Avionics schematics
- Manufacturing logs
- Test reports
- Recovery system procedures
- Propulsion integration notes

And we have a weekly group session in which progress over the weeks is shared and discussed with all to foster a shared sense of progress and leadership.

Structured Learning Tracks

Apart from informal discussion, we have designed training sessions like The EII to preserve and spread the institutional knowledge through curated aerospace literature:

- Modern Engineering for Design of Liquid Propellant Rocket Engines — Huzel & Huang
- Modern High-Power Rocketry 2 — Canepa
- Introduction to Multicopter Design and Control — Quan Quan
- Drone Development: From Concept to Flight — Sharma

These texts form the backbone of structured learning tracks in propulsion, flight dynamics, structures, and avionics. These exact resources will be used for the upcoming internship session.

Future-Focused Knowledge Systems

As UREPL transitions toward:

- Metallic airframes
- Metal 3D printed parts for faster prototyping (Additive manufacturing)
- Advanced propulsion
- Autonomous flight systems
- Multistage rockets

The team is developing long-term documentation standards to support dual-use aerospace capability development aligned with Canada's Defense Industrial Strategy (DIS).

12.3 OUTREACH

At UREPL, we are conducting extensive outreach to promote STEM, attract new talent, and establish ties with Atlantic Canada and, overall, with Canada's defense.

STEM and Community Engagement

- Public demonstration days at UNB Fredericton to present our development to UNB community
- Very soon launching our formal Avionics and propulsion workshops
- Recovery system demonstrations
- EII training sessions are open to UNB students
- We have planned to arrange a workshop for school kid to foster an interest for STEM
- UNB Alumni engagement

These activities significantly increased recruitment and awareness of aerospace engineering on campus.

Defense-Aligned Outreach

Military

One great part of UREPL is that its Fredericton office is strategically positioned near **CFB Gagetown**, one of Canada's largest military bases (1,100 km²) and a major training hub for Canadian and allied forces (*DND, CFB Gagetown Overview*). This proximity enables future collaboration in:

- Autonomous systems testing
- Multistage or Clustered Rocket Testing
- Materials evaluation
- Dual-use aerospace research

Industry

It's a good sign that we have already received some positive appreciation from the industrial community. And we have established a plan to reach out to major aerospace companies and startups to support our future development. The following few companies could be great support for us if we get a formal collaboration or skilled knowledge support.

- **Bombardier**
(advanced composites, aircraft systems)
- **Pett** & **White**
(defense manufacturing)
- **NordSpace**
(Canadian propulsion and launch systems)

In fact, we have planned to present at the Launch Canada event; our team will present to industry professionals and companies on our strategic plans for the future. If luck favors us, such partnerships will support future development of metallic airframes, propulsion testing, and avionics research.

12.4 BUSINESS AND MARKETING

One of the best things about our UREPL team is that we have industry-experienced engineers with start-up founding experience. After the launch of the Canada event, we will focus on organic branding for the first few months. And so far with our organic outreach we have been able to reach out to a good number of the

community. It's evident that rocket development requires disciplined financial management along with technical dedication. UREPL maintained a subsystem-level budget covering aerostructures, avionics, recovery, propulsion, and travel. Our disciplined and transparent approach helped us secure sponsorship from the following sponsors.

Sponsorship Success

UREPL secured sponsorships from:

- Dassault Systèmes
- Ansys
- SoftInWay
- UNB Associated Alumni
- UNBSU
- SRC
- Notion
- IEEE Canada Foundation

These sponsors provided software licenses, funding, and technical resources essential to the Zaphod rocket, which we plan to launch at the Launch Canada 2026 event.

Defense-Aligned Funding Opportunities

After the UREPL is preparing to participate in some of the available grant or funding options that we might have within fredericton.

- **MITACS Accelerate – Defence Innovation Call**
 - Supports projects aligned with Canada's Defense Industrial Strategy
 - Deadline: August 17, 2026 (*Government of Canada*)
- **Ignite Fredericton & Planet Hatch**
 - Startup incubation and commercialization support

Strategic Long-Term Investment Plan:

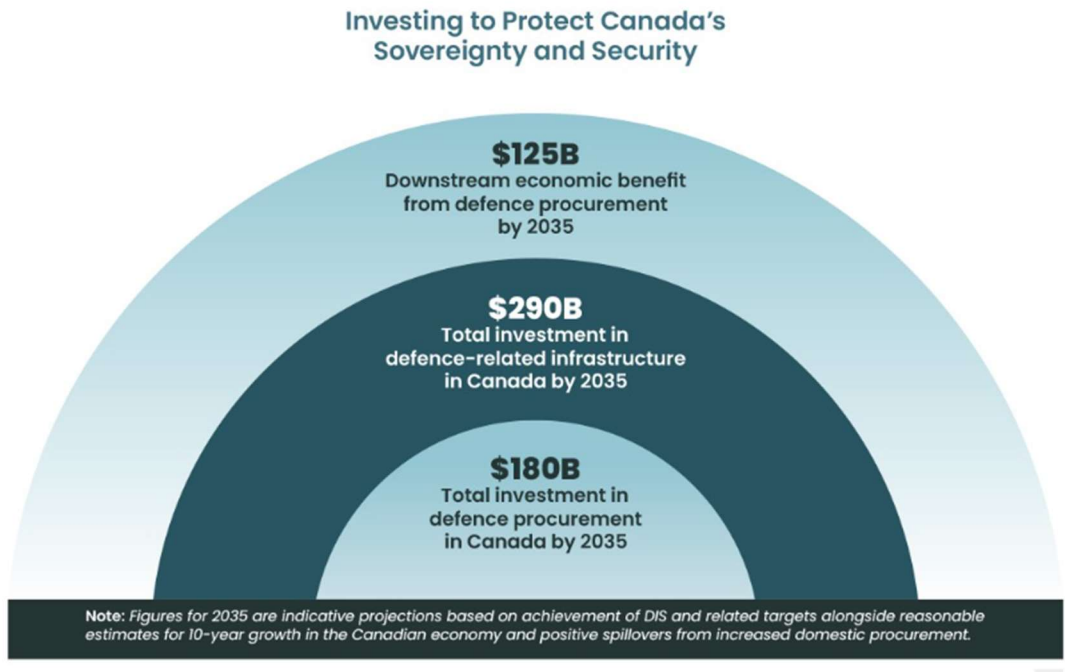


Figure: Canada’s long-term defense strategy shows a layered investment profile \$180B in procurement at the core, \$290B in infrastructure forming the middle arc, and \$125B in wider downstream economic impact as the outer ring- totaling \$ 596 B by 2035

Canada’s new Defense Industrial Strategy lays out one of the most ambitious innovation agendas the country has ever pursued, placing universities and small technology teams at the center of that effort. Beginning in 2026, the federal government will establish a Science and Research Defense Advisory Council to connect post-secondary researchers directly to national defense priorities [DIS 2025]. Alongside this, the Carney Administration is opening major funding streams specifically for small and mid-sized businesses, including a \$244-million Defense Industry Assist program through NRC-IRAP to advance dual-use technologies and provide innovators with access to Canadian Armed Forces ranges and training areas for testing [DIS 2025]. Budget 2025 also introduces a \$4-billion Defence Platform at BDC to provide venture capital and advisory support to defence-sector startups, paired with a \$ 357.7 million Regional Defense Investment Initiative to help SMBs integrate into domestic and international supply chains, a critical move given that SMBs make up 92% of Canada’s defense industrial base and 40% of its employment [DIS 2025]. The government has a plan to grow Defense revenues for Canadian small and medium-sized businesses by more than \$5.1 billion annually. The strategy further commits \$105 million to create a Drone Innovation Hub at the National

Research Council and \$460 million for a new defense R&D platform focused on emerging technologies [DIS 2025]. For a university-based engineering group like UREPL, these programs represent a rare opportunity: they signal that Canada is actively looking for new, homegrown innovators who can contribute to sovereign capability, dual-use aerospace systems, and defense-aligned research. Our long-term plan to evolve into a dual-use aerospace startup, develop advanced propulsion and avionics systems, and collaborate with Defense Industries aligns directly with this national direction, and we intend to position UREPL as one of the university-led teams contributing to Canada's defense innovation pipeline.

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