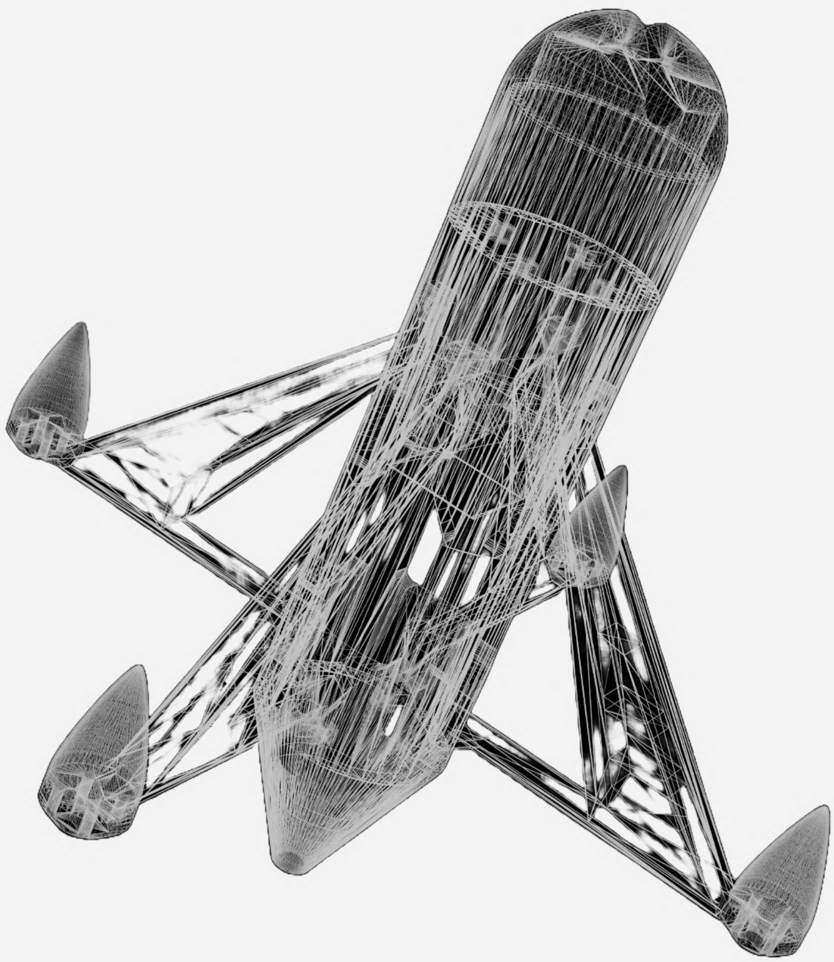
Razorbill C-UAS

Formative Project Report

Muhammad Qazi
Mechanical Engineering
University of Guelph



This report contains a chronological breakdown of the design, assembly, and testing of the Razorbill Counter UAV drone

This report was not in any way written or assisted by AI.

Pretext

This report is an up-to-date summary of my Interceptor Drone project. Starting in January, I set out to produce an unconventional UAS which could be capable of performance metrics which are used on the battlefield.

My journey started with a 10” standard FPV drone, using a frame similar to those currently in operation in Ukraine. I was successfully able to manufacture a long range FPV drone with the help of online sources and youtube tutorials.

From there, I 3D-printed my first custom frame, which was a simple tube fitted with smaller drone parts, using the same hardware assembly as my 10” drone (minus the motors). Field testing revealed many setbacks and allowed me to focus on a specific goal (high speed). The next iteration improved upon all aspects, which allowed me to gather meaningful data from successful flight trials.

By the 3rd design, I had come up with a functioning prototype capable of reaching ~200km/h. This drone allowed me to target airborne objects, fly at high speeds, and cover long distances. As of September 2025, I am working on a new prototype which should be capable of surpassing any interceptor drone available on the market. This project has taught me a lot about the R&D process, the importance of reliable design, and approaching problems with an engineered solution.

This report contains a comprehensive breakdown of the design process, technical analysis, and qualimetric results of the Razorbill C-UAS.

If you would just like to see performance metrics and visual proof of the drone, you can skip ahead to the appendix

- *Muhammad Qazi*

Mechanical Engineering
University of Guelph

Table of Contents

1. Title page
2. Pretext
3. Table of contents
4. Background
    a. Design Objectives
    b. Baseline FPV Drone
5. Razorbill 0.1
6. Razorbill 0.2
    a. Redesign
    b. Initial Test Results
7. Razorbill 0.3
    a. Functional Design
    b. Field Testing
    c. Improvements Needed
    d. 0.3.5
8. Razorbill 0.4
    a. Planned Improvements
9. Reflection
    a. What's Next
10. Appendix
    a. 10” drone
    b. Razorbill 0.1
    c. Razorbill 0.2
    d. RAzorbill 0.3
    e. Razorbill 0.4

Important terms

C-UAS - Counter Unmanned Aerial System
FPV - First Person View
FC - Flight Controller
ESC - Electronic Speed Controller
VTX - Video Transmitter
ELRS - Express Long Range System (radio communication)
PID - Proportional Integral Derivative (motor control feedback)
LiPo - Lithium Polymer (batteries, 4s: 4 cells, 6s: 6 cells)

Background

Combat focused Drones have become popular as of recently as a result of the Russia-Ukraine war. Unconventional tactics and technology have become extremely effective in neutralizing targets on the battlefield, with the available technology, guerilla warfare tactics are much more effective in many cases.

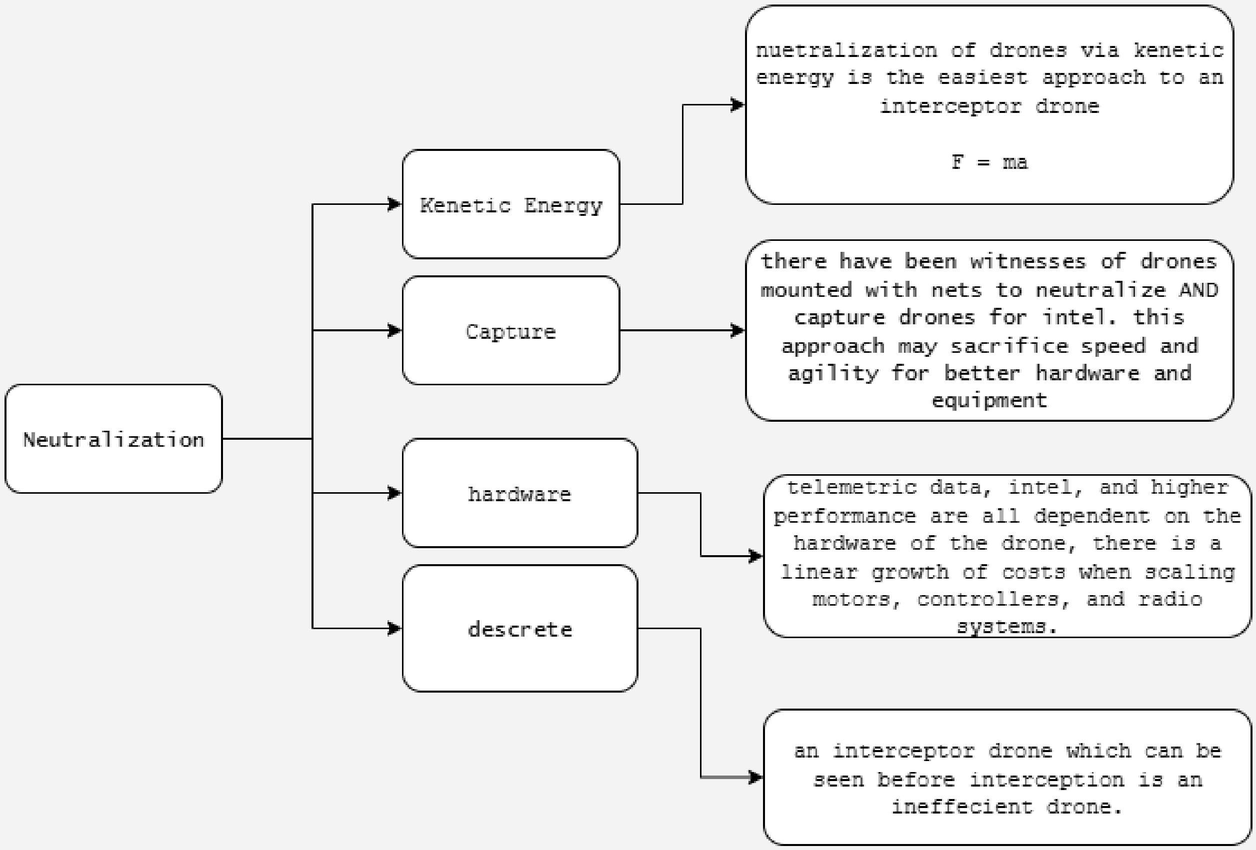
Design Objectives

Modern fpv drones often reach speeds of up to 180km/h, 10” fpv drones fitted with explosives, hardware, and fibre optic cables often reach speeds of 135km/h.

To effectively intercept a drone of such calibre, speed is your best friend.

Drone	Top Speed
Shahed-136	~185km/h
10” FPV bomb drone	~135km/h
Zala Lancet	~300km/h
Sting interceptor	~320km/h

From real world reported data, we can see drones are reaching speeds on average of 200km/h, this means to intercept more drones. ***<u>The target should be 400km/h</u>***.



In the planning process of an interceptor drone, balancing trade-offs are mandatory. It is crucial to identify the important characteristics required for your operation, speed, weight, range, and cost determine the type of drone one can produce.

Baseline FPV Drone

The drone journey started with research in pre-made kits for fpv drones. In February 2025 I built a 10” prop FPV drone. Which required a steep learning curve for someone with little drone knowledge.

Through youtube tutorials and wiring diagrams, the drone was successfully wired up with a speedybee f405 flight controller to a 60amp ESC,connecting to 750KV brushless motors, a 1 watt VTX, and running on ELRS 2.4ghz radio communications. The flight controller ran on betafight configurator software.

This project was costly, mainly due to the lack of experience related to drones. Constant replacement of parts, crashes, and simple mistakes made me familiar with the r&d process. The only part not requiring repair/replacement was the carbon fibre frame, which would be rather difficult to break even with applied effort.

By March 2025, the 10” was a successful drone. This UAV was capable of lifting up to 20Kg with its high pitch tri-blade props, a lower KV value made the motors torque heavy, allowing responsive changes in direction and velocity at an unnatural level.

Figure 0.1. 10” drone with custom raised legs

Razorbill 0.1

[The bird razorbill looks & sounds cool,no other relation]

Using the experience from the 10” fpv drone, a custom 3D printed frame was designed to fit all of the drone parts in a cylindrical body.

5” tri-blade propellers on 2300KV motors was the chosen powertrain, a small platform capable of 1kg of thrust per motor.

Razorbill 0.1 is a simple rocket-like cylindrical drone. Upwards facing propellers were selected as the primary choice as reverse thrust can require complicated PID tuning or ESC configuration.

Initial flight was successful, the drone maintained stable vertical orientation, with the battery in the bottom section of the body, the low center of gravity helped keep the drone vertically stable.

When attempting to fly at higher speeds, the uneven weight distribution would make it very difficult to keep the drone horizontal. Imagine a pendulum.

2 solutions -> balanced/dynamic frame or constant acceleration

Figure 1.1. First Razorbill prototype

Razorbill 0.2

Using the concepts learned from the previous prototype, a new frame was designed for real world testing

Redesign

- Thinner shell walls
- Ailerons for vertical and horizontal stability (standing & flying)
- Lowered motor arms to bring up CG
- Shortened base
- Aerodynamic nose piece
- Fasteners for all parts (except ailerons & nose)

After reprinting every part with thinner walls, assembly of razorbill 0.2 took ~4 hours. Smaller 1350 mah lipo batteries were used instead of the previous 3300mah batteries for weight reduction.

Figure 2.1. Razorbill 0.2

Initial Test Results

The shorter, lighter frame proved effective for interception. The flight was done in an open football field with little to no wind interference. Initial flight was stable, the balanced CG allowed rocket-like horizontal flight. The football field did not have enough space to maintain longer distances of horizontal flight, and due to the lack of a GPS on the drone, ground speed could not be calculated.

Overall the flight test proved the concept with promising results. The 1 watt VTX maintained solid communication, and allowed for easy maneuverability albeit requiring experienced control in FPV flight; it could be observed that the drone was flying horizontally stable at ~120km/h with the throttle at 75%.

Razorbill 0.3

With the previous prototypes proving a successful concept of drone interception. It was time to design a working product, capable of a specific goal. This meant designing every aspect of the frame/hardware mathematically and with precision.

Functional Design

The tube design was maintained, but a major shift in design was the modularity; sharp corners were no longer printed as a whole but rather attached via M3 fasteners. Arms were longer, lighter with a hollow frame, and fastened to the main body, this was done for 2 reasons. Motors could be mounted further from the shell if larger 7” propellers were desired, and for easy replacement, after every crash the motor arms were the first to fail, it was an easy choice to make them modular and easy to replace.

A solid body study on SolidWorks was necessary to identify stress concentration and prevent easy breakage in the event of unwanted impacts. 10N acting on the motor arm takes in the factor of safety (n=2) for static failure.
A fluid flow study was the next important study to apply to the frame,the goal was to identify any spots for turbulent flow, of course with a blunt nose end and camera opening, there will be dead spots causing drag.

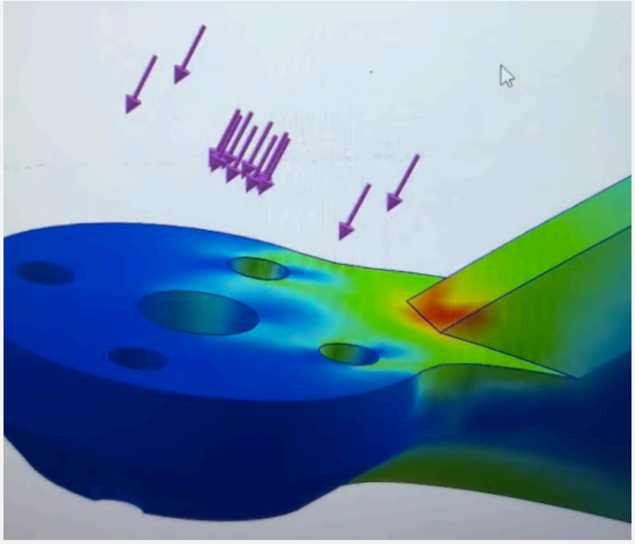


Figure 3.1. Solid body stress study

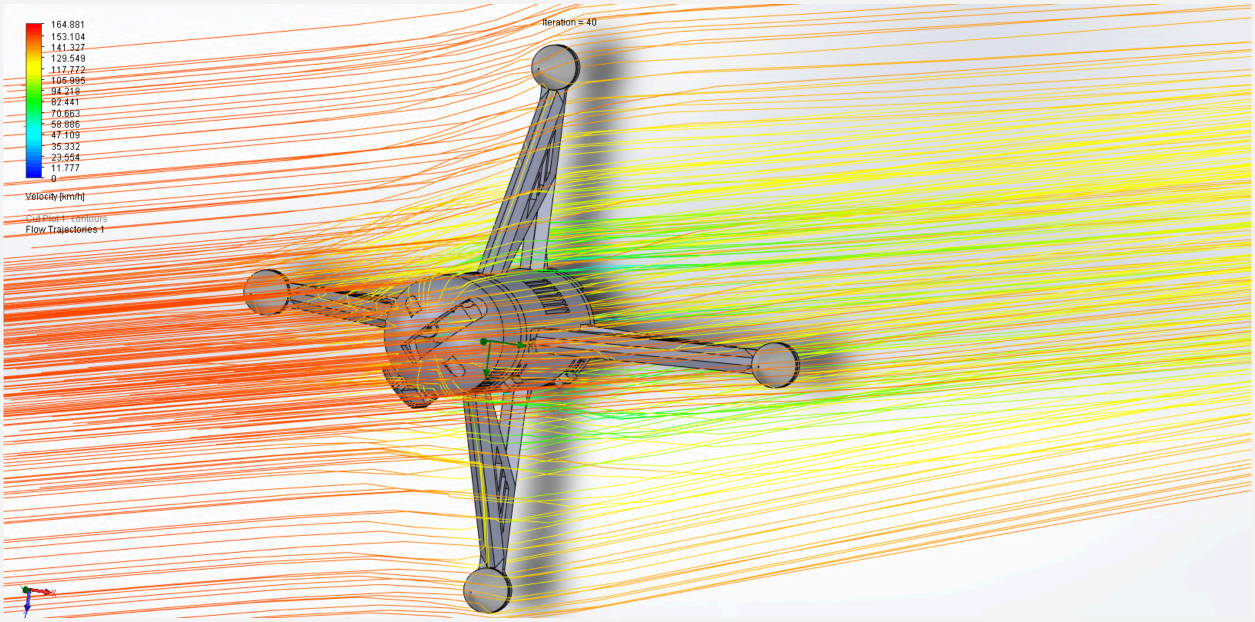


Figure 3.2. Fluid flow simulation
Flow around the body is laminar, of 200 points arbitrarily studied acting on the drone, only 4 stream lines were turbulent.

Field Testing

Assembly 0.3 was quick - due to the modularity of each part

Due to past experiences in consistent malfunctions, crashes and faulty launches, a preflight check was standard operation before each launch, which allowed for more reliable tests at the cost of constant trips from the workshop and the field.

Preflight Checklist

- [ ] Check for loose wires and parts, shake the drone
- [ ] Connect GPS, make sure OSD Displays correct information
- [ ] Plug in battery 3-4 times, checking for proper sequence of beeps
- [ ] Pull at any glued part, everything should be tight
- [ ] Arm drone while holding with a firm grip, 15% throttle, test for stable resistance
- [ ] Do a signal test in the ELRS settings of Radio, bar drop off should be consistent.
- [ ] Test failsafe by powering off radio while hovering while holding, drone should slowly decrease power, not disarm.

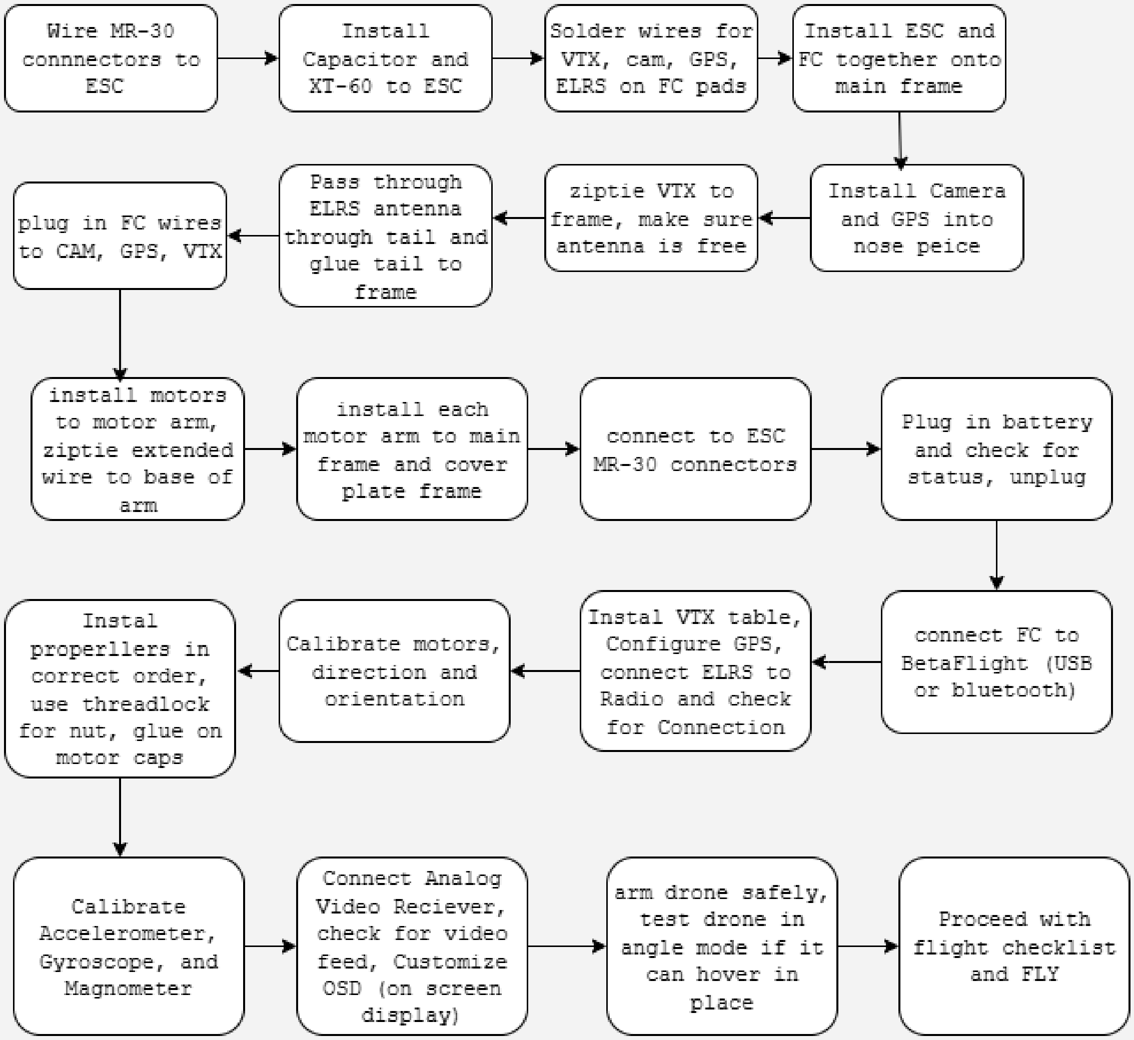


Figure 3.3. General process flow of assembly of Razorbill 0.3

After taking detailed precautions, testing razorbill 0.3 was successful for data collection. A top speed of 199km/h was logged by the GPS ground speed monitor, although an impressive figure, there was definitely more potential for reaching higher speeds with a higher altitude and flight path. Razorbill 0.3 was not quantitatively weighed, via spec sheet data of each part, the drone weighed about 1500g. With a thrust to weight ratio of 2.5 to 1, there was definitely room for improvement.

Right: Figure 3.4. Razorbill 0.3 ready for takeoff

0.3.5

With the successful design of 0.3. There were also multiple aspects which could be improved without starting a new design from scratch

The newer design consisted of a shorter frame, with the nose piece being a part of the main frame, and splitting the frame in half with screws and nuts to attach them. Another feature worth mentioning was the magnetic mount rail system, a protruding mount with powerful magnets glued into recessed holes allowing for easy mounting of a variety of devices.

From the Picture on the right, the new frame can be easily taken apart via 4 screws, which allows for battery swaps and quick fixes for short term issues on the field without “grounding” the drone.

Figure 3.5. New modular frame

The magnetic mount was a feature designed to mount any part to the drone without sacrificing any internal space. For testing, a 3D printed wing was fitted with magnets and attached to the mount. 6-7 small magnets made an easy job of holding the wing in place, small clearances provided enough friction to prevent any harmful vibrations.

See appendix for detailed photos of the drones, CAD Drawings, and features

Razorbill 0.4

This is the latest design, Currently in progress - this drone will reach all the targets set out in the beginning of this project, designed to be visually appealing, reliable, and desirable for anyone looking to intercept drones.

Planned Improvements

A large interceptor drone contains lots of wasted space, round frames serve no purpose if all the electronic hardware is rectangular.

Taking inspiration from Raytheon's mach 5 hypersonic ballistic missile concept. The frame was designed from the scratch, improving all aspects, below is a short description of every changed feature and its reasoning:

1. **Rectangular cross section**
    a. Compact internals, un-used space is saved, allows for a more discrete profile

2. **Thinner arms, single mounting point**
    a. Lighter, thinner profile improves streamlined design
    b. Motor mounts are angled downwards for a perfect CG

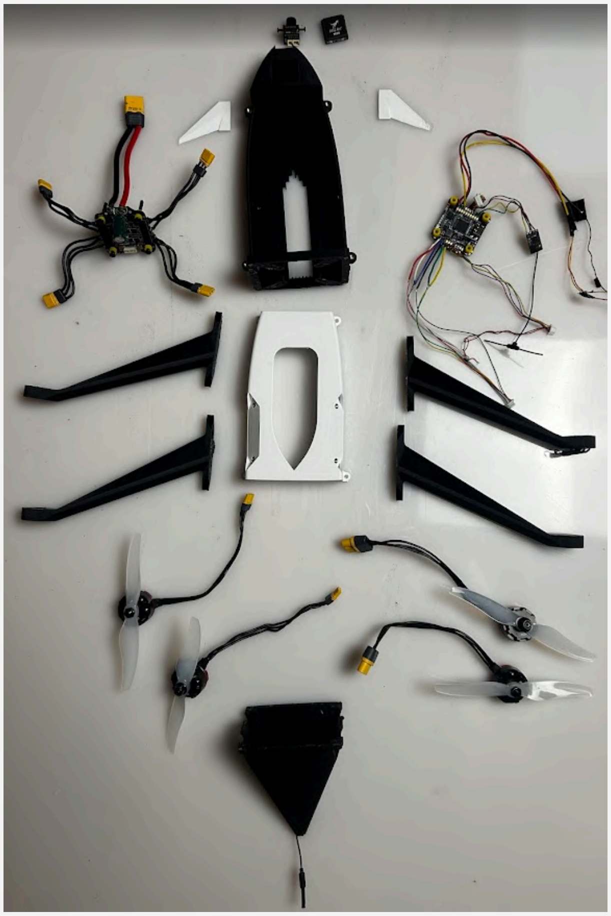


Figure 4.1. Disassembled

3. **Threaded inserts**
    a. Instead of using M3 screws and nuts, I installed m2 threaded inserts, M3 was overkill and this allows for a seamless installation, greatest improved for assembly so far

4. **Canards**

    a. Canards installed with a steep angle of attack, which generates lift when flying horizontally. In theory, it will help keep the drone’s front end from dropping down without sacrificing drag

5. **2 blade propellors**
    a. All previous prototypes have used high pitch 3-blade propellers. With 2300KV motors, having higher resistance is a bottle neck for speed, lighter props will run at significantly higher RPMs with less resistance. Looking for improvements in battery life and speed
6. **Smallest and lightest frame as of yet**
    a. Theoretical thrust to weight ratio of 4:1, the goal is to reach 300KM/H

Razorbill 0.4 has been produced and is awaiting testing, hover test was successful.

During testing, a flight controller shorted and fried the ESC connector, lead times for parts are long due to sourcing cheaper chinese parts.

Figure 4.2. Assembled frame

Reflection

From February 2025 to August 2025, some goals were set;

- ➢ Assemble a functioning FPV drone
- ➢ Make a custom FPV drone
- ➢ Design a functioning rocket-style drone
- ➢ Reach 200 km/h top speed
- ➢ Reach 400 km/h top speed

All but one goal has been achieved so far.

Prototype Comparison Table

Parameter	Razorbill 0.1	Razorbill 0.2	Razorbill 0.3	Razorbill 0.4
Frame type	Cylindrical	Slim cylinder, aerodynamic nose	Modular tube, replaceable arms	Rectangular frame, canards
Propellors	5” 5140 tri-blade props	5” 5140 tri-blade props	5” 51466 tri-blade props	5” 5126 bi-blade props
Motors	2300KV	2300KV	2300KV	2300KV
Battery	4s 2200mAh LiPo	4S 1350mAh LiPo	4s 1500mAh LiPo	6s 1500mAh Lipo
Weight (approx)	2000g	1700g	1500g	Target: 1000g
Thrust to weight	~2:1	~2.2:1	~2.5:1	~4:1
Top speed	Limited telemetry	120km/h (visual guess)	199km/h (GPS Logged)	Target: 300km/h
Flight time (aggressive flight)	~7 mins	~5 mins	~4-5 mins	target: 4-5 mins
Major issues	Poor horizontal stability	Limited telemetrics (GPS, VTX)	Heavy, prone to damage	Parts delay

This project has come with its challenges, from constant unaccounted design flaws to critical flight crashes. Building drones can be expensive and time consuming, but every setback has come with valuable experience which could not be learnt any other way. The R&D process can be rewarding to anyone who is committed to an engineering goal. The difference between academic learnt and self taught engineering solutions are night and day, each with their own importance in this project.

The application of Razorbill 0.3 alone is worth looking into, a modular payload drone with a range of 10km, and speeds of up to 200km/h can allow for a wide variety of solutions, from combat focused missions to reconnaissance. With the right funding and research, razorbill 0.3 and beyond can be capable of competing with the industry's standard drones at a fraction of the cost.

What’s Next

This project is not finished. A solid drone frame has been developed, with concrete proof of the concept. The next target with Razorbill is a frame and powertrain which can reach 400km/h, be it with more powerful motors and batteries.

There is an untouched ceiling of potential with the C-UAV Razorbill Interceptor Drone, from an AI driven platform much like Anduril industry's Lattice OS, or even improving hardware for other purposes such as night stealth, product delivery, and large distance reconnaissance.

This report serves as an open source tool for drone enthusiasts to gauge the complexity and production of interceptor drones, and an inspiration to anyone that believes they are not capable of developing high-performance high-tech solutions to real world problems.

Appendix

10” drone

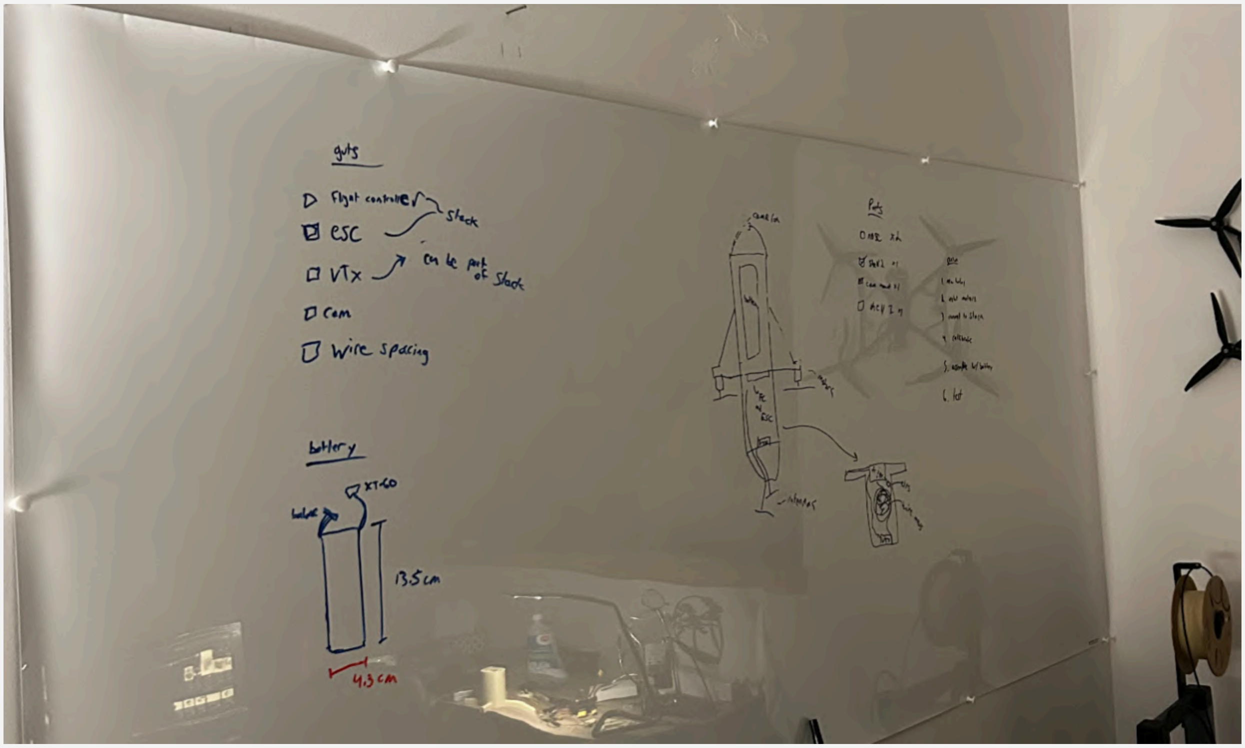
10” drone BOM		
Part name	quantity	Cost per unit
Carbon Fibre Frame	1	$35
750KV EMAX motors	4	$40
10” Propellors	4	$3
SoloGood f405 FC and ESC Stack	1	$78
1000mW VTX	1	$30
Rush cam nano FPV camera	1	$25
XT60, MR60 Connectors	9	$1
3300mah Lipo Battery (6s)	2	$65
ELRS module	1	$15

10” drone ready for flight

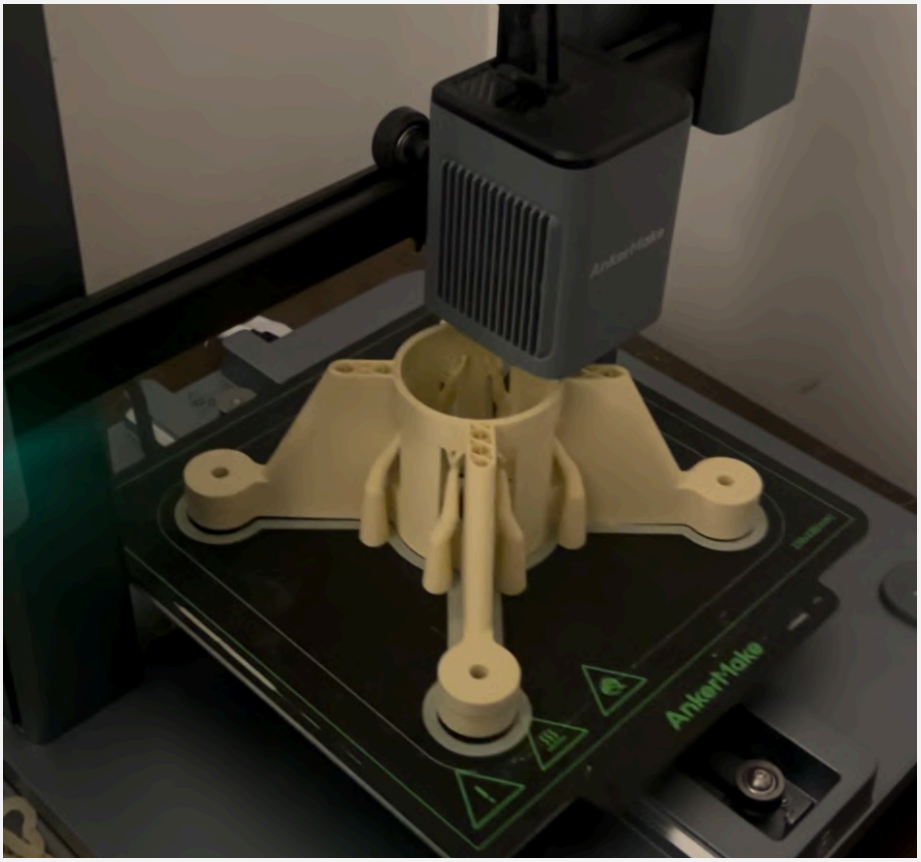
Carbon Fibre lightweight Frame

Razorbill 0.1

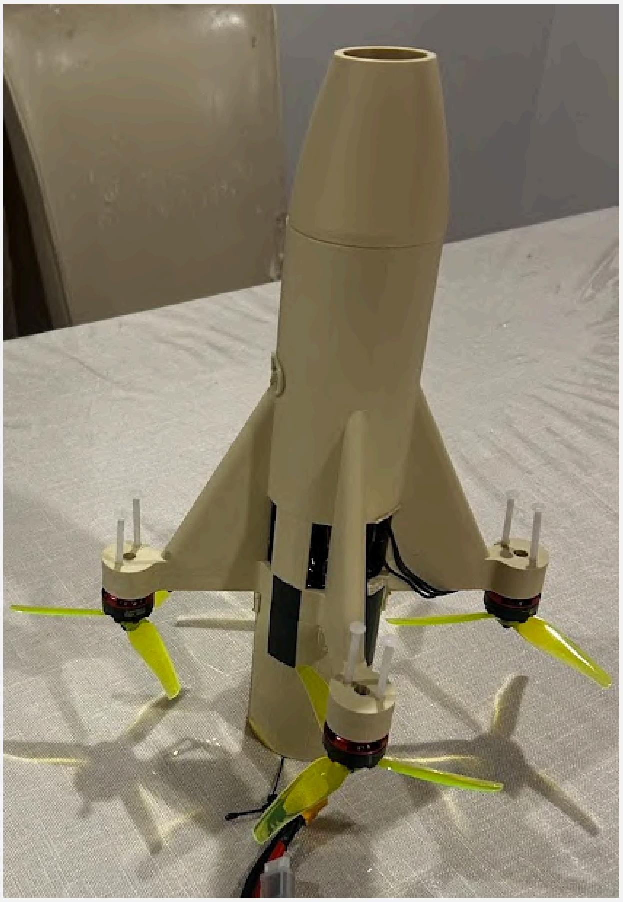
Razorbill 0.1 BOM		
Part name	quantity	Cost per unit
3D print Frame		
2300KV Motors		
5” tri-blade Propellors		
Speedybee F405 Stack		
XT60, MR30 Connectors		
2200mah Lipo Battery (4s)		
ELRS module		



Design process for first custom frame



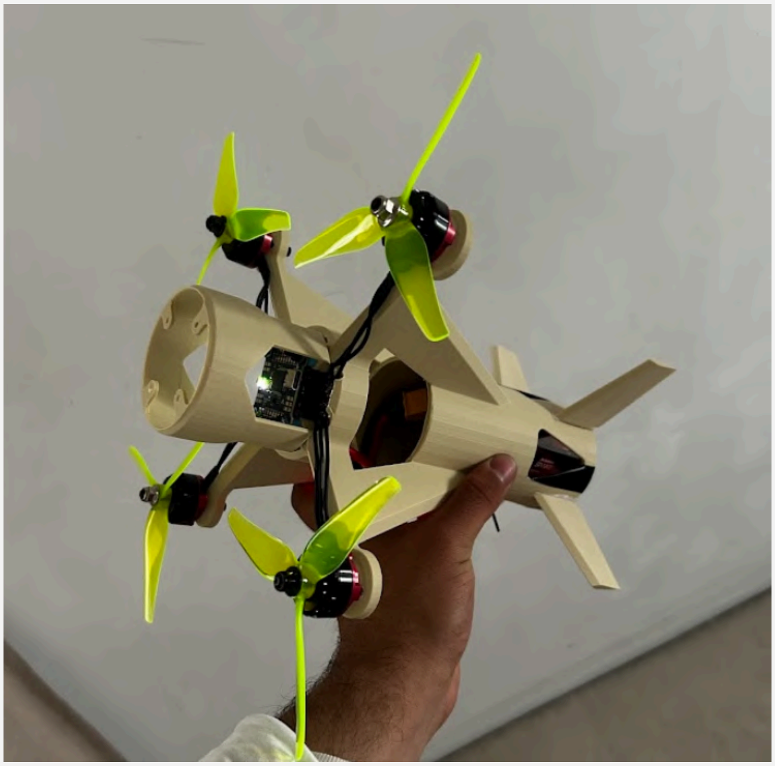
Custom 3D print frame, base would warp after extended period of time on the print bed



Downwards facing motors were unsuccessful, flipped frame orientation and moved the nose piece to the bottom

Razorbill 0.2

Razorbill 0.2		
Part name	quantity	Cost per unit
3D print Frame		
2300KV motors		
5” tri-blade Propellors		
SoloGood f405 FC and ESC Stack		
1000mW VTX		
Rush cam nano FPV camera		
XT60, MR30 Connectors		
1350mah Lipo Battery		
ELRS module		



Static ailerons are great for having the drone stand stable rocket, higher speeds played a role in reducing rear drop off and unwanted spinning.

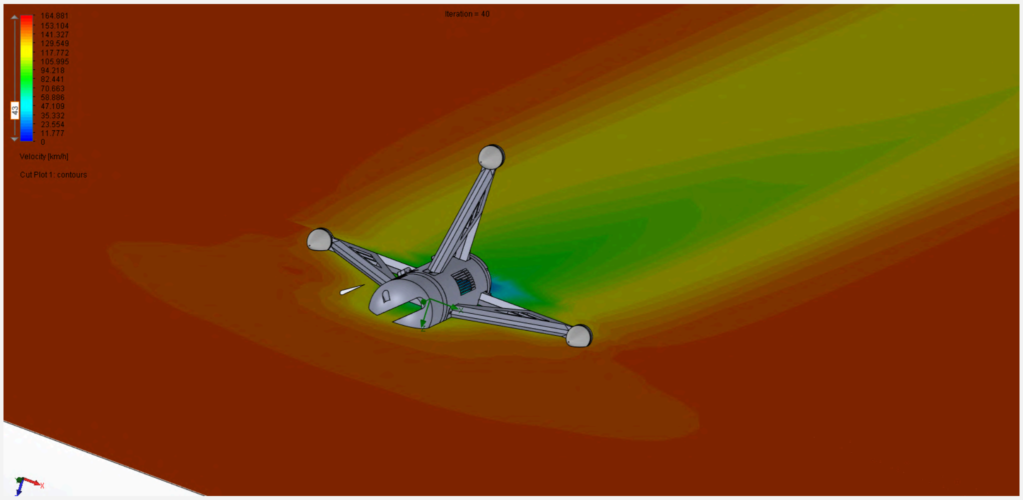
Due to the force absorption of the PLA printed Frame, no electronic parts were damaged apart from a missing antenna.

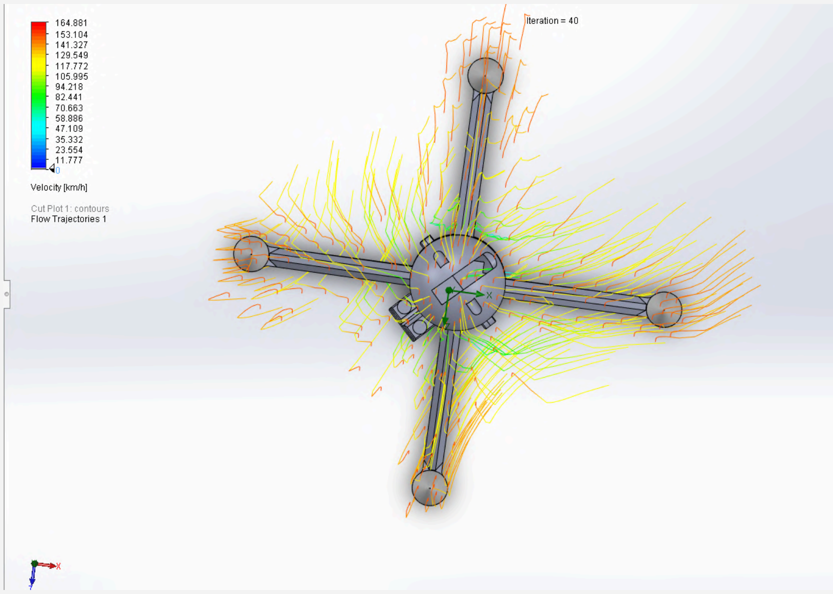
Razorbill 0.3

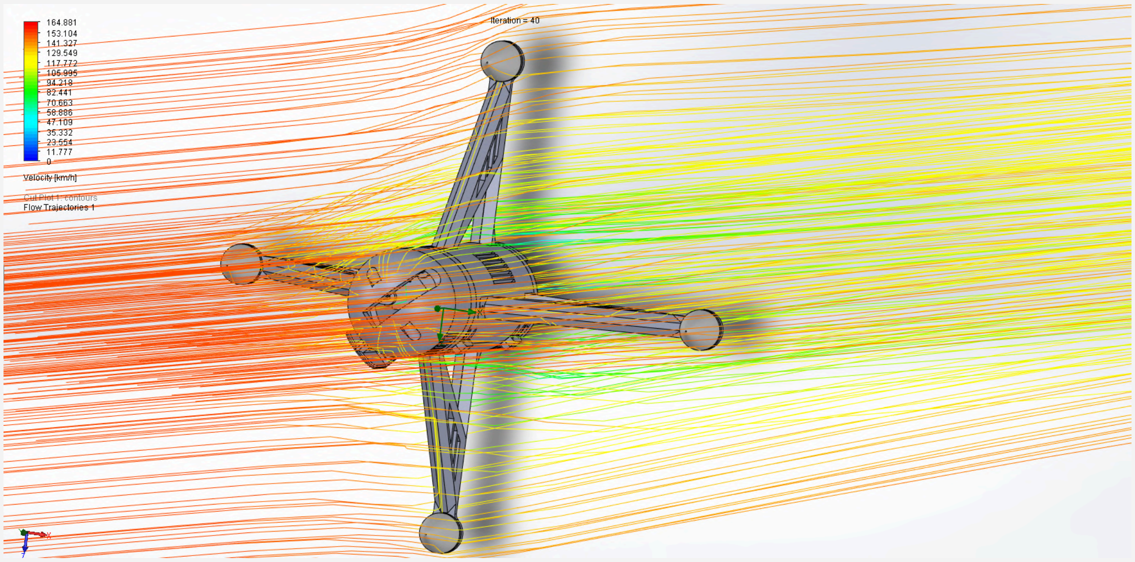
Razorbill 0.3		
Part name	quantity	Cost per unit
3D print Frame	2	
3D motor Arms	4	
5” tri-blade Propellors	4	
SoloGood f405 FC and ESC Stack	2	
1000mW VTX		
Rush cam nano FPV camera		
XT60, MR30 Connectors		
1350mah Lipo Battery		
ELRS module		

Crashes can be more helpful for redesigning than successful trials, they highlight weak spots and underprotected areas.

Flow Study for







Flight times varied with wind conditions and throttle behaviour, longest flight was about 10 mins, shortest was 3 minutes at full throttle.

Successful wing mount

Razorbill 0.4

Razorbill 0.4		
Part name	quantity	Cost per unit
3D print Frame	2	
3D print motor Arms	4	
5” bi-blade Propellors	4	
Speedybee FC and ESC	1	
2.5W VTX	1	
Rush cam nano FPV camera	1	
XT60, MR30 Connectors	9	
1500mAh 6s LiPo Battery	1	
HGLRC M100 GPS	1	
ELRS module	1	

Raytheon’s Mach 5 Concept

Smaller profile and thinner arms played a role in a lighter and more compact design.

Compared to version 0.3, CFD studies show less drag, fewer turbulent streamlines, and a less aggressive drop in velocity