ASME IAM3D U.A.R.C.V Competition Design Report

Bryan Pham

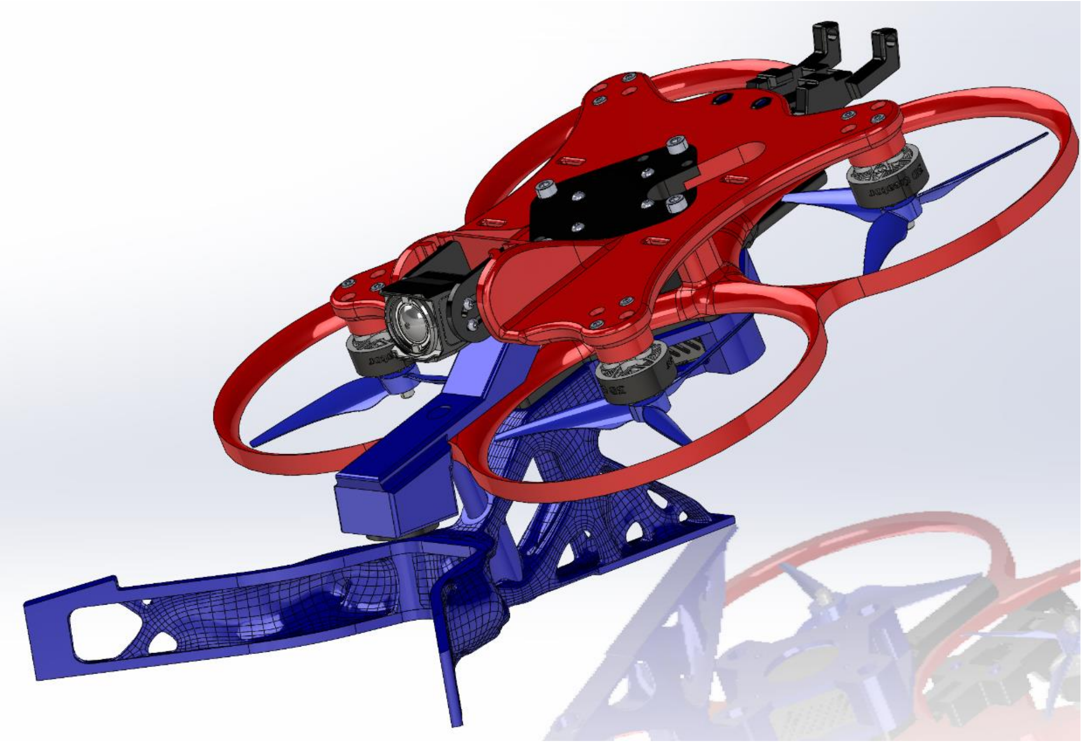
Aidan Pulaski

Kyle Richardson

Nikolaos Takos

Francis College of Engineering

University of Massachusetts Lowell



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Iterative Design Process:

This project embarked on an ambitious journey to create a competitive unmanned aerial racing cargo vehicle (U.A.R.C.V.) leveraging the potential of 3D printing and the principles of iterative design. The primary objective was to conceptualize, design, and fabricate a drone that would not only comply with the competition's regulations but also excel in performance.

From the beginning, we understood that an effective design would need to consider several critical aspects, such as material selection for the frame, optimal motor performance, reliable payload carrying capabilities, structural rigidity, and compliance with the weight and size restrictions set by the competition's rules. These foundational parameters steered our research and development process, ensuring that our efforts were targeted and productive.

The research phase looked beyond traditional engineering standards, which often emphasize military applications not pertinent to our competition's scope. We scrutinized a variety of resources, including industry publications, drone enthusiast forums, and historical data from past competitions, to determine the most critical elements of drone design. The validity of our sources was cross-checked against each other and benchmarked with previous competition insights, fostering an informed selection of components and materials.

Decision matrices played a pivotal role in guiding our design choices, particularly in selecting the electronic components and the drone's structural elements. Preliminary designs began modestly with a drone fitted with 2.5-inch propellers. With each subsequent iteration, we refined the tolerancing, enhanced the performance, and tested rigorously. After each testing phase, we gathered insights and fed them back into the design process, refining and evolving our U.A.R.C.V.

Optimization was conducted using ANSYS Finite Element Analysis and Altair lightweighting software, which provided data-driven guidance on where we could change the design and reduce mass without compromising structural integrity. This iterative process of design, analysis, and testing was the crucible in which we tempered our drone, ultimately achieving a balance between rigidity, weight, and maneuverability. The Ansys simulation results can be seen at the end of the report in Appendix B.

This report will outline our comprehensive journey through the iterative design process. The report will delve into the specifics of the iterations in subsequent sections, and it will set the stage for the detailed exposition of our methodology and the evolutionary progression of our design. Our commitment to the iterative process has been unwavering, rooted in the conviction that each cycle brings us closer to the apex of innovation and performance.

Design Iterations Overview:

Our design philosophy was grounded in simplicity and functionality. We aimed for a lightweight yet robust drone that could be easily assembled and maintained, with a structure firm enough to support stable flight and the precise operation of electronics like the flight controller (FC) and camera.

First Iteration:

The initial concept was built around 2.5-inch propellers. However, this version presented several challenges: insufficient clearance for wiring, excessive vibration transfer from an undersized camera mount, inadequate space for the capacitor, oversized battery straps, and no dedicated mounting option for the electromagnet we planned to use. As expected with a first attempt, this prototype was far from perfect, but it was invaluable in highlighting areas for improvement.

Figure 1. Images of design iteration 1 in CAD and the physical prototype

Second Iteration:

Addressing the issues from the first design, we modified the frame to include a top cutout for the battery leads and capacitor. We rearranged the FC and ESC, positioning the FC underneath and the ESC above for better use of space in the frame leaving room for the capacitor and battery leads. The frame also gained four new holes to accommodate a battery stand and an antenna mount, though we still needed to resolve the placement of the electromagnet.

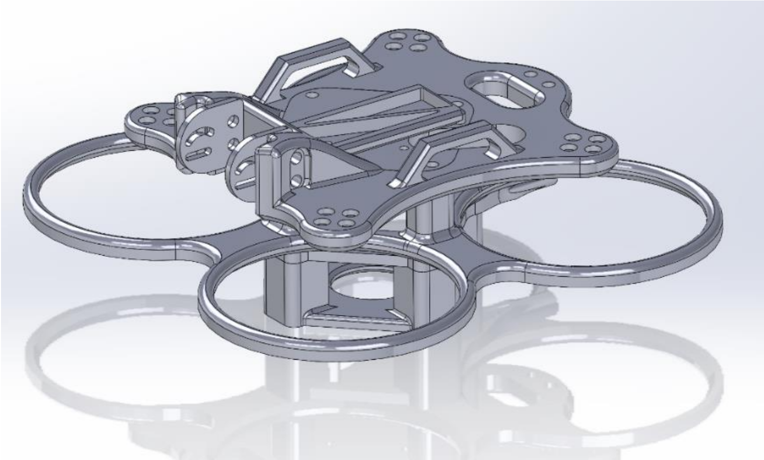


Figure 2. The second CAD model of iteration 2.

Third Iteration:

This version began to resemble our final vision. We introduced spacers to elevate the motor mounts, increasing airflow to the propellers and enhancing lift. The prop guards were enlarged for better clearance and streamlined to reduce weight. We added TPU landing feet for improved shock absorption upon landing. Additionally, we extended the antenna mount for greater resilience.

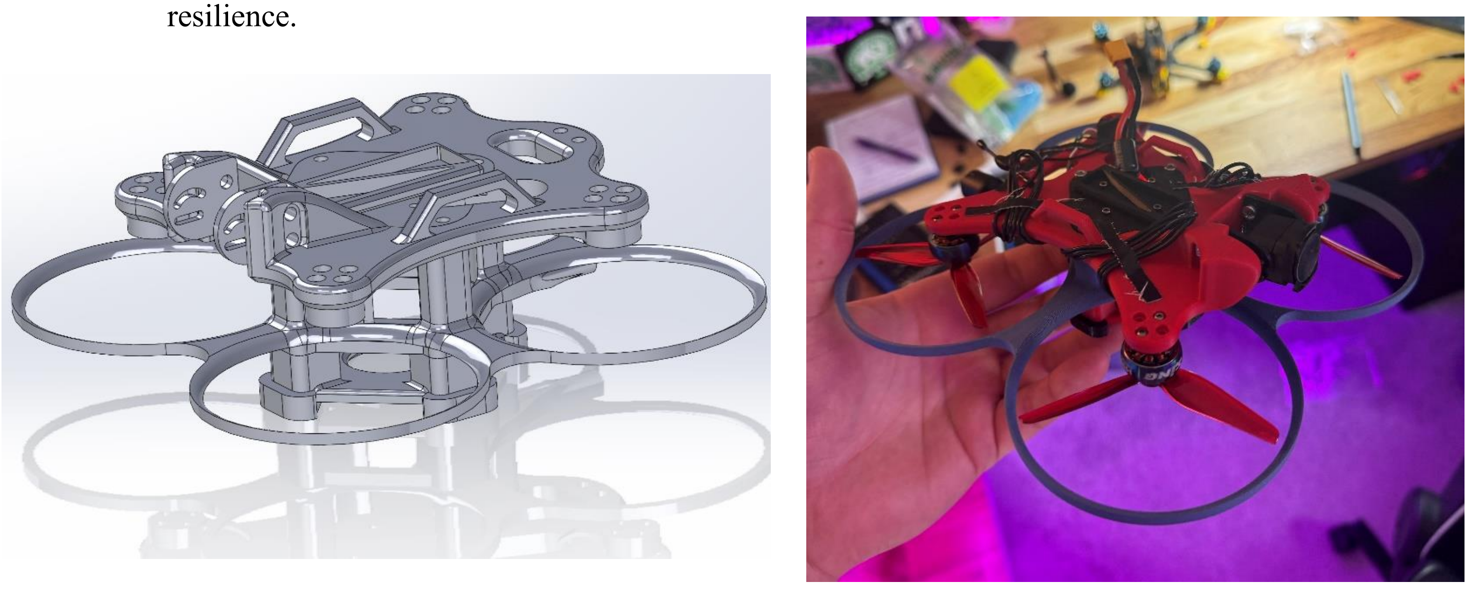


Figure 3. The CAD and real-life assemblies of iteration 3.

Fourth Iteration:

A significant upgrade in this iteration was the transition to larger 2004, 2400KV motors, facilitating the use of 3.5-inch propellers. This change markedly improved the drone's thrust, control, and stability, capitalizing on the new motors' higher torque. In this and subsequent iterations, we honed our focus on minimizing non-printed parts. Reflecting the competition's scoring criteria, we began to innovate ways to incorporate more 3D-printed elements into the design, without sacrificing the drone's integrity or performance.

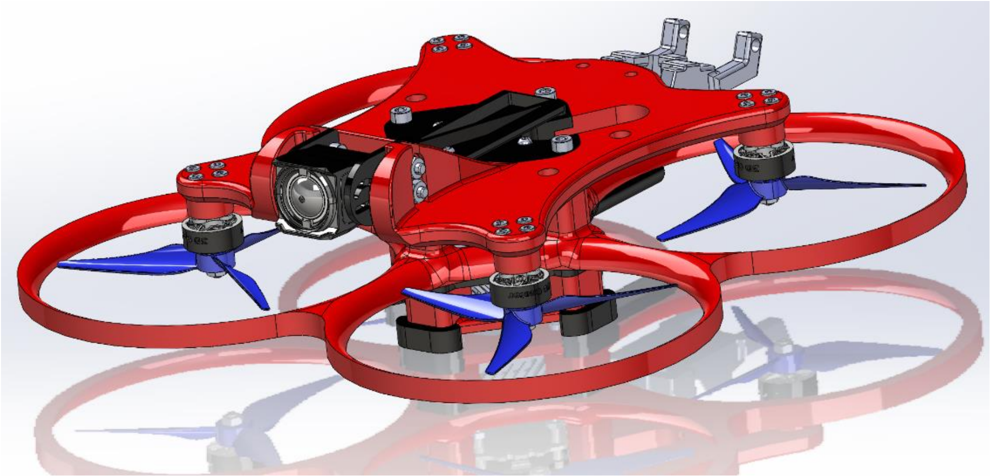


Figure 4. The fourth iteration in CAD and physically assembled.

Fifth and Final Design Iteration:

For our conclusive design iteration, we refined the frame to a version we were certain would perform well in the competition. This iteration prioritized reducing the number of parts, especially non-3D printed ones.

A significant innovation was the camera mount, which now features a dovetail joint. This clever design allowed us to eliminate eight pieces of hardware (including nuts and bolts), streamlining the assembly process. Beyond simplifying construction, this adjustment enhanced the camera mount's stability, reducing vibration transmission for clearer footage.

Figure 5. The final iteration with the grabbing mechanism installed in CAD and with all physical parts.

We also overhauled the battery mounting system. The earlier model used a combination of zip ties and a fabric Velcro strap, which incorporated three non-3D printed parts. Our new design utilized custom-made TPU straps that were not only durable but also improved the battery's secure attachment to the frame.

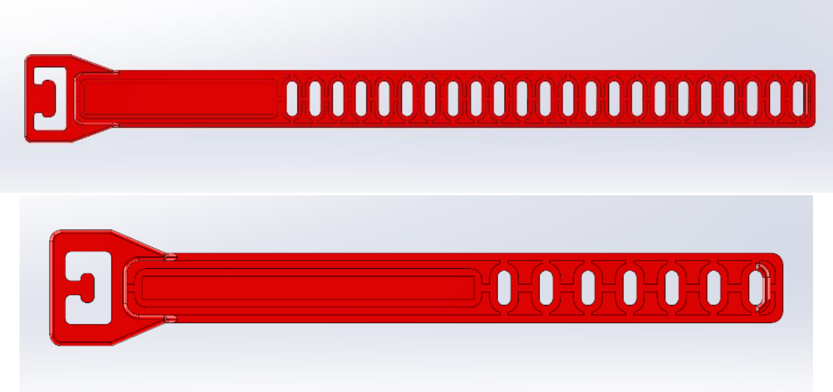


Figure 6. The CAD models for the 3D printed strap designs.

This iteration was also crucial for perfecting the payload pickup system. We remained committed to using an electromagnet for its simplicity and lightness compared to a mechanical gripper system. To ensure consistent pickup, we developed a funnel arm mechanism that guided the payload directly to the electromagnet. This feature underwent multiple refinements to achieve reliability without compromising the drone’s aerodynamics.

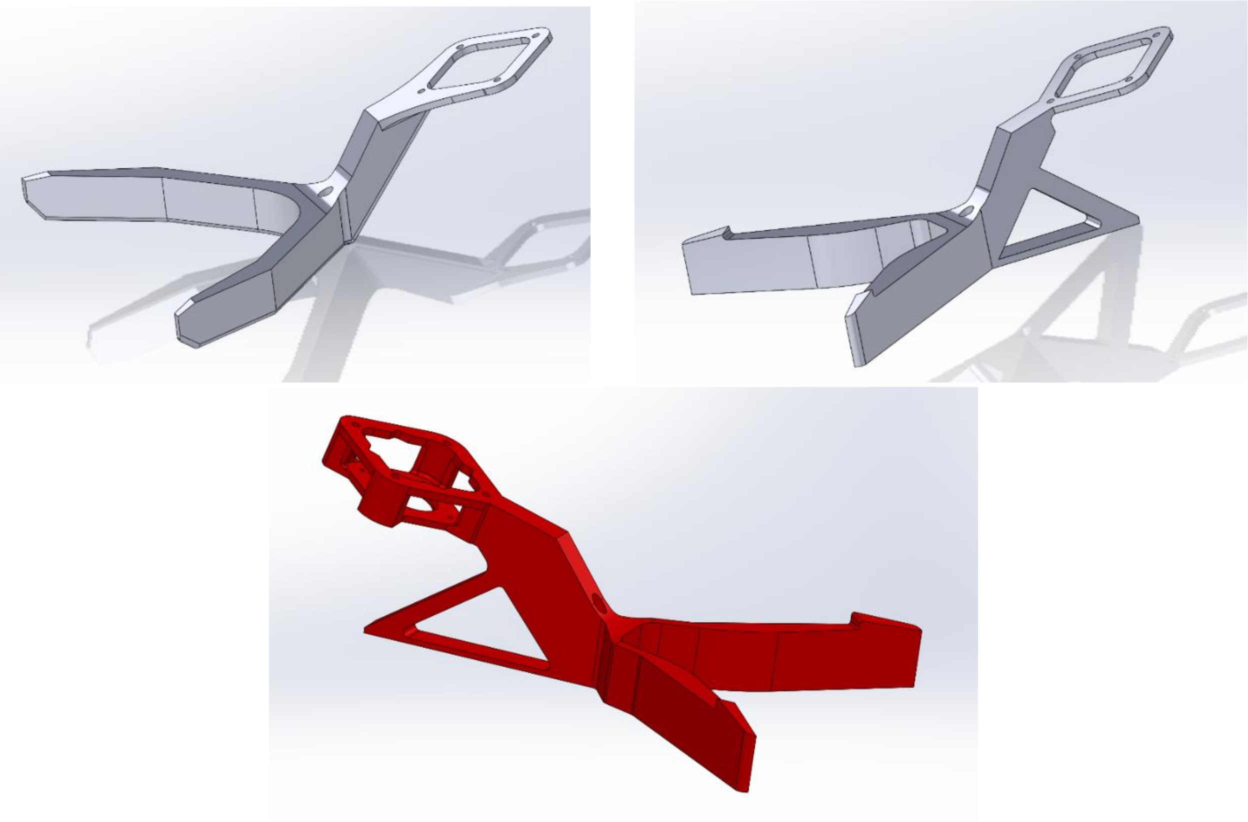


Figure 7. The different iterations of the funnel design.

The iterative design process, underpinned by 3D printing, was instrumental in evolving our drone. It allowed us to swiftly move from concept to physical model, test it, and then refine it further. This rapid prototyping capability was invaluable, enabling continuous improvement in design with each iteration. Additive manufacturing empowered us to experiment with and realize complex geometries that traditional manufacturing methods could not easily achieve.

Our journey from the initial concept to the final iteration epitomizes the transformative power of 3D printing in design and engineering. The ability to quickly adapt and materialize new ideas is a potent advantage in any competitive engineering endeavor. As a result of this process, our confidence in our drone's design has soared, and we eagerly anticipate showcasing its capabilities in the upcoming competition.

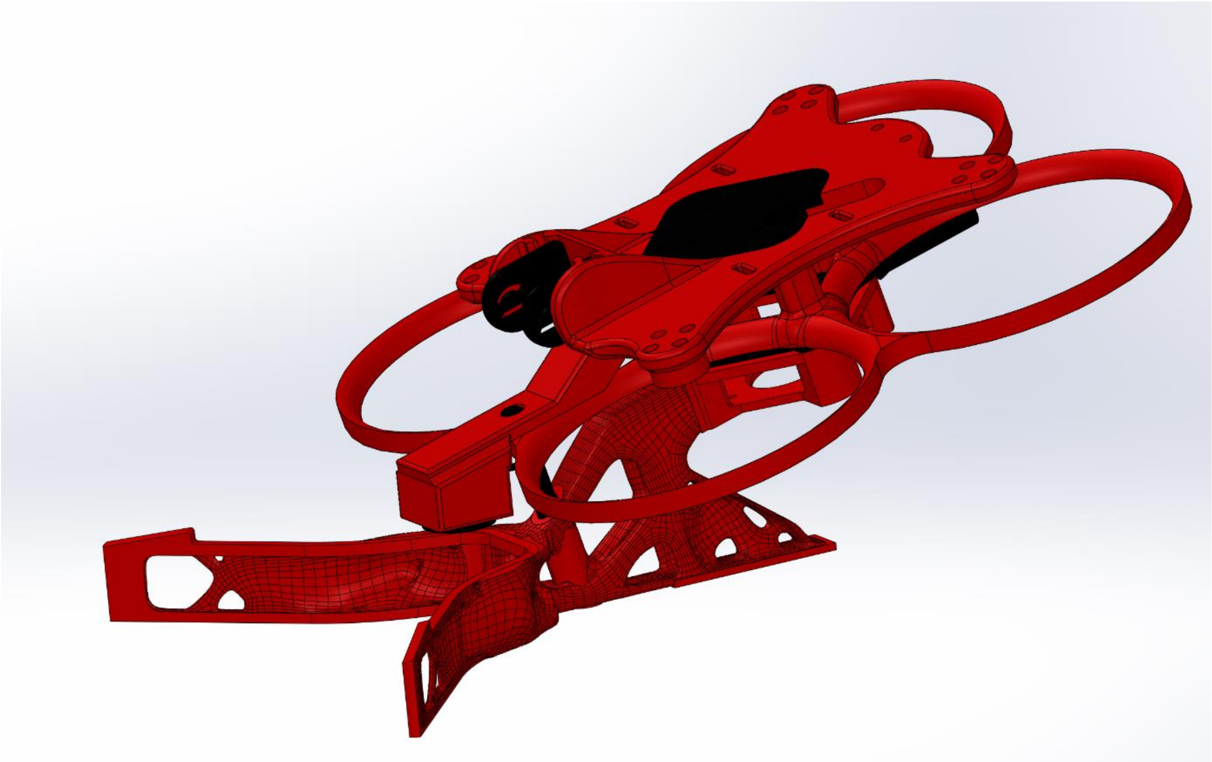


Figure 8. Final CAD assembly of all 3D-printed frame parts.

In designing our drone, the main goals were to achieve high speed, high rigidity, and low weight, all while prioritizing a simplistic design. We focused on finding the best combination of power, weight, torque, and energy efficiency in our parts. Initially, we opted for XING size 1404, 4600KV motors for their high RPMs and low weight. However, during initial test flights, these motors didn't deliver the torque or power we needed and drained the battery quickly.

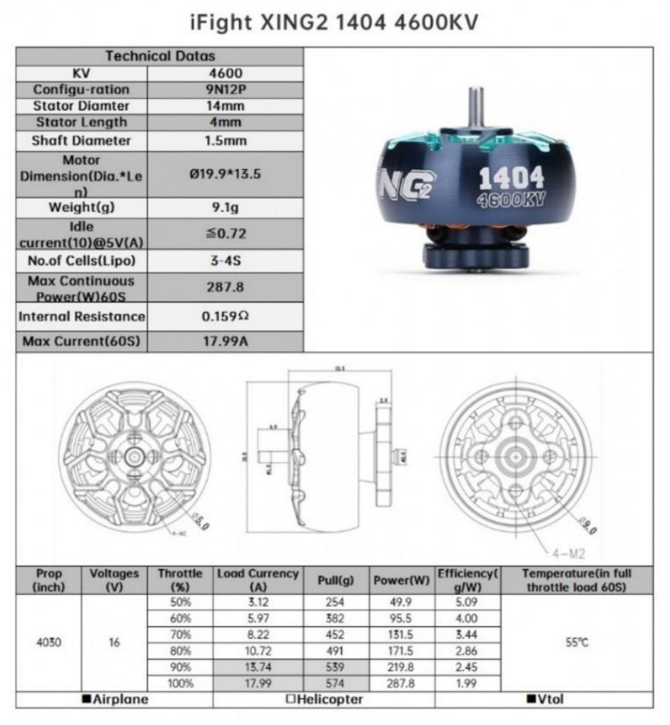
To address this, we switched to larger size 2004, 2400KV motors. These provided more torque and better power, which was crucial for the obstacle course. They were heavier, but we compensated for this by modifying the drone frame. Using these motors, we were able to run larger propeller sizes and with a higher blade count on the propellers. Since these new motors were a lower KV, they provided more torque, allowing us to use 3.5-inch, 5-bladed propellers instead of the 25-inch 2 and 3- blade propellers we were using in the initial design. We opted towards the larger diameter and higher blade count propellers because they were able to provide much more thrust while also making the drone much more controllable. The 5 blade propellers offer an increased level of stability compared to the lesser blade number propellers. Stability was crucial in this design so we could reliably complete the cargo carrying portion of the competition. The increased stability allowed for smoother transitions from flying to hovering, making picking up the payload much easier for the pilot.

These major changes—swapping the motors and selecting the right propellers—were critical to improving our drone's performance. Using finite element analysis, we reduced the frame's weight by adjusting the infill percentage without compromising its strength. We made additional tweaks to the frame based on what we learned from these tests.

We opted to use an electromagnet to pick up and carry the payload during this competition. Our design around this electromagnet allowed for simple geometry and seamless integration into the frame design. We tested a few different electromagnets to find one with a good balance of weight and holding force.

This approach reflects the engineering process: starting with a plan, testing, and then iterating based on results. This project hasn't just been about building a drone; it's been a real-world engineering challenge, teaching us about design, testing, and making data-driven decisions. The attached table below lists all the parts we used, along with their specifications and weight.

Table 1. The part specifications for the XING2 [3].

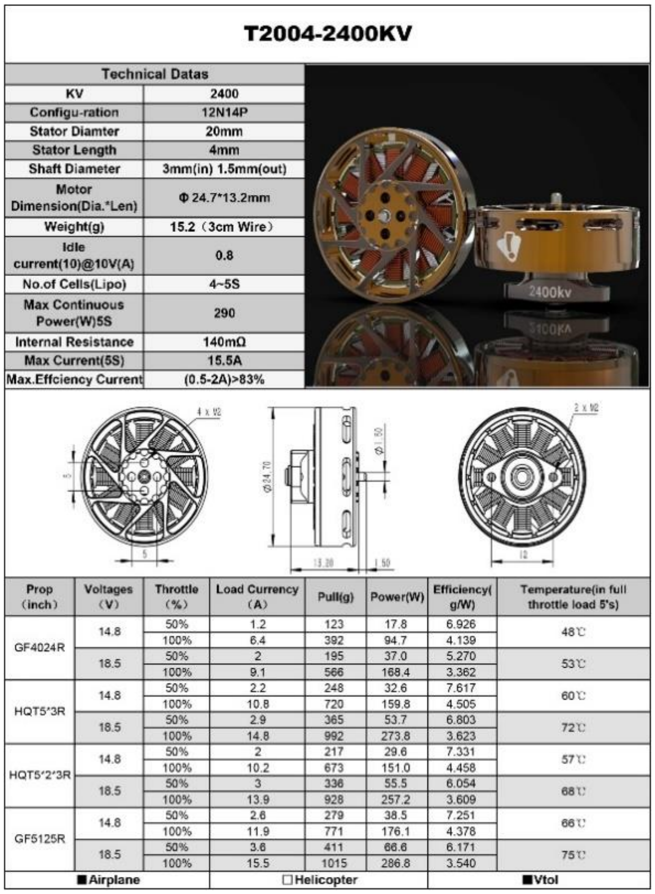


iFight XING2 1404 4600KV

Technical Datas	
KV	4600
Configu-ration	9N12P
Stator Diamter	14mm
Stator Length	4mm
Shaft Diameter	1.5mm
Motor Dimension(Dia.*Len)	Ø19.9*13.5
Weight(g)	9.1g
Idle current(10)@5V(A)	≦0.72
No.of Cells(Lipo)	3-4S
Max Continuous Power(W)60S	287.8
Internal Resistance	0.159Ω
Max Current(60S)	17.99A

Prop (inch)	Voltages (V)	Throttle (%)	Load Currency (A)	Pull(g)	Power(W)	Efficiency(g/W)	Temperature(in full throttle load 60S)
4030	16	50%	3.12	254	49.9	5.09	55℃
		60%	5.97	382	95.5	4.00	
		70%	8.22	452	131.5	3.44	
		80%	10.72	491	171.5	2.86	
		90%	13.74	539	219.8	2.45	
		100%	17.99	574	287.8	1.99	
■Airplane			☐Helicopter			■Vtol	

Table 2. The part specifications for the UMMAGAWD motor [13].

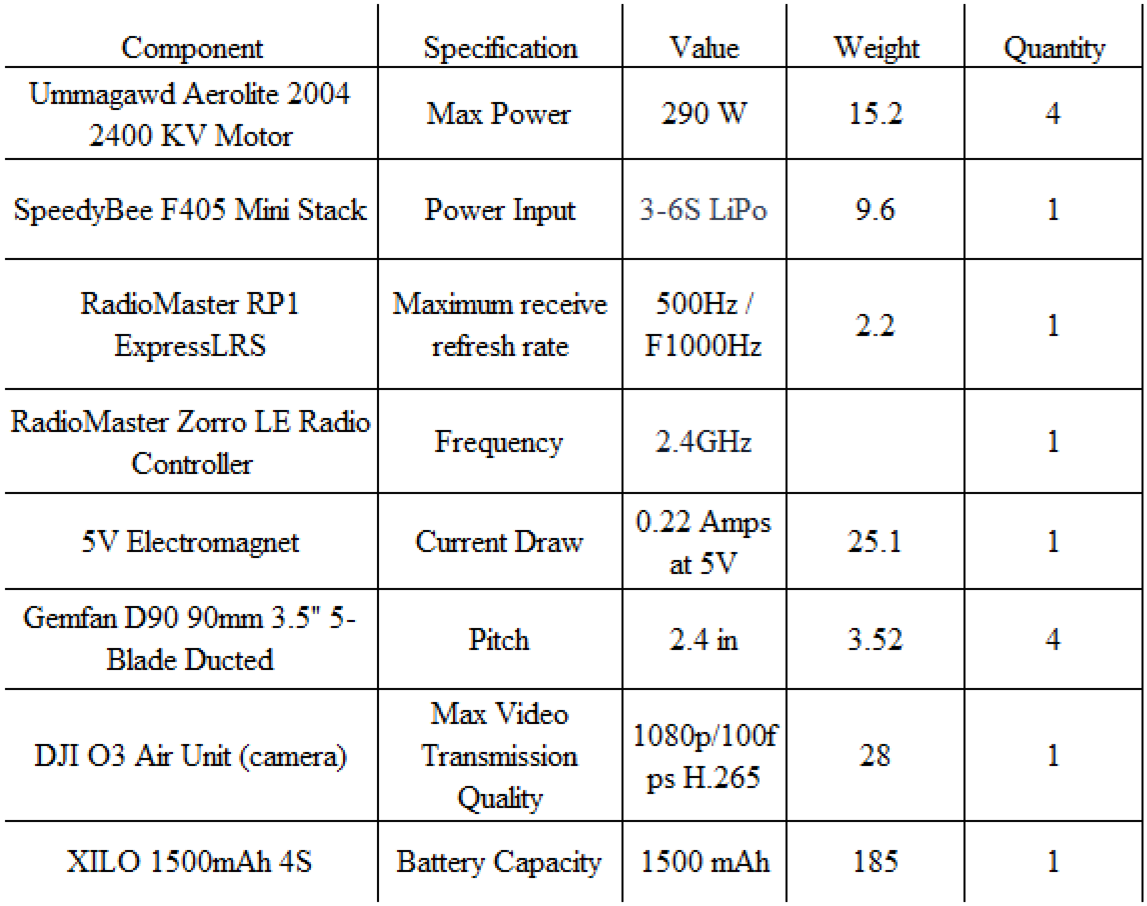


T2004-2400KV

Technical Datas	
KV	2400
Configu-ration	12N14P
Stator Diamter	20mm
Stator Length	4mm
Shaft Diameter	3mm(in) 1.5mm(out)
Motor Dimension(Dia.*Len)	Φ 24.7*13.2mm
Weight(g)	15.2（3cm Wire）
Idle current(10)@10V(A)	0.8
No.of Cells(Lipo)	4~5S
Max Continuous Power(W)5S	290
Internal Resistance	140mΩ
Max Current(5S)	15.5A
Max.Effciency Current	(0.5-2A)>83%

Prop （inch）	Voltages （V）	Throttle （%）	Load Currency （A）	Pull(g)	Power(W)	Efficiency(g/W)	Temperature(in full throttle load 5's)
GF4024R	14.8	50%	1.2	123	17.8	6.926	48℃
		100%	6.4	392	94.7	4.139	
	18.5	50%	2	195	37.0	5.270	53℃
		100%	9.1	566	168.4	3.362	
HQT5*3R	14.8	50%	2.2	248	32.6	7.617	60℃
		100%	10.8	720	159.8	4.505	
	18.5	50%	2.9	365	53.7	6.803	72℃
		100%	14.8	992	273.8	3.623	
HQT5*2*3R	14.8	50%	2	217	29.6	7.331	57℃
		100%	10.2	673	151.0	4.458	
	18.5	50%	3	336	55.5	6.054	68℃
		100%	13.9	928	257.2	3.609	
GF5125R	14.8	50%	2.6	279	38.5	7.251	66℃
		100%	11.9	771	176.1	4.378	
	18.5	50%	3.6	411	66.6	6.171	75℃
		100%	15.5	1015	286.8	3.540	
■Airplane			☐Helicopter			■Vtol	

Table 3. Part specifications and weights



Component	Specification	Value	Weight	Quantity
Ummagawd Aerolite 2004 2400 KV Motor	Max Power	290 W	15.2	4
SpeedyBee F405 Mini Stack	Power Input	3-6S LiPo	9.6	1
RadioMaster RP1 ExpressLRS	Maximum receive refresh rate	500Hz / F1000Hz	2.2	1
RadioMaster Zorro LE Radio Controller	Frequency	2.4GHz		1
5V Electromagnet	Current Draw	0.22 Amps at 5V	25.1	1
Gemfan D90 90mm 3.5" 5-Blade Ducted	Pitch	2.4 in	3.52	4
DJI O3 Air Unit (camera)	Max Video Transmission Quality	1080p/100fps H.265	28	1
XILO 1500mAh 4S	Battery Capacity	1500 mAh	185	1

Drone Performance and Design Considerations:

Our drone's performance exceeded our initial expectations significantly. We managed to reduce the total weight to approximately 550 grams, including the battery, a substantial improvement from our initial target of under 700 grams. The frame and all the electronics, minus the battery, came in at about 350 grams. Through iterative design and finite element analysis, we aimed to break the 400-gram barrier for our frame design, which we achieved. This weight reduction, paired with our choice of powerful yet lightweight motors, allowed our drone to be both swift and agile.

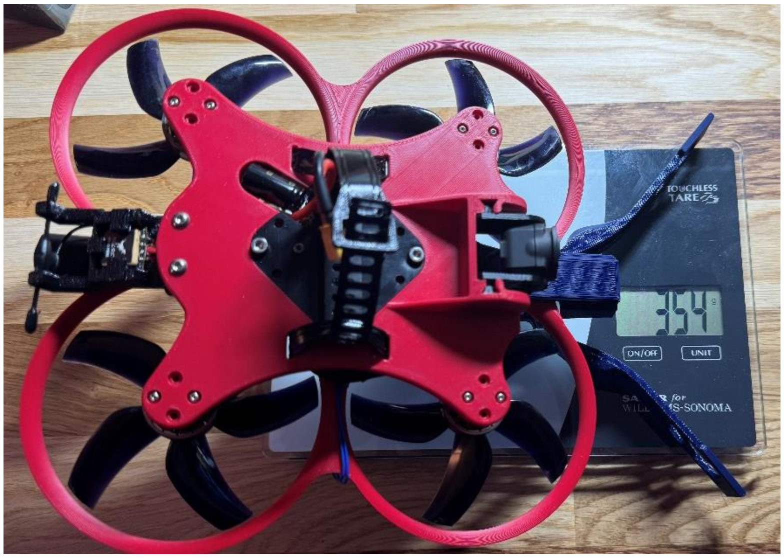


Figure 9. Complete Drone Assembly (Without Battery) on the scale

During our tests, the drone clocked speeds up to 85 miles per hour and showcased impressive maneuverability around the obstacle course. It handled corners smoothly without any noticeable loss of balance or power—this is a marked improvement from the original prototype's 50 mph speed cap and less responsive handling.

We also focused on enhancing the drone's endurance by upgrading the battery from 850mAh to 1500mAh. This not only allowed for extended flight times during tests but also provided us with more data to refine each design iteration, particularly the payload pick-up and delivery system.

Payload Pick-Up Mechanism Design and Optimization:

For the payload pick-up mechanism, our initial design incorporated an electromagnet to secure the PLA cube, which had a metal washer to ensure magnetic attachment. The challenge was to guide the cube precisely onto the electromagnet during flight. Our innovative solution was to design a funnel arm that extended in front of the drone, streamlining the cube directly to the electromagnet for consistent pick-up.

This funnel arm was not just a static piece, but a critical component evolved through several design iterations. We meticulously balanced the weight, aerodynamics, 3D printability, and structural integrity of the funnel arm. Various shapes were prototyped and tested, with each iteration informed by the previous flight tests' performance data. Our goal was to achieve the most efficient design that would enable quick, reliable cube engagement without adversely impacting the drone's maneuverability or speed.

In conjunction with refining the funnel design, we also conducted extensive testing with different electromagnets. The aim was to identify the lightest option that could still provide the necessary magnetic force to lift the cube. This search was a delicate balance; the electromagnet needed to be strong enough to hold the payload securely during high-speed maneuvers while remaining light enough not to affect the drone's agility.

Through this iterative process, we optimized the funnel arm's design for the most effective payload pick-up. It had to be lightweight to not drastically hurt flight dynamics, aerodynamic to minimize drag, strong enough to endure the stresses of rapid maneuvers, and perfectly shaped to align the cube with the electromagnet every time. The result was a streamlined and effective pick-up system tailored to the unique demands of drone racing and payload retrieval, embodying the ingenuity and problem-solving skills central to mechanical engineering.

3D Printing and Material Selection Refinement:

Our project capitalized on FDM (Fused Deposition Modeling) 3D printing technology to fabricate various components of the drone. Throughout the design process, the drone's frame experienced a number of iterations—initially, some designs were too bulky which hampered agility, while others were too compact, causing issues with internal component fit and heat dissipation.

To keep prototyping both practical and budget-friendly, we started with Polylactic Acid (PLA) for early frame versions. Although PLA is a go-to for its ease of printing, we discovered its fragility was a drawback—it fractured on impact even after we increased the frame thickness for strength.

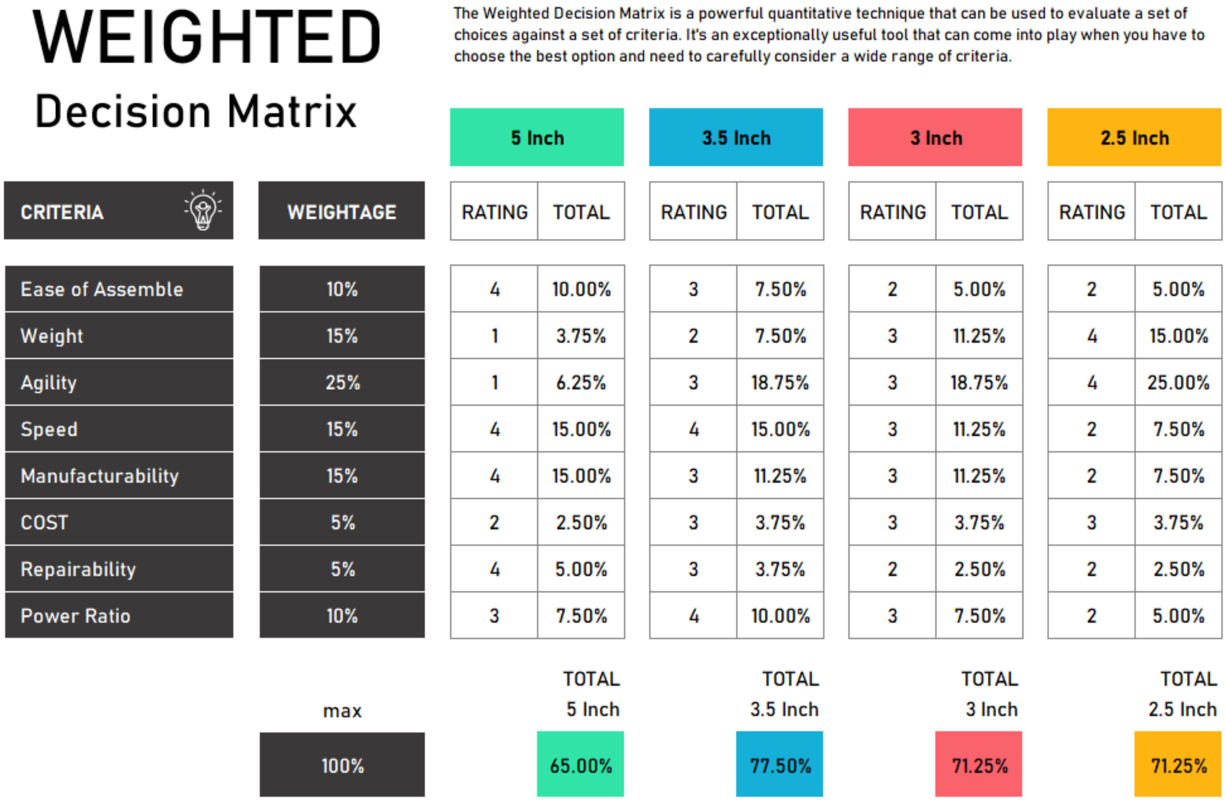
We transitioned to Acrylonitrile Styrene Acrylate (ASA) for its superior toughness, beneficial for the main frame structure to endure the rigors of racing. For parts where elasticity was paramount, like the mounts for electronic components and the camera, we selected Thermoplastic

Polyurethane (TPU). TPU's resilience significantly dampened vibrations, which was pivotal for maintaining a clear video feed during flights.

When our design approached its final form, we chose to use nylon carbon fiber for the ultimate iteration. The high cost and challenging printability of nylon carbon fiber meant that we reserved it until we were confident no further modifications were necessary. Its abrasive nature required careful handling, especially to prevent premature nozzle wear during printing. Yet, its excellent strength-to-weight ratio justified the choice, giving us a frame that was not only sturdy and reliable but also kept our drone light on its wings—an essential attribute for competitive drone racing.

Through this material selection process, we sought to align our choices with the principles of design for additive manufacturing, ensuring that each component was not only functional but optimized for the 3D printing process.

Table 4. Decision matrix to find the optimal drone size.



WEIGHTED

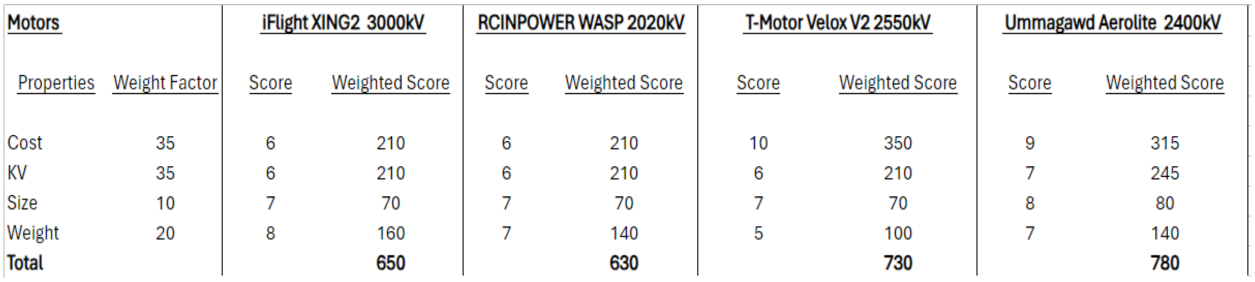
Decision Matrix

The Weighted Decision Matrix is a powerful quantitative technique that can be used to evaluate a set of choices against a set of criteria. It's an exceptionally useful tool that can come into play when you have to choose the best option and need to carefully consider a wide range of criteria.

		5 Inch		3.5 Inch		3 Inch		2.5 Inch	
CRITERIA	WEIGHTAGE	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL
Ease of Assemble	10%	4	10.00%	3	7.50%	2	5.00%	2	5.00%
Weight	15%	1	3.75%	2	7.50%	3	11.25%	4	15.00%
Agility	25%	1	6.25%	3	18.75%	3	18.75%	4	25.00%
Speed	15%	4	15.00%	4	15.00%	3	11.25%	2	7.50%
Manufacturability	15%	4	15.00%	3	11.25%	3	11.25%	2	7.50%
COST	5%	2	2.50%	3	3.75%	3	3.75%	3	3.75%
Repairability	5%	4	5.00%	3	3.75%	2	2.50%	2	2.50%
Power Ratio	10%	3	7.50%	4	10.00%	3	7.50%	2	5.00%

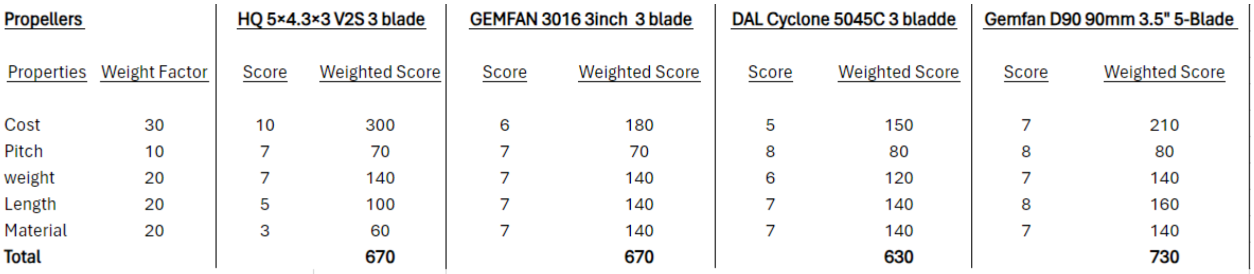
	max	TOTAL 5 Inch	TOTAL 3.5 Inch	TOTAL 3 Inch	TOTAL 2.5 Inch
	100%	65.00%	77.50%	71.25%	71.25%

Table 5. Decision matrix for the motor.



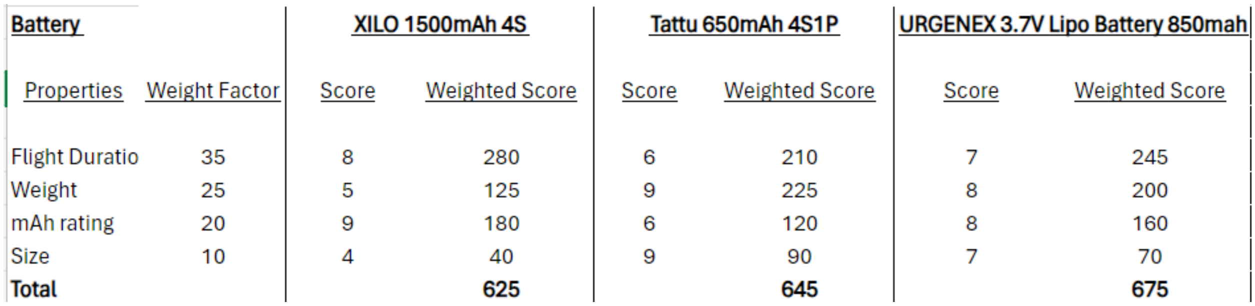
Motors		**iFlight XING2 3000kV**		**RCINPOWER WASP 2020kV**		**T-Motor Velox V2 2550kV**		**Ummagawd Aerolite 2400kV**	
Properties	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	35	6	210	6	210	10	350	9	315
KV	35	6	210	6	210	6	210	7	245
Size	10	7	70	7	70	7	70	8	80
Weight	20	8	160	7	140	5	100	7	140
Total			**650**		**630**		**730**		**780**

Table 6. Decision matrix for the propellers.



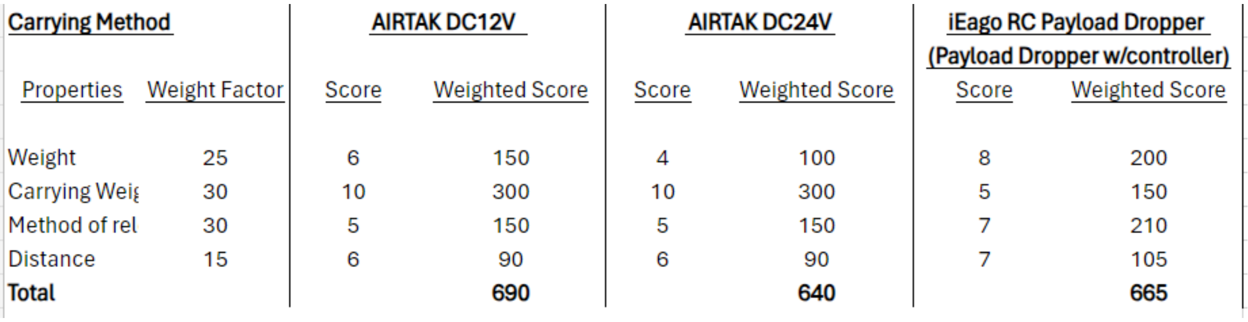
Propellers		**HQ 5×4.3×3 V2S 3 blade**		**GEMFAN 3016 3inch 3 blade**		**DAL Cyclone 5045C 3 bladde**		**Gemfan D90 90mm 3.5" 5-Blade**	
Properties	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	30	10	300	6	180	5	150	7	210
Pitch	10	7	70	7	70	8	80	8	80
weight	20	7	140	7	140	6	120	7	140
Length	20	5	100	7	140	7	140	8	160
Material	20	3	60	7	140	7	140	7	140
Total			**670**		**670**		**630**		**730**

Table 7. Decision matrix for the battery.



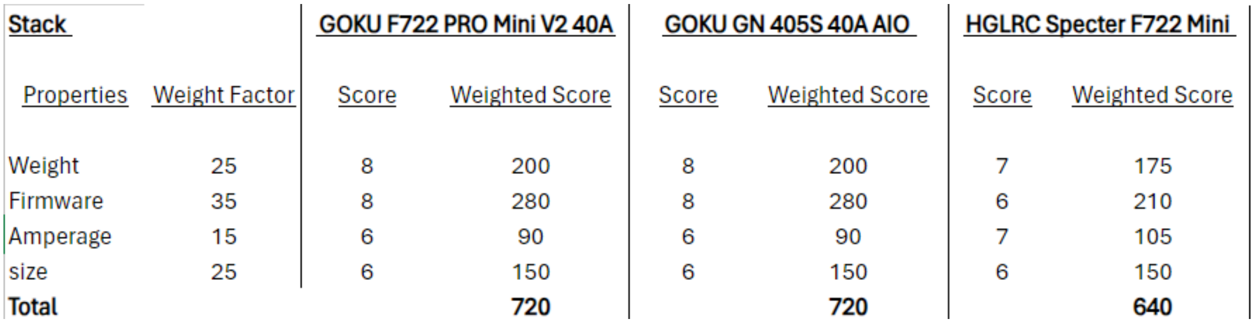
Battery		**XILO 1500mAh 4S**		**Tattu 650mAh 4S1P**		**URGENEX 3.7V Lipo Battery 850mah**	
Properties	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Flight Duratio	35	8	280	6	210	7	245
Weight	25	5	125	9	225	8	200
mAh rating	20	9	180	6	120	8	160
Size	10	4	40	9	90	7	70
Total			**625**		**645**		**675**

Table 8. Decision matrix for the carrying method.



Carrying Method		**AIRTAK DC12V**		**AIRTAK DC24V**		**iEago RC Payload Dropper (Payload Dropper w/controller)**	
Properties	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Weight	25	6	150	4	100	8	200
Carrying Weig	30	10	300	10	300	5	150
Method of rel	30	5	150	5	150	7	210
Distance	15	6	90	6	90	7	105
Total			**690**		**640**		**665**

Table 9. Decision matrix for the stack.



Stack		GOKU F722 PRO Mini V2 40A		GOKU GN 405S 40A AIO		HGLRC Specter F722 Mini	
Properties	Weight Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Weight	25	8	200	8	200	7	175
Firmware	35	8	280	8	280	6	210
Amperage	15	6	90	6	90	7	105
size	25	6	150	6	150	6	150
Total			**720**		**720**		**640**

Design for Manufacture and Assembly Analysis (DFMA):

The essence of our IAM3D project is the interplay between aerodynamics and manufacturability—each decision made with an eye towards reducing weight, cost, and assembly time. From the start, our team targeted weight reduction through iterative design and testing various configurations and materials suitable for 3D printing.

Our engineering focus led to the creation of a three-part frame, robust enough to support the drone's components—motors, battery, and electronics—without the risk of breakage or deformation under stress. The design includes a top layer with motor spacers that allow for unobstructed airflow, a middle layer to house the flight controller (FC) and electronic speed controller (ESC) secured with screws, and a top mount for the battery, strapped in place with flexible TPU material. This modular approach simplifies the replacement of any single part without dismantling the entire structure, ensuring quick and efficient repairs.

The three-part assembly, combined with a minimal screw count, not only contributes to the frame’s lightweight and strength but also enhances the drone's reliability. If a component such as the propeller guard were to fail, it can be easily swapped out, avoiding extensive disassembly or complete frame replacement.

This streamlined design—characterized by fewer parts and dependent connections—reduces potential failure points and allows for easier maintenance. Each element has been carefully crafted to fit the constraints of FDM 3D printing, ensuring that the parts are optimally laid out on the print bed for efficiency. By prioritizing simplicity, we’ve managed to achieve a drone that embodies the balance between lightweight construction, structural integrity, and ease of manufacture and assembly—key to quick iterations and adaptability in a competitive environment.

Design for Additive Manufacturing Analysis (DFAM):

When we began developing our drone, we initially chose to use PLA filament for our test prints due to its affordability and ease of access. These test prints allowed us to evaluate various frame designs and print orientations to determine the most effective approach for our needs. Through this initial phase, it became clear that a major design goal was to reduce the use of fasteners by maximizing the use of 3D printed interlocking components. This necessitated precise print settings to maintain a tolerance fit of at least 0.01 millimeters, ensuring that all 3D printed parts would fit together seamlessly.

Our frame's design evolved into three main segments: the top part hosts the camera, antenna, and motor mounts, with small extensions on the motor mounts to lower them, optimizing airflow to the propellers. The middle section was adjusted to allow more space for wiring and improve air circulation to prevent the electronic stack from overheating. The bottom part serves as the landing gear and the structural foundation for lifting off. To unify these segments, we used long screws that extend from the top to the bottom, securing the components while allowing for straightforward disassembly and maintenance.

Achieving a design that was both lightweight and precisely fitted for assembly required extensive testing and refinement of our 3D printing parameters. We experimented with extrusion thicknesses, eventually settling on 0.2 millimeters (about 0.01 in) for the best balance of detail and strength. Wall counts, thicknesses, infill percentages, and patterns were all rigorously tested through various iterations, leading us to our final design criteria.

Our iterative tests with PLA paved the way for our eventual transition to more advanced materials—ASA for the main frame and TPU for parts requiring flexibility and shock absorption. These materials were chosen for their superior qualities: ASA's strength and durability for the main structure, and TPU's flexibility for impact resistance.

The accumulated knowledge from our testing informed our final print settings. As a result, we engineered a drone frame that was not just optimized for weight but also for strength, rigidity, and ease of assembly—all while being finely tuned to the nuances of FDM 3D printing. This careful planning and iterative process underscores the potential and versatility of additive manufacturing in the realm of drone design.

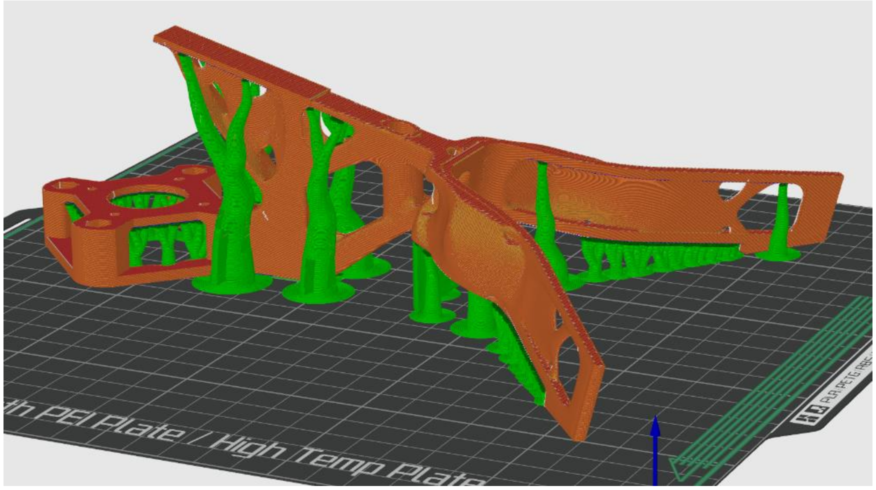


Figure 10. The funnel/scooper design in the slicing software

Testing Methods and Results

Our testing approach was hands-on and iterative, focusing on both the assembly process and flight performance of each drone iteration. We started by 3D printing each component and assembling the drone, which allowed us to pinpoint any issues with the assembly process or part tolerances. As the assembly became more streamlined, we shifted our attention to test flights, using these to gauge and enhance the drone's flying capabilities.

Initially, our drone models didn't perform as well as we expected. For instance, they struggled with lift and maneuverability. To address this, we introduced extensions above the motors, which improved air intake for the propellers and noticeably enhanced flight performance. Each design iteration underwent this cycle: we'd test fly the drone, observe how it performed, and then refine the design based on our observations.

During the test flights, we relied heavily on direct observation to assess improvements. While some changes were subtle, others significantly boosted the drone's capabilities. Through this iterative testing and refining process, we fine-tuned the design until we were confident enough to proceed with lightweighting using Altair software, aimed at further enhancing performance while keeping the design compatible with additive manufacturing techniques.

The final phase of our testing involved creating a practice course to simulate the competition environment. This was crucial not just for refining the drone's design, but also for giving our pilot essential hands-on experience, particularly with using the electromagnet to pick up the payload. This end-to-end testing approach ensured that our drone was not only optimized in design but also proven in action, ready to meet the challenges of the competition.

Lightweighting Process with Altair Inspire:

In our quest to optimize the drone's design, we turned to Altair Inspire, a software renowned for its topology optimization capabilities. Our focus was on the funnel arm piece—a crucial component designed to guide the payload into the magnet for pickup. Given its initial blocky design, this part presented an excellent opportunity for weight reduction without compromising its functionality. After some initial tests with the other frame components, it was discovered that it was not super beneficial to run the lightweighting software on those other frame components. The Precise geometry we created for the other frame components did not have as much room for optimization and it did not make sense to use the lightweighting for these other parts. Since we had to design for FDM 3d printing we had some limitations in what geometry we could print. The complex geometries generated from the Altair software for the other frame components would have been too complex and would not have been feasible to print on an FDM style machine. As such, we decided to optimize the scooper arm and focus our lightweighting efforts around that.

Utilizing Altair Inspire, we set out to refine the funnel arm's structure through topology optimization. This process involves a computational approach where the software algorithmically removes unnecessary material from the part, creating a design that maintains structural integrity while minimizing weight. To achieve this, we input specific parameters into the software, defining the loads and stresses the funnel arm would encounter during flight and payload interaction.

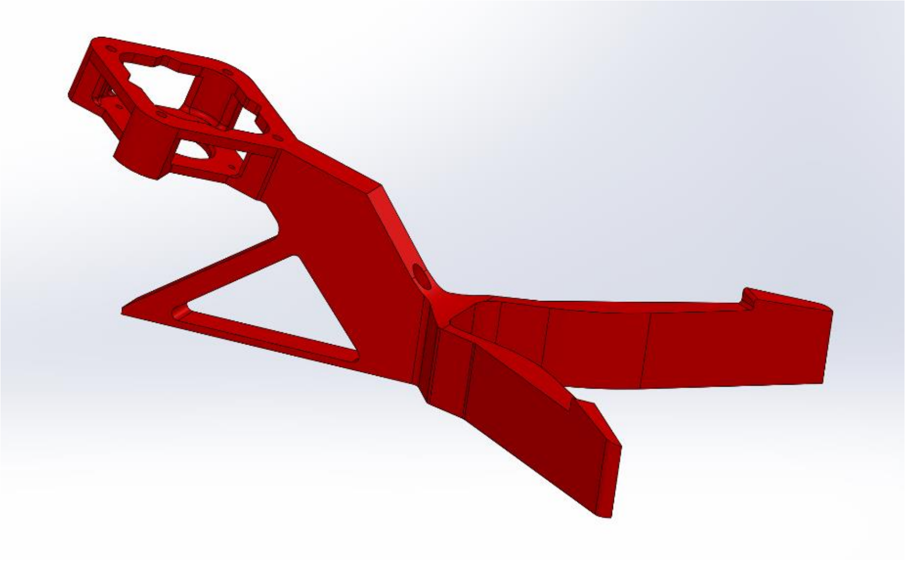


Figure 11. Image of the funnel in CAD before being optimized in the Altair software.

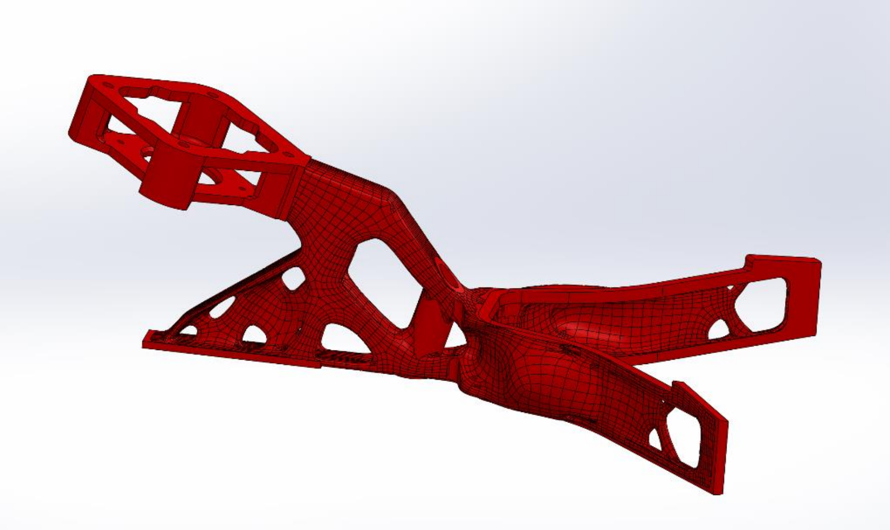


Figure 12. Image of the funnel in CAD after being optimized in the Altair software.

We meticulously set the optimization constraints, indicating the areas of the part we wanted to enhance and the material properties, ensuring the final design would be suitable for 3D printing on an FDM machine. Altair Inspire's powerful engine then worked its magic, analyzing the part's stress points and material distribution to generate an intricate, organic geometry that excelled in both form and function.

The outcome was a lighter, more efficient funnel arm, boasting a geometry that could only be achieved through the sophisticated algorithms of topology optimization. The initial design, which had very blocky geometry weighed in at about 62 grams. After using Altair topology optimization, the weight was able to be cut down to just 40 grams. This came out to about a 35% decrease in weight of this part which was great. This design not only met our weight reduction goals but also exemplified the advanced capabilities of additive manufacturing, enabling us to produce complex shapes that are both strong and lightweight.

By integrating Altair Inspire into our design process, we not only leveraged the cutting-edge in engineering software but also aligned with the competition's encouragement to utilize such tools for innovation. This lightweighting step was a pivotal moment in our project, showcasing how technology can transform a simple component into an optimized piece that contributes significantly to the overall efficiency and performance of our drone. Through this process, we've not only optimized a crucial part of our drone but also embraced a narrative that highlights the synergy between software innovation and practical engineering solutions.

Appendix A – Resources/References

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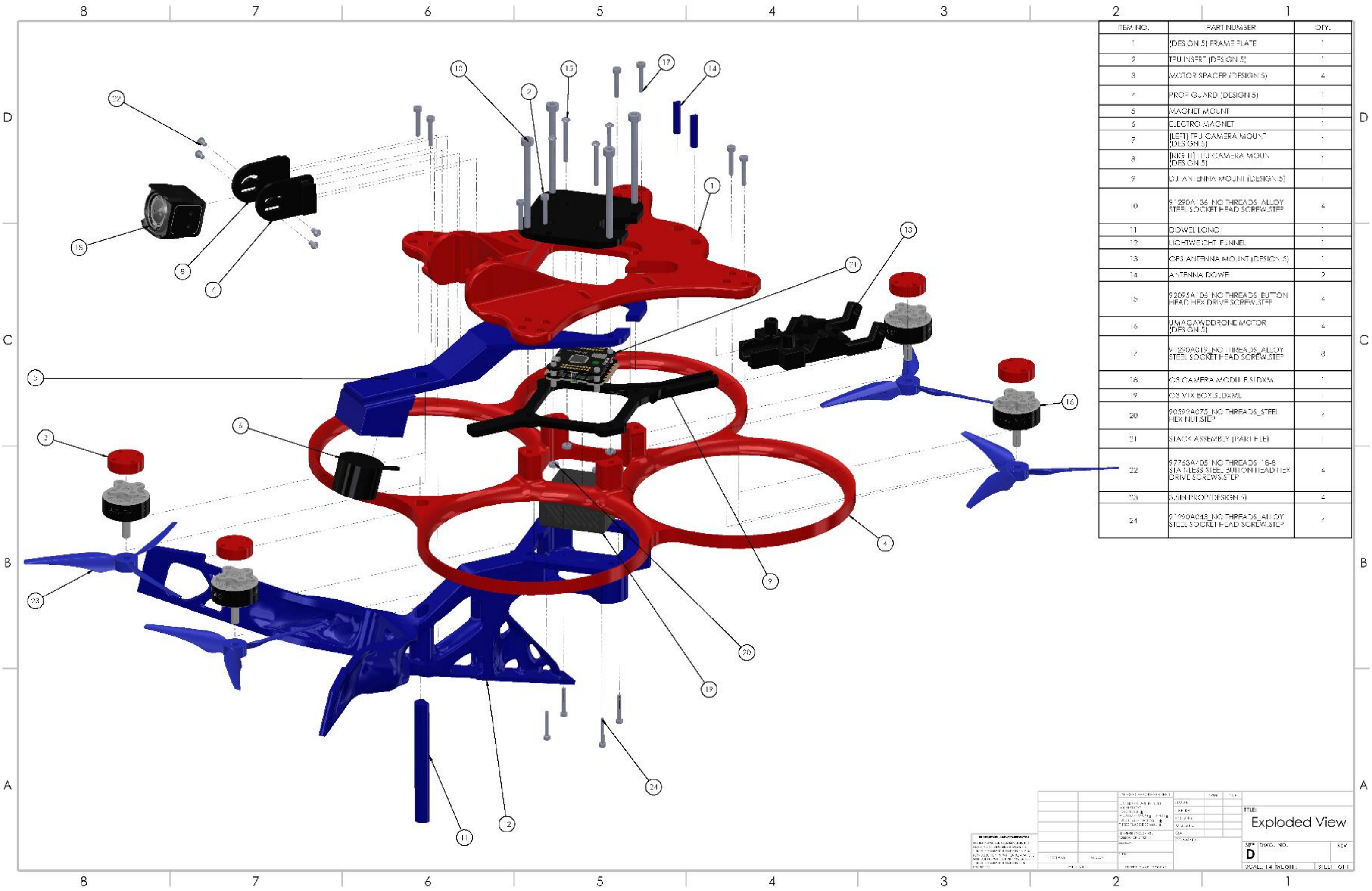
Appendix B – Extra Images of Designs, Simulations, and Physical Prototypes



ITEM NO.	PART NUMBER	QTY.
1	(DESIGN 5) FRAME PLATE	1
2	TPU INSERT (DESIGN 5)	1
3	MOTOR SPACER (DESIGN 5)	4
4	PROP GUARD (DESIGN 5)	1
5	MAGNET MOUNT	1
6	ELECTRO MAGNET	1
7	[LEFT] TPU CAMERA MOUNT (DESIGN 5)	1
8	[RIGHT] TPU CAMERA MOUNT (DESIGN 5)	1
9	DJI ANTENNA MOUNT (DESIGN 5)	1
10	91290A136_NO THREADS_ALLOY STEEL SOCKET HEAD SCREW.STEP	4
11	DOWEL LONG	1
12	LIGHTWEIGHT FUNNEL	1
13	GPS ANTENNA MOUNT (DESIGN 5)	1
14	ANTENNA DOWEL	2
15	92095A106_NO THREADS_BUTTON HEAD HEX DRIVE SCREW.STEP	4
16	UMAGAWDDRONE MOTOR (DESIGN 5)	4
17	91290A019_NO THREADS_ALLOY STEEL SOCKET HEAD SCREW.STEP	8
18	O3 CAMERA MODULE.SLDXM	1
19	O3 VTX BOX.SLDXML	1
20	90592A075_NO THREADS_STEEL HEX NUT.STEP	4
21	STACK ASSEMBLY (PART FILE)	1
22	97763A105_NO THREADS_18-8 STAINLESS STEEL BUTTON HEAD HEX DRIVE SCREWS.STEP	4
23	3.5IN PROP(DESIGN 5)	4
24	91290A043_NO THREADS_ALLOY STEEL SOCKET HEAD SCREW.STEP	4

Figure B-1. The exploded assembly of the final iteration as a CAD drawing.

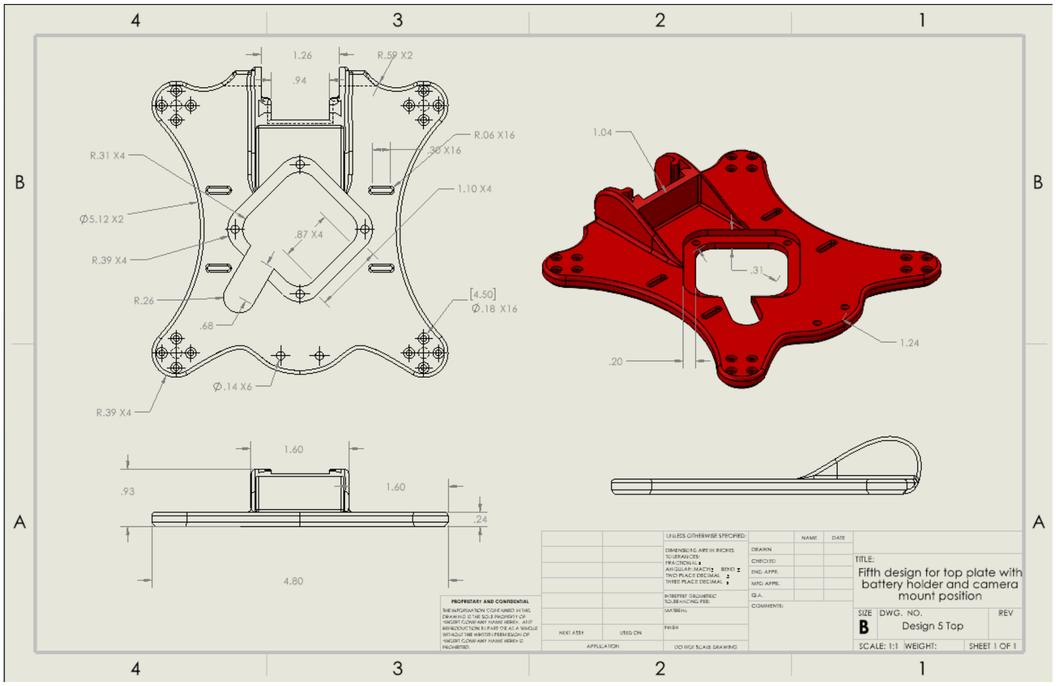


Figure B-2. The CAD drawing of the top plate.

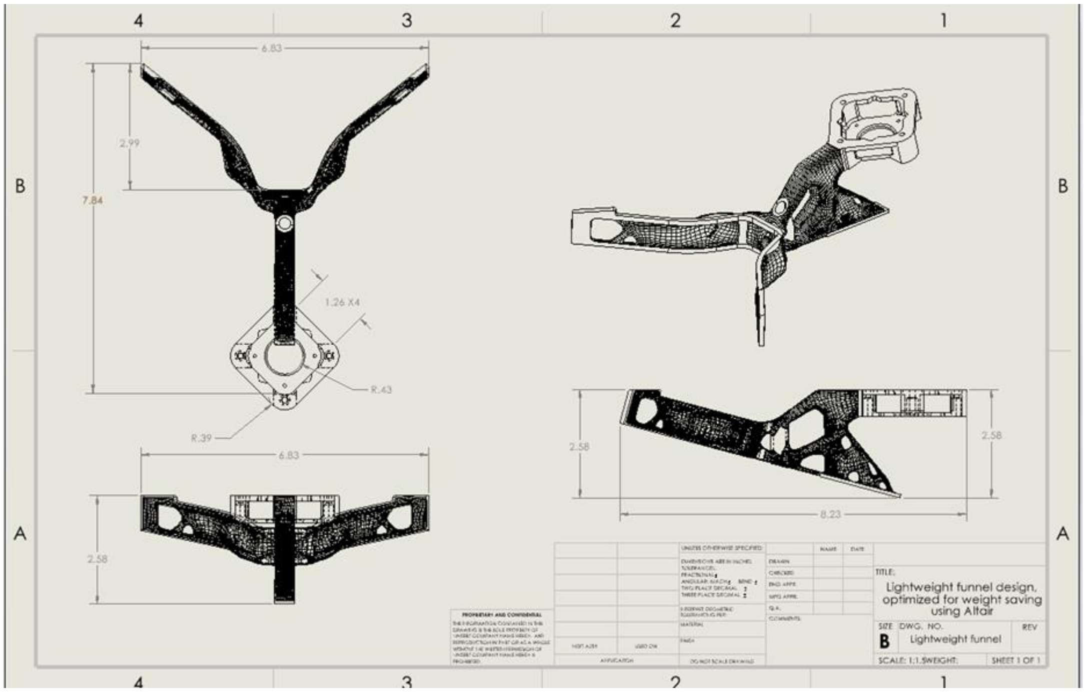


Figure B-3. The CAD drawing of the funnel and bottom section of the frame.

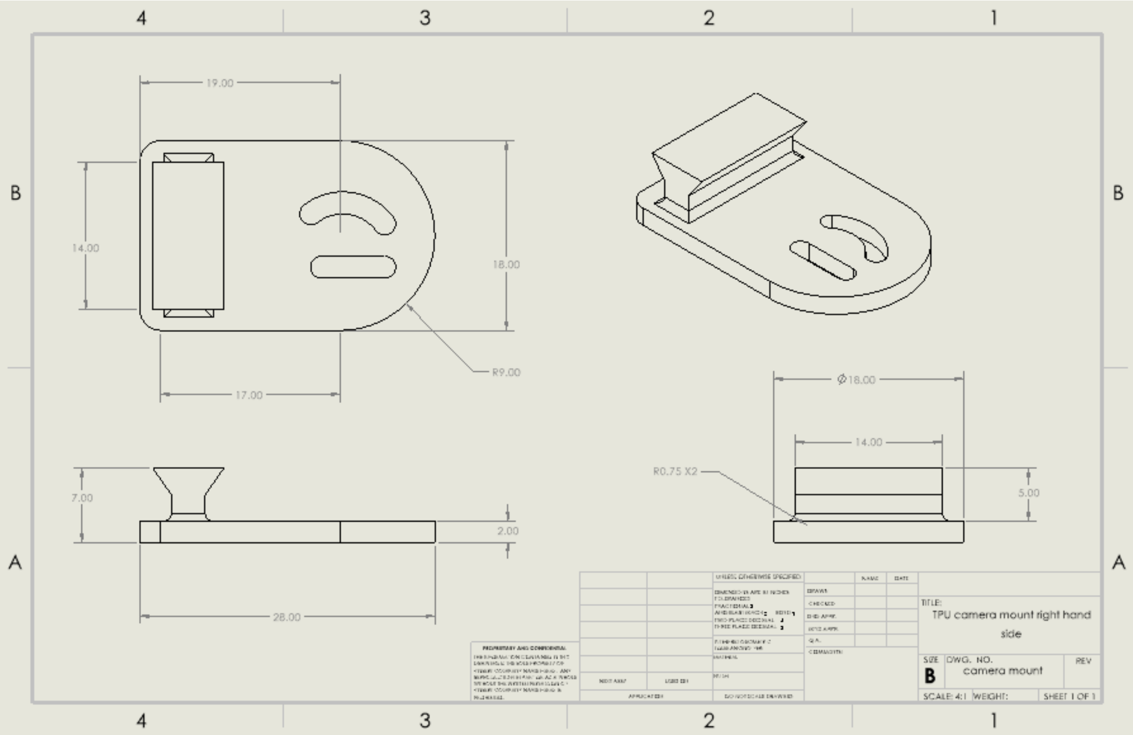


Figure B-4. The CAD drawing of the TPU camera mount insert.

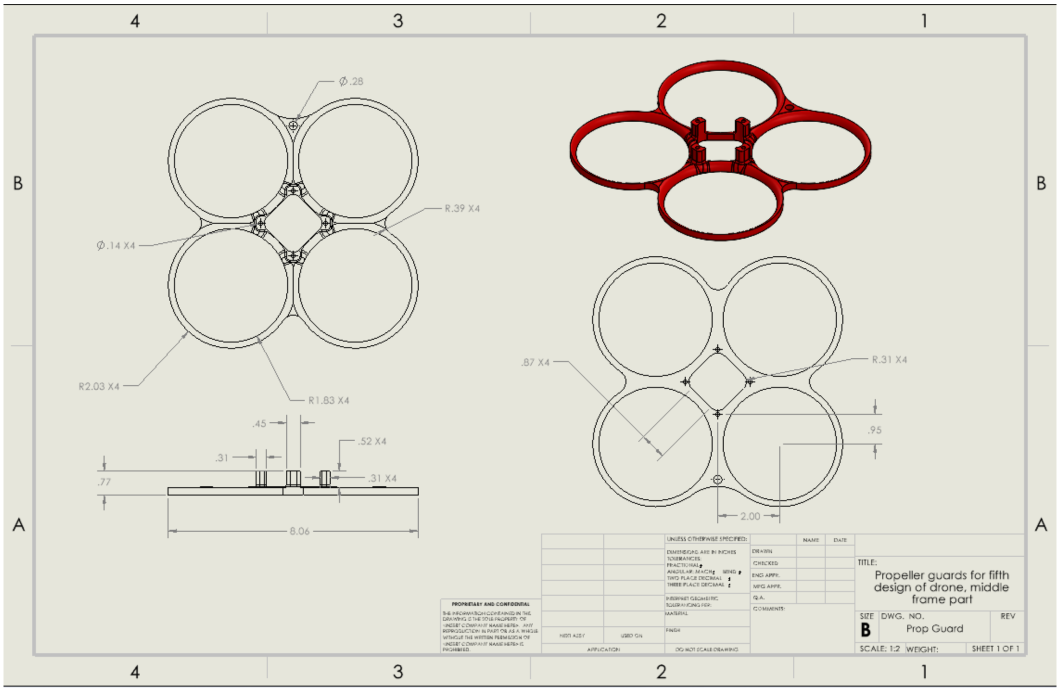


Figure B-5. The CAD drawing of the propeller guard.

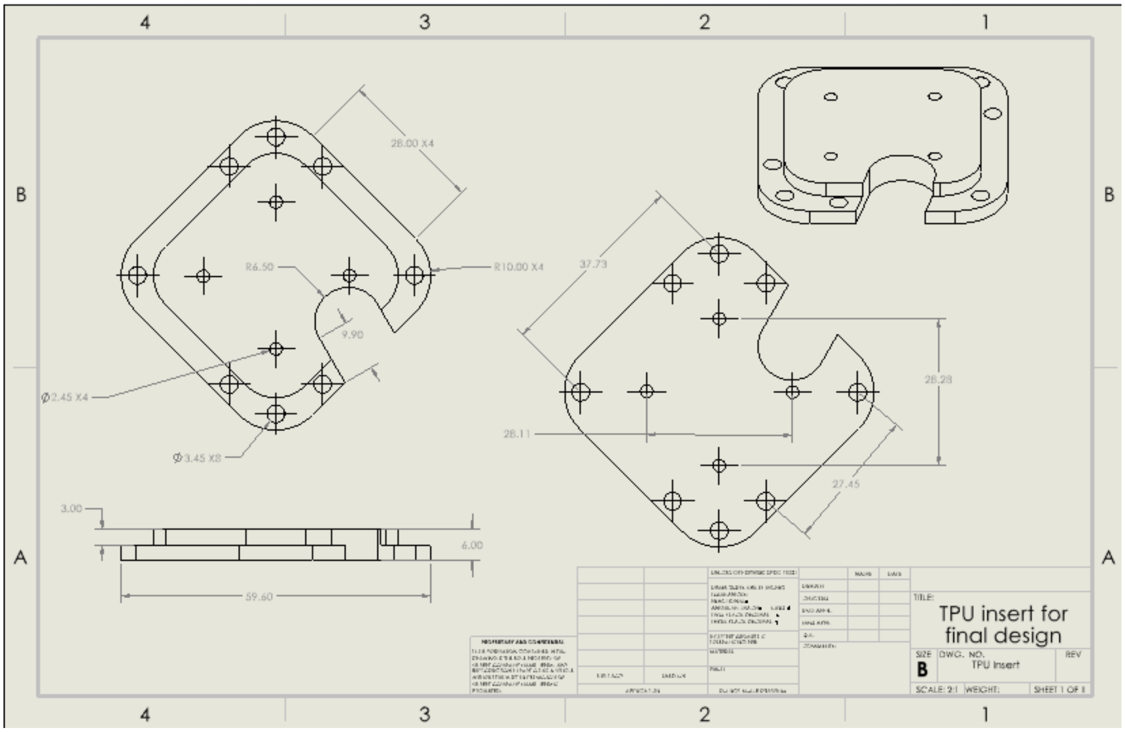


Figure B-6. The CAD drawing of the TPU stack mount.

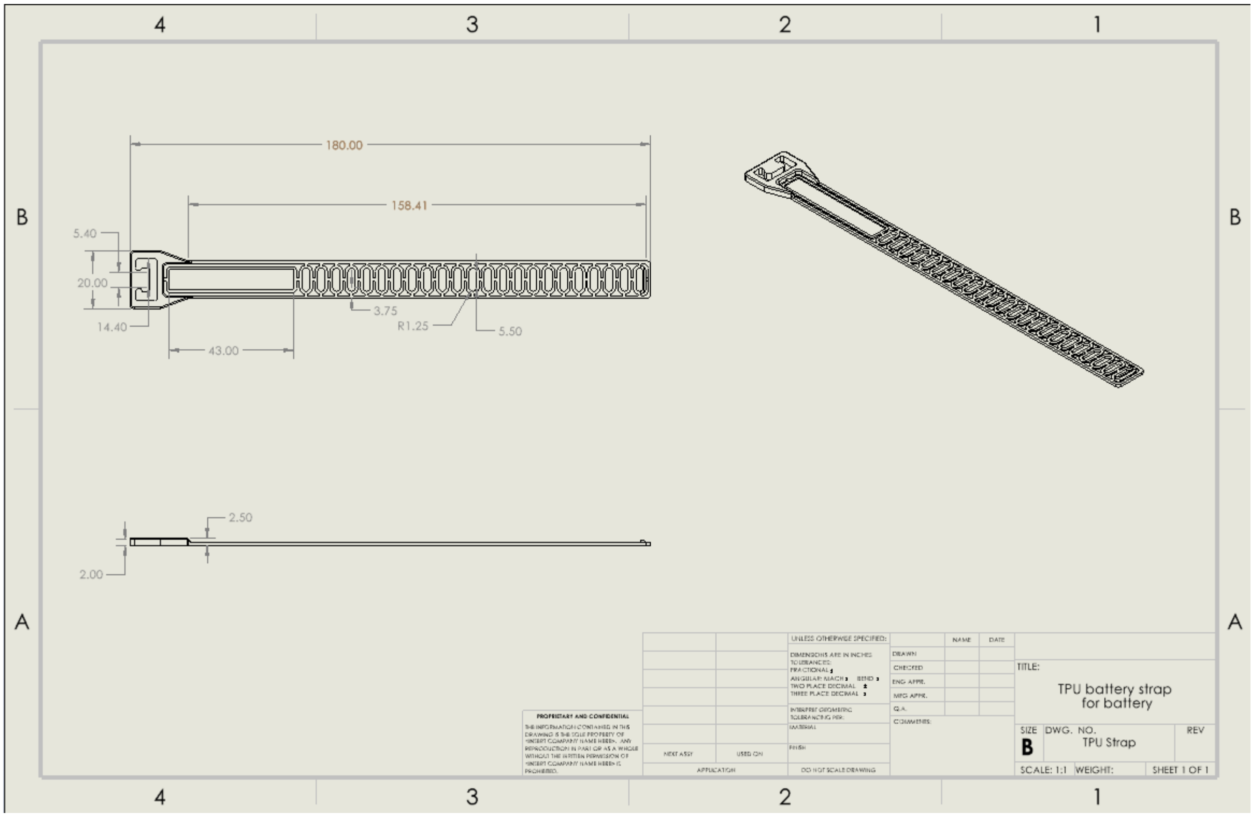


Figure B-7. The CAD drawing of the TPU flex strap.

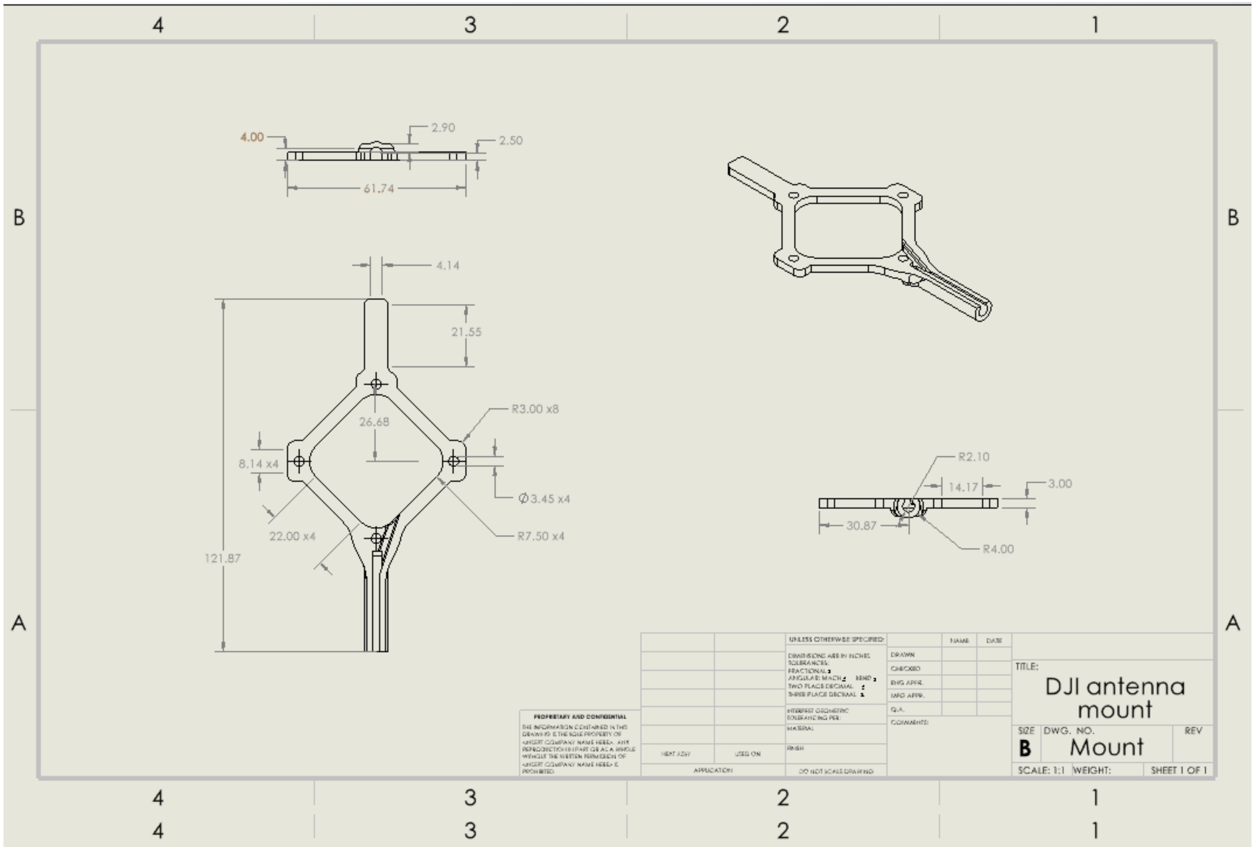


Figure B-8. The CAD drawing of the video antenna mount.

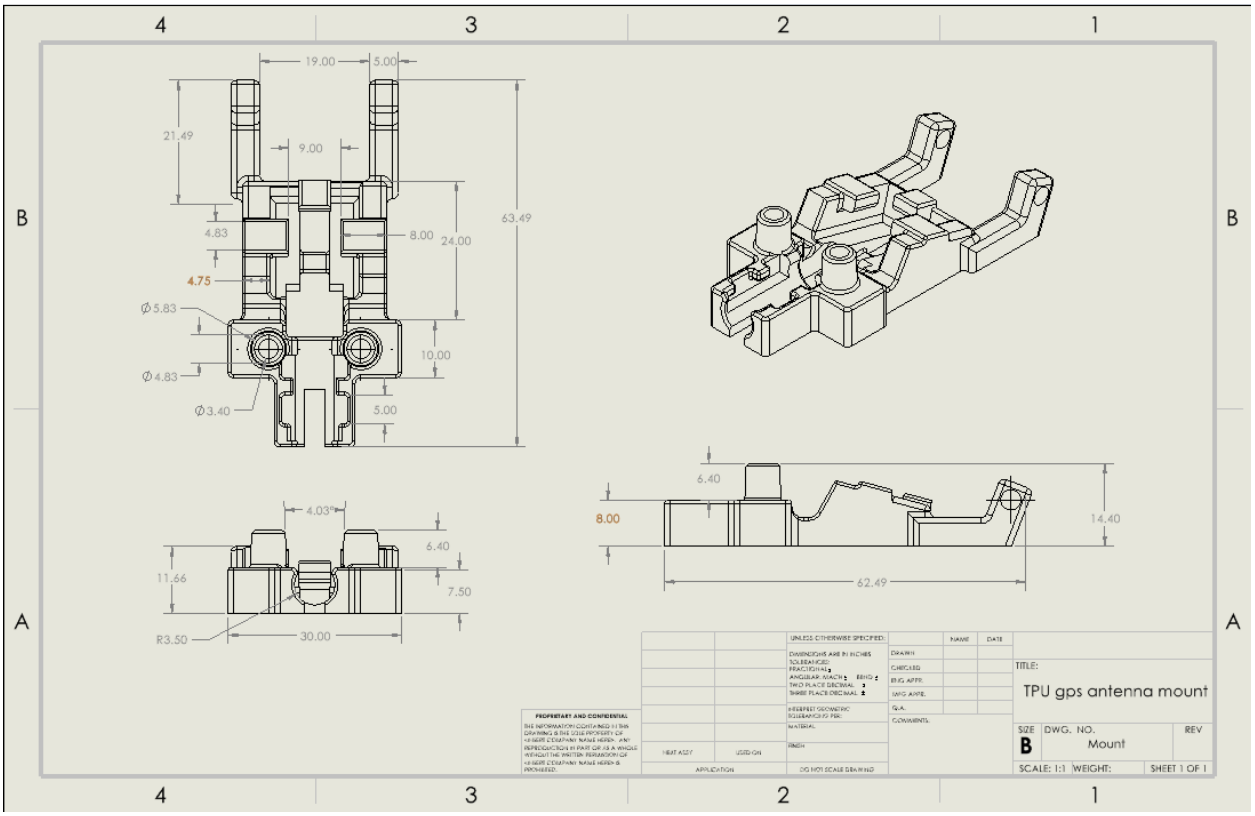


Figure B-9. The CAD drawing of the GPS/ELRS antenna mount.

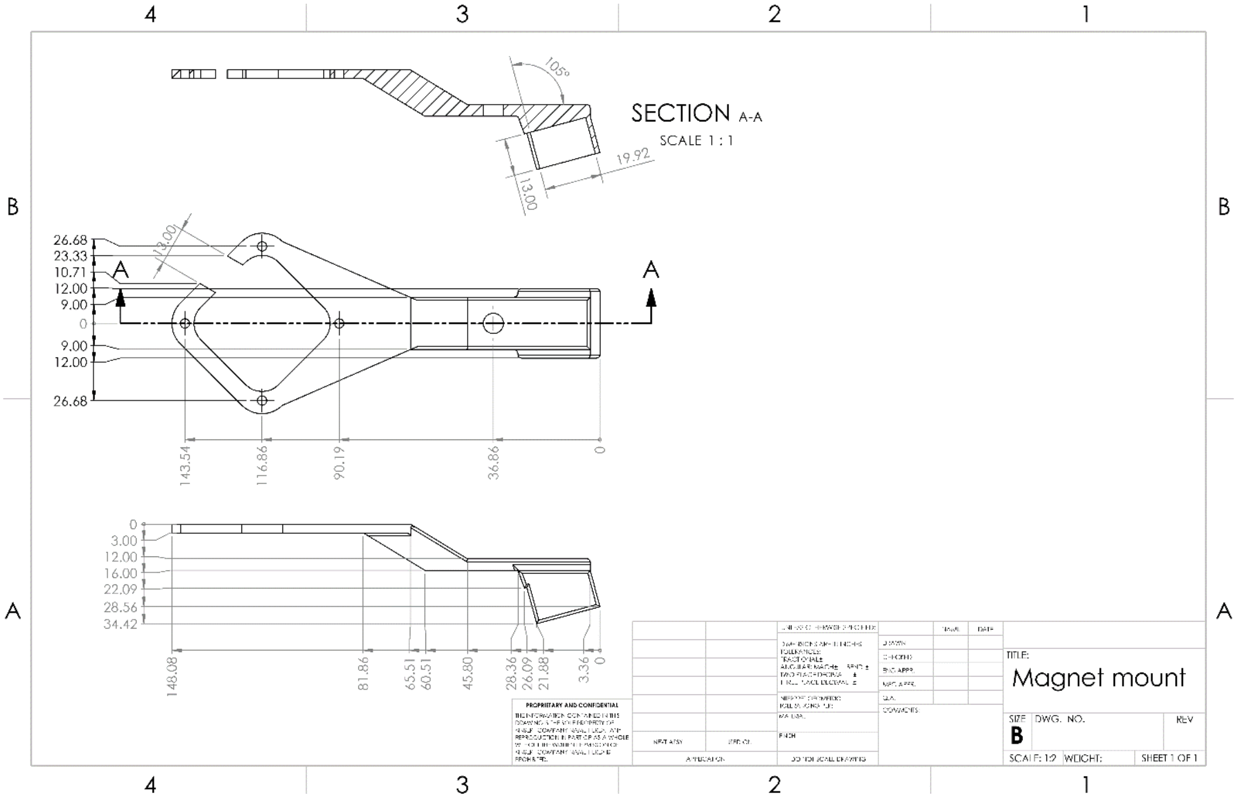
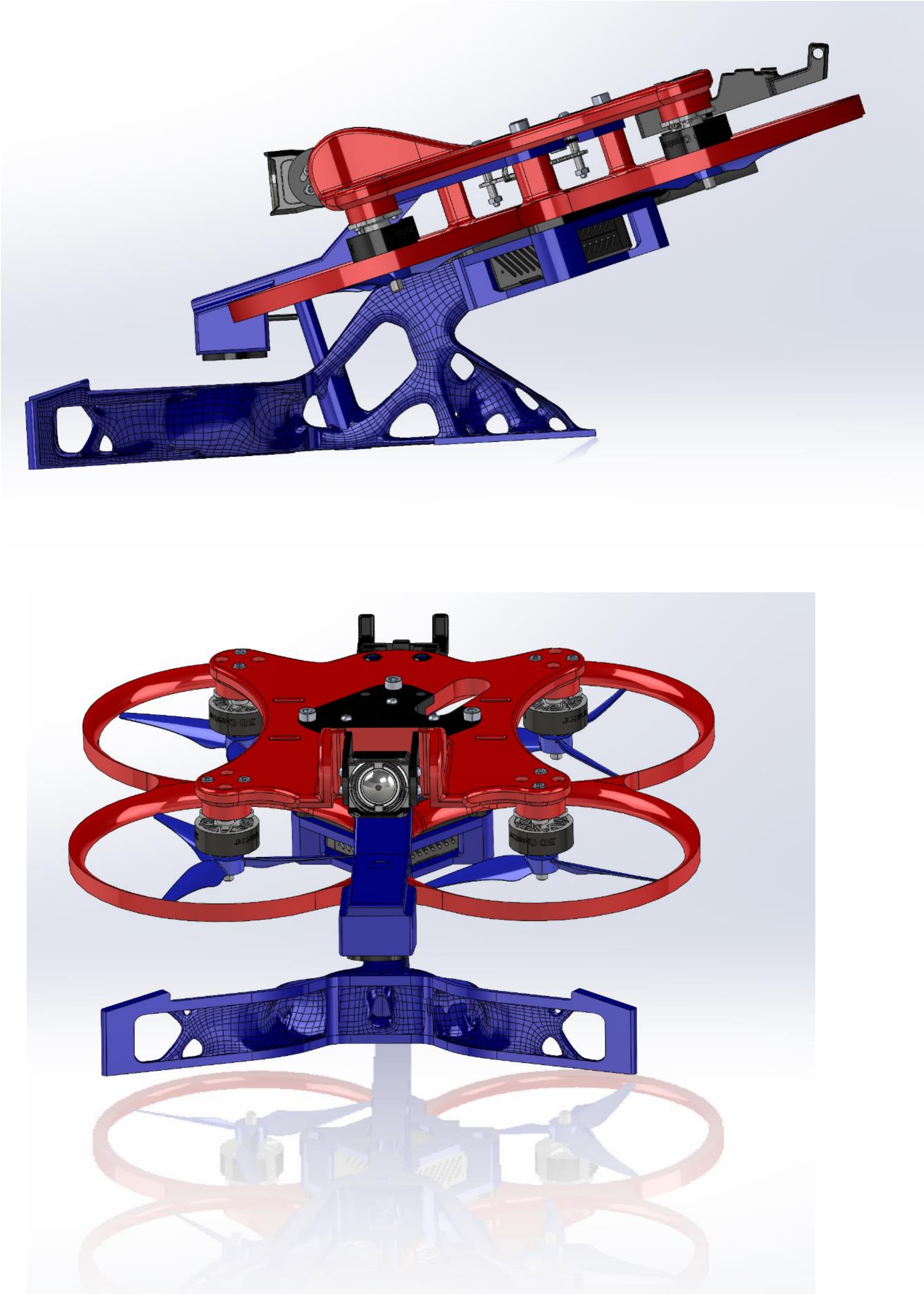
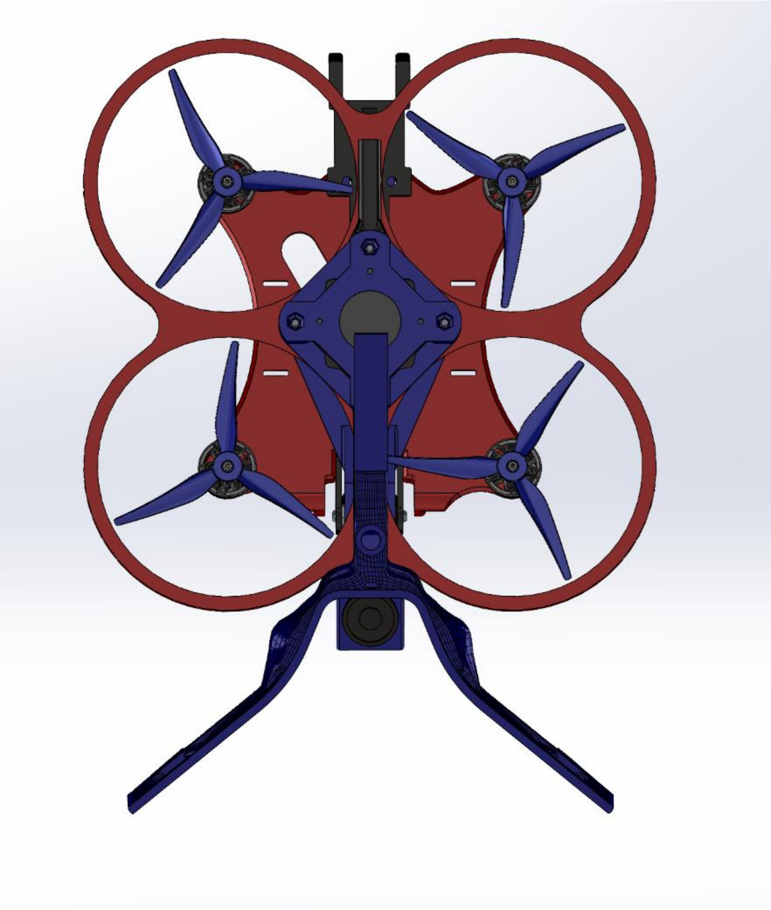


Figure B-10. The CAD drawing of the video antenna mount.

Figure B-11. Additional Images of final CAD Assembly





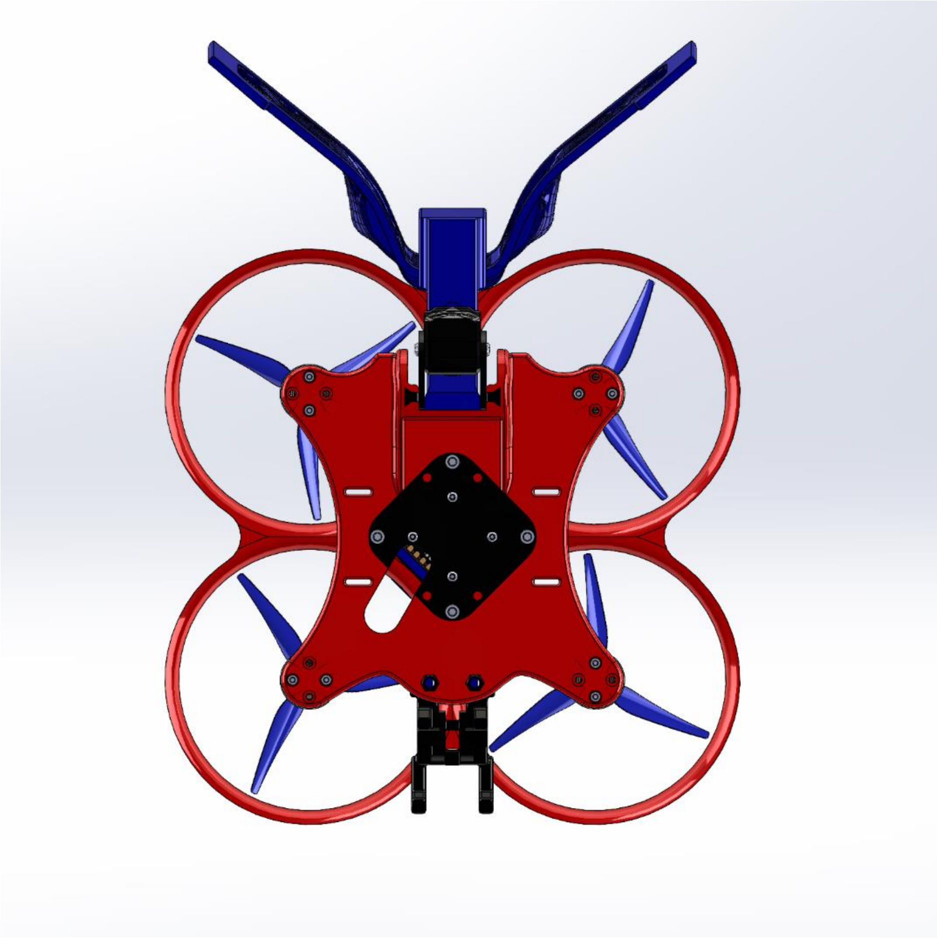


Figure B-12. Additional Images of final assembled drone