2024 Design, Build, Fly Competition Summary

The 2023-24 AIAA/Textron Aviation/Raytheon Design, Build, Fly Competition Flyoff was held at the Textron Aviation Employees' Flying Club in Wichita, KS on the weekend of April 18-21, 2024. This was the 28th year for the competition. Of the 149 proposals submitted and judged, 110 teams were invited to submit a formal report for the next phase of the competition. 107 teams submitted design reports to be judged, and 93 teams attended the flyoff (19 international teams). About 1100 students, faculty, and guests were present. This was a record year for the number of teams and students attending the fly-off. Of the 93 teams in attendance, 85 successfully completed tech inspection. The weather was just about perfect all weekend, which allowed for non-stop flying. Of the 236 official flight attempts, 156 resulted in a successful score with 65 teams achieving at least one successful flight score and 31 teams successfully completing all four missions (one ground and three flight). The quality of the teams, their readiness to compete, and the execution of the flights was exceptional.

The contest theme this year was Urban Air Mobility. The airplane was limited to a maximum of a 5 foot wingspan but had to be able to fit in a 2 ½ foot wide parking space. The airplanes were required to complete three flight missions, each taking off within 20 feet. The first mission was a Delivery Flight with a crew but no payload for three laps within five minutes. The second mission was a Medical Transport Flight with a crew, 2 EMTs, a patient on gurney and a Medical Supplies Cabinet with the score based on the weight of the Medical Supplies Cabinet and the time to fly three laps. The final mission was an Urban Taxi Flight with a crew and passengers with the scored based on the number of passengers, number of laps flown in 5 minutes and the capacity of the propulsion battery. Teams were also required to complete a ground mission demonstrating the efficiency of converting from the parking configuration to the medical transport configuration and then to the urban tax configuration. The total score is the product of the total mission score and design report score plus participation score. More details on the mission requirements can be found at the competition website: http://www.aiaa.org/dbf.

First Place went to Embry-Riddle Aeronautical University Daytona Beach, Second Place went to Georgia Institute of Technology and Third Place went to University of Washington Seattle. A full listing of the results is included below. The Best Paper Award, sponsored by the Design Engineering TC for the highest report score, went to the University of Southern California with a score of 93.60.

We owe our thanks for the success of the DBF competition to the efforts of many volunteers from Textron Aviation, Raytheon, and the AIAA sponsoring technical committees: Applied Aerodynamics, Aircraft Design, Flight Test, and Design Engineering. These volunteers collectively set the rules, judge the proposals and reports, and execute the flyoff. Thanks also to the Premier Sponsors: Textron Aviation and Raytheon, and to the AIAA Foundation for their financial support as well as our Gold sponsors this year – AeroVironment, General Atomics Aeronautical and Mathworks. Special thanks go to Textron Aviation for hosting the flyoff this year.

Finally, this event would not be nearly as successful without the hard work and enthusiasm from all the students and advisors. If it weren't for you, we wouldn't keep doing it!!

DBF Organizing Committee

2024 Design, Build, Fly Competition Summary

2024 Design/Build/Fly Competition Final Results

Rank	Team		Participation	Mission Scores					Report	2024 DBF
	Queue #	Name	P	GM	M1	M2	M3	Total	Score	Score
1	5	Embry-Riddle Aeronautical University Daytona Beach	3	0.11	1.00	1.90	3.00	6.01	90.62	547.96
2	4	Georgia Institute of Technology	3	1.00	1.00	1.71	2.07	5.78	90.67	527.34
3	8	University of Washington Seattle	3	0.21	1.00	2.00	2.59	5.79	89.40	521.02
4	3	Virginia Polytechnic Institute and State University	3	0.13	1.00	1.69	2.36	5.18	91.20	475.46
5	13	FH Joanneum	3	0.14	1.00	1.45	2.55	5.14	87.37	452.07
6	33	The University of Akron	3	0.14	1.00	1.46	2.71	5.31	83.33	445.54
7	6	University of Notre Dame	3	0.31	1.00	1.18	2.41	4.90	89.70	442.67
8	18	Embry-Riddle Aeronautical University - Prescott	3	0.19	1.00	1.52	2.33	5.04	86.28	437.93
9	26	University of Michigan	3	0.22	1.00	1.58	2.32	5.12	84.42	435.63
10	16	The University of Sydney	3	0.15	1.00	1.40	2.38	4.93	86.97	431.40
11	52	Rensselaer Polytechnic Institute	3	0.16	1.00	1.22	2.83	5.21	79.57	417.22
12	17	Rutgers, The State University of New Jersey - New Brunswick	3	0.45	1.00	1.08	2.16	4.70	86.83	410.72
13	41	The Pennsylvania State University	3	0.08	1.00	1.56	2.29	4.93	81.58	405.44
14	24	University of California, Los Angeles	3	0.13	1.00	1.21	2.25	4.60	84.67	392.34
15	35	University of Massachusetts, Amherst	3	0.19	1.00	1.13	2.30	4.62	83.28	387.67
16	42	The Hong Kong University of Science and Technology	3	0.22	1.00	1.16	2.30	4.67	81.55	383.99
17	22	The University of Oklahoma	3	0.22	1.00	1.07	2.19	4.48	84.87	383.26
18	37	The Hong Kong Polytechnic University	3	0.16	1.00	1.17	2.25	4.58	82.77	382.27
19	27	Washington University in St. Louis	3	0.12	1.00	1.12	2.21	4.45	84.20	377.36
20	48	Auburn University at Auburn	3	0.34	1.00	1.11	2.21	4.66	80.23	376.95
21	49	Universidad de Antioquia	3	0.20	1.00	1.23	2.24	4.67	80.05	376.67
22	25	Utah State University	3	0.10	1.00	1.18	2.10	4.39	84.50	373.81
23	77	The University of California, Irvine	3	0.54	1.00	1.06	2.41	5.01	70.17	354.47
24	39	University of New South Wales	3	0.18	1.00	1.01	2.09	4.28	82.13	354.40
25	66	University of Illinois Urbana-Champaign	3	0.26	1.00	1.11	2.20	4.58	75.38	347.89
26	45	Birla Institute of Technology and Science, Pilani, K.K. Birla Goa Campus	3	0.15	1.00	1.04	2.01	4.21	80.67	342.30
27	70	RWTH-Aachen	3	0.13	1.00	1.08	2.17	4.38	72.70	321.65
28	68	California State Polytechnic University, Pomona	3	0.14	1.00	1.07	2.08	4.29	73.38	317.83
29	78	North Dakota State University	3	0.22	1.00	1.06	2.14	4.42	67.37	300.45
30	28	University of Massachusetts Lowell	3	0.83	1.00	1.01	0.00	2.84	83.97	241.18
31	96	Royal Melbourne Institute of Technology University	3	0.41	1.00	1.14	2.26	4.80	48.78	237.31
32	1	University of Southern California	3	0.33	1.00	1.08	0.00	2.41	93.60	228.83
33	23	Stanford University	3	0.22	1.00	1.38	0.00	2.60	84.67	222.77
34	9	Massachusetts Institute of Technology	3	0.17	1.00	1.25	0.00	2.42	88.90	218.04
35	94	The University of Memphis	3	0.07	1.00	1.00	2.06	4.13	50.70	212.51
36	29	University at Buffalo	3	0.04	1.00	1.45	0.00	2.49	83.92	211.58
37	60	University of Texas at Austin	3	0.39	1.00	1.21	0.00	2.61	77.13	204.07
38	34	Colorado State University	3	0.10	1.00	1.31	0.00	2.41	83.30	203.80
39	15	Universidad Pontificia Bolivariana	3	0.19	1.00	1.09	0.00	2.28	87.00	201.35
40	32	The University of Hong Kong	3	0.11	1.00	1.18	0.00	2.29	83.73	195.12
41	31	University of Kansas	3	0.14	1.00	1.15	0.00	2.29	83.87	194.95
42	55	University of Texas at Dallas	3	0.16	1.00	1.24	0.00	2.40	78.67	191.85
43	59	Case Western Reserve University	3	0.41	1.00	1.03	0.00	2.43	77.17	190.76
44	36	Missouri University of Science and Technology	3	0.14	1.00	1.09	0.00	2.23	83.23	188.69
45	53	Columbia University	3	0.23	1.00	1.03	0.00	2.26	79.28	181.83
46	44	Iowa State University	3	0.16	1.00	1.02	0.00	2.17	80.92	178.95
47	80	San Diego State University	3	0.15	1.00	1.26	0.00	2.40	65.10	159.36
48	93	New Mexico State University - Main Campus	3	0.31	1.00	1.00	0.00	2.31	51.08	121.10
49	56	Khalifa University of Science, Technology and Research	3	0.31	1.00	0.00	0.00	1.31	78.67	106.12
50	19	West Virginia University	3	0.16	1.00	0.00	0.00	1.16	85.93	102.71
51	12	University Of Maryland, College Park	3	0.14	1.00	0.00	0.00	1.14	87.70	102.68
52	46	Clarkson University	3	0.21	1.00	0.00	0.00	1.21	80.50	100.51
53	20	Purdue University, Main Campus	3	0.10	1.00	0.00	0.00	1.10	85.77	97.51
54	50	Western Michigan University	3	0.17	1.00	0.00	0.00	1.17	79.82	96.70

2024 Design, Build, Fly Competition Summary

Cessna Beechcraft BY TEXTRON AVIATION · Raytheon An RTX Business · AIAA FOUNDATION

2024 Design/Build Fly Competition Final Results (cont)

Rank	Team		Participation	Mission Scores					Report	2024 DBF
	Queue #	Name	P	GM	M1	M2	M3	Total	Score	Score
55	67	Trine University	3	0.25	1.00	0.00	0.00	1.25	74.93	96.70
56	2	University of Ljubljana	3	0.00	1.00	0.00	0.00	1.00	91.33	94.33
57	47	University of Florida	3	0.13	1.00	0.00	0.00	1.13	80.25	93.99
58	101	University of Missouri - Kansas City	3	0.25	1.00	1.00	0.00	2.26	33.67	79.01
59	90	California State University, Long Beach	3	0.29	1.00	0.00	0.00	1.29	56.75	76.28
60	92	University of Kentucky-Paducah	3	0.18	1.00	0.00	0.00	1.18	55.78	68.91
61	86	Worcester Polytechnic Institute	3	0.06	1.00	0.00	0.00	1.06	59.47	66.27
62	95	University of Central Florida	3	0.21	1.00	0.00	0.00	1.21	48.83	61.95
63	99	Lehigh University	3	0.24	1.00	0.00	0.00	1.24	35.67	47.38
64	11	Wentworth Institute of Technology	3	0.44	0.00	0.00	0.00	0.44	88.18	42.02
65	10	University of Missouri - Columbia	3	0.35	0.00	0.00	0.00	0.35	88.52	34.02
66	105	University of Maryland, Baltimore County	3	0.09	1.00	0.00	0.00	1.09	25.72	30.99
67	106	Johns Hopkins University	3	0.09	1.00	0.00	0.00	1.09	24.80	30.12
68	89	Alfred University	3	0.44	0.00	0.00	0.00	0.44	57.17	28.38
69	30	National University of Singapore	3	0.25	0.00	0.00	0.00	0.25	83.90	23.93
70	62	The University of Adelaide	3	0.27	0.00	0.00	0.00	0.27	76.50	23.50
71	61	Military Institute of Science and Technology	2	0.23	0.00	0.00	0.00	0.23	76.93	19.37
72	7	VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE, MUMBAI	2	0.19	0.00	0.00	0.00	0.19	89.43	18.66
73	21	Cornell University	3	0.16	0.00	0.00	0.00	0.16	85.72	16.53
74	65	UC San Diego	3	0.13	0.00	0.00	0.00	0.13	75.72	12.53
75	14	Dayananda Sagar College of Engineering	3	0.11	0.00	0.00	0.00	0.11	87.10	12.16
76	75	Institut supérieur de l'aéronautique et de l'espace	3	0.12	0.00	0.00	0.00	0.12	71.00	11.58
77	51	University of Alabama at Birmingham	3	0.09	0.00	0.00	0.00	0.09	79.73	10.42
78	97	Illinois Institute of Technology	2	0.12	0.00	0.00	0.00	0.12	47.87	7.93
79	104	University of Nebraska-Lincoln	3	0.13	0.00	0.00	0.00	0.13	27.47	6.62
80	54	CUNY City College of New York	3	0.04	0.00	0.00	0.00	0.04	78.85	6.10
81	43	The Ohio State University	3	0.00	0.00	0.00	0.00	0.00	81.03	3.00
82	57	Texas A&M University	3	0.00	0.00	0.00	0.00	0.00	78.45	3.00
83	64	University of West Florida Pensacola Campus	3	0.00	0.00	0.00	0.00	0.00	75.97	3.00
84	87	Arizona State University Tempe	3	0.00	0.00	0.00	0.00	0.00	57.40	3.00
85	88	University of Houston	3	0.00	0.00	0.00	0.00	0.00	57.20	3.00
86	58	Clemson University	2	0.00	0.00	0.00	0.00	0.00	77.57	2.00
87	69	University of Arkansas	1	0.00	0.00	0.00	0.00	0.00	73.25	1.00
88	71	The Cooper Union for the Advancement for Science and Art	1	0.00	0.00	0.00	0.00	0.00	72.33	1.00
89	72	Kent State University	1	0.00	0.00	0.00	0.00	0.00	72.12	1.00
90	76	Atilim University	1	0.00	0.00	0.00	0.00	0.00	70.33	1.00
91	83	University of Connecticut Storrs	1	0.00	0.00	0.00	0.00	0.00	61.92	1.00
92	84	Texas Tech University	1	0.00	0.00	0.00	0.00	0.00	61.10	1.00
93	85	Colorado School of Mines	1	0.00	0.00	0.00	0.00	0.00	59.82	1.00
94	38	Tribhuvan University	0	0.00	0.00	0.00	0.00	0.00	82.70	0.00
95	40	The University of Alabama Tuscaloosa	0	0.00	0.00	0.00	0.00	0.00	81.98	0.00
96	63	Yıldız Teknik Üniversitesi	0	0.00	0.00	0.00	0.00	0.00	76.17	0.00
97	73	Ain Shams University	0	0.00	0.00	0.00	0.00	0.00	71.70	0.00
98	74	Cairo University	0	0.00	0.00	0.00	0.00	0.00	71.68	0.00
99	79	University of Texas at El Paso	0	0.00	0.00	0.00	0.00	0.00	67.00	0.00
100	81	University of Colorado Boulder	0	0.00	0.00	0.00	0.00	0.00	64.77	0.00
101	82	Rochester Institute of Technology	0	0.00	0.00	0.00	0.00	0.00	62.78	0.00
102	91	University of Georgia	0	0.00	0.00	0.00	0.00	0.00	56.67	0.00
103	98	University of California, Merced	0	0.00	0.00	0.00	0.00	0.00	43.13	0.00
104	100	Vellore Institute of Technology - Vellore	0	0.00	0.00	0.00	0.00	0.00	34.42	0.00
105	102	University of Minnesota - Twin Cities	0	0.00	0.00	0.00	0.00	0.00	32.93	0.00
106	103	University of Nevada, Las Vegas	0	0.00	0.00	0.00	0.00	0.00	29.05	0.00
107	107	University of Pennsylvania	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Massachusetts Institute of Technology
2023-24 AIAA Design/Build/Fly Proposal

1. Executive Summary

This proposal outlines Massachusetts Institute of Technology's (MIT) preliminary design, manufacturing, and testing plan for "Ariel: The Little Airplane" to compete in the 2023/2024 AIAA Design/Build/Fly Competition. The MIT Design/Build/Fly team is organized into three sub-teams to efficiently manage tasks and facilitate the transfer of knowledge to new members. The team's objective is to design, build, and test an electric remote control aircraft simulating urban air mobility through four different missions. The score is a function of aircraft lap time, the mass of the "Medical Supply Cabinet" carried, the number of passengers carried, and the battery capacity. The aircraft will be optimized to maximize the overall score by the use of computational analysis and design trade studies.

The team will use an iterative design process in order to produce a competitive design. The team's strategy is to maximize the weight of the payload and the speed of the aircraft, while being able to carry the maximum number of passengers. To achieve this goal, a high wing configuration with a rectangular fuselage and a single propeller propulsion system is chosen. The SG6043 airfoil with a wingspan of 1.52 m and chord of 0.41 m will be used, forming a tapered wing with winglets. The fuselage will be 0.80 m in length, 0.152 m in height, and 0.26 m in width in order to carry roughly 5 kg for Mission 2 (M2) and 80 passengers for Mission 3 (M3). A conventional tail with a tail dragger landing gear will be used due to the short takeoff constraint. The following months will involve detailed design, analysis, prototyping, and testing of the configuration, propulsive system, structure, and mechanism of the aircraft.

2. Management Summary

2.1: Organization Description

MIT Design/Build/Fly is a fully student run club with faculty and graduate student advisors. The advisors provide the team with guidance and share their technical expertise. The executive board plays a dual role, encompassing both administrative and technical responsibilities as shown in Fig. 1. Administrative functions are overseen by the club president, who takes charge of organizing meetings and supervising the schedule. The vice president and social chair collaborate closely with the president to create the budget, acquire sponsorships, update the social media, and plan team events.

On the technical side, the chief engineer and project manager assume leadership roles. The chief engineer guides the design and optimization of the aircraft and the project manager creates a schedule and oversees the testing of components and prototypes. The collaboration between these two roles enhances communication and integration among the three distinct sub-teams: aerodynamics, mechanisms, and propulsion. The roles and skills of each sub-team are explained in Table 1. Each sub-team is managed by a sub-team lead who is responsible for the delegation of tasks and functions.

Sub-Teams	Tasks	Skills
Aerodynamics	Wing and tail design and manufacturing, airfoil selection	Knowledge in aircraft performance, stability and control, CFD, XFLR5, XFoil
Mechanisms	Fuselage design and manufacturing, landing gear selection, mechanism design and manufacturing.	Knowledge in mechanics and materials, FEA, CAD, rapid prototyping.
Propulsion	Propulsion system optimization (battery, motor, propeller selection), motor and propeller testing	Knowledge in propulsion calculations, thrust tests

Table 1: **Sub-team tasks and required skills**

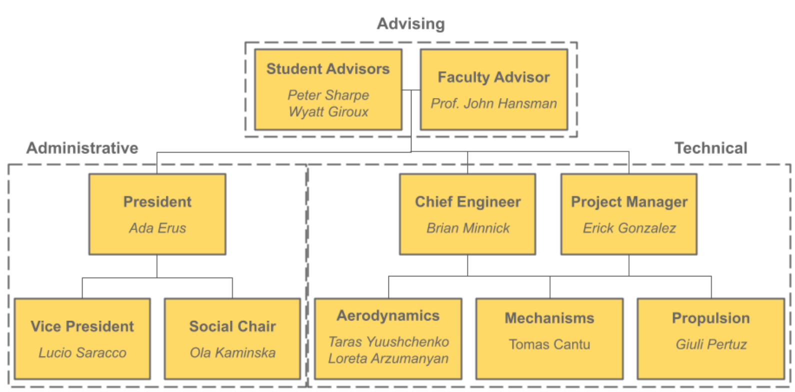


Figure 1: **Team organization structure**

2.2: Schedule

The team's proposed schedule is illustrated by the Gantt chart in Fig. 2. This chart is referenced throughout the year to ensure timely completion of the objectives and milestones. The executive board meets weekly to set goals for the week and review progress. This allows the leadership team to be aligned on priorities and maintain a cohesive vision. All members are expected to attend the weekly General Body Meetings (GBM) where the majority of the work is done. Additionally, each sub-team hosts weekly meetings for detailed discussions and a focus on specific tasks. Extra build sessions are held as required by the schedule.

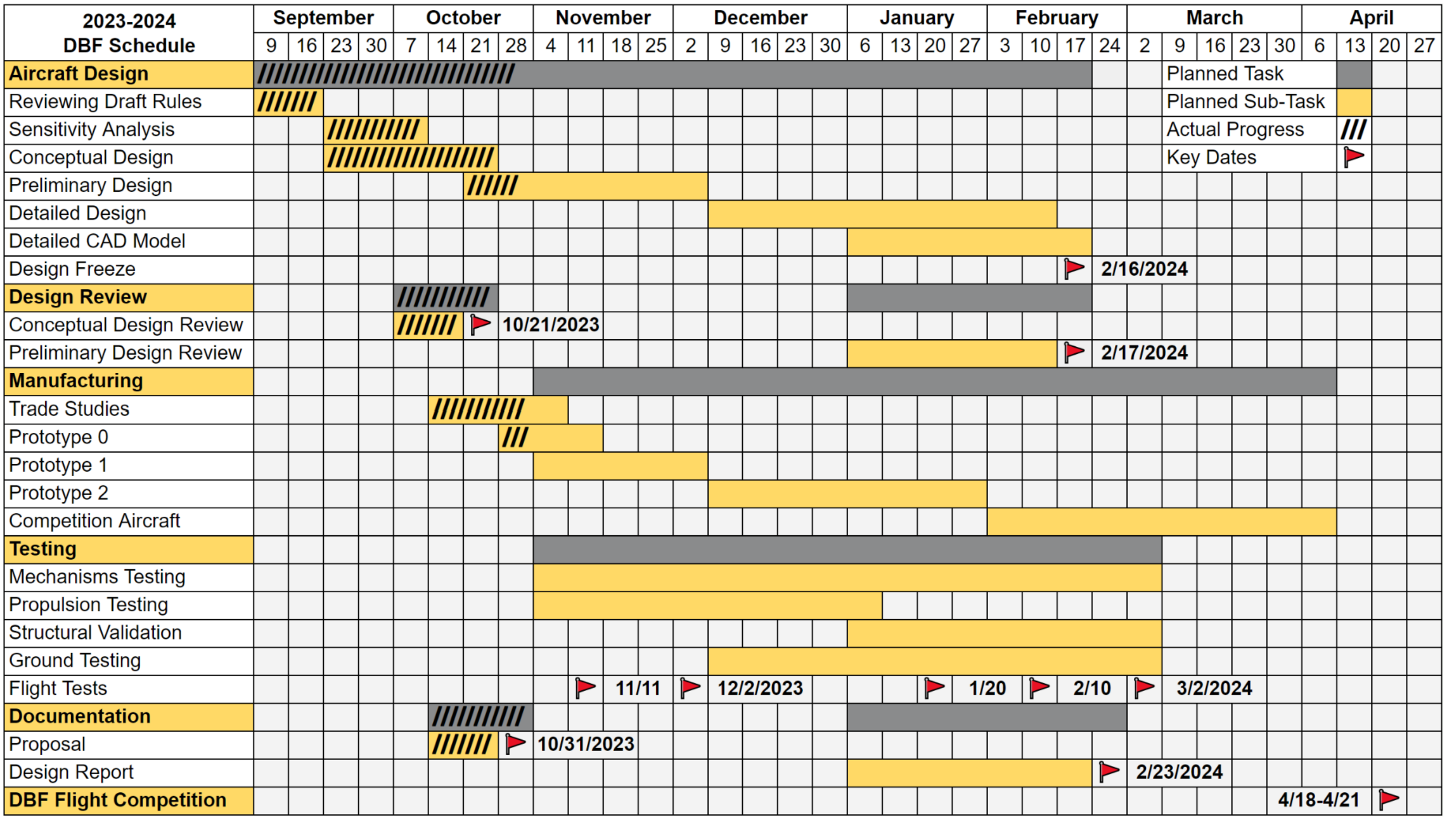


Figure 2: **Schedule Gantt Chart**

2.3: Budget

A summary of the anticipated costs for the fiscal year 2024 is shown by Table 2. The budget includes funds for three main categories: training of new members, software and physical materials for design and manufacturing of parts, and travel costs associated with competition. The combination of funds remaining from the previous competition cycle and additional sponsorships will be used to cover the expenses.

Expenses	Item	Cost
Materials and Manufacturing	Composites (Carbon fiber, Kevlar, Glass fiber)	$870
	Layup Material (Vacuum bags, Epoxy, Resin)	$1,250
	Electronics (Batteries, ESC's, Motors, Servos)	$1,010
	Mechanisms(Wooden peg dolls, Thermoplastics)	$340
	Structures (Foam sheet, Balsa)	$820
New Member Training	Trainer Planes (Foam board, Servos, Battery)	$680
	Recruitment and Social Events	$400
Competition	Travel (Flight tickets, Car rental)	$10,730
	Lodging (Hotel, Food)	$6,260
	Total Cost	**$22,760**

Table 2: **Estimated budget for 2023-24**

3. Conceptual Design Approach

3.1: Analysis of Mission Requirements

The competition has an Urban Air Mobility (UAM) theme, consisting of three flight missions and one ground mission. The mission requirements are outlined below in Table 3.

Mission	Scoring	Requirements	Sub-System Design Considerations
M1: Delivery	1	Aircraft must be put in flight configuration within 5 minutes.	The aircraft's wings must fit within the 2.5' parking space and deploy quickly.
M2: Medical	$1 + N\left(\frac{W_{med}}{t_{3\ laps}}\right)$	Payload and flight battery installed in 5 minutes. Must fly 3 laps quickly with weight.	The aircraft must be loaded quickly including payload and battery, from hatches.
M3: Air Taxi	$2 + N\left(\frac{n_{laps} \times n_{people}}{Wh_{battery}}\right)$	Flight config. in 5 minutes. Must fly passengers as efficiently as possible.	The aircraft must have enough fuselage volume and structure to contain all passengers on the floor.
Ground	$N(t_{total})$	Cycle through mission configurations as fast as possible.	The loading of all payloads, specifically passengers, must be as fast as possible.

Table 3: **Mission scoring and requirements**

After reviewing all mission scoring functions, the final aircraft must have a few common features. M2 drives the design towards a high wing loading and high airspeed to carry the most amount of weight in the least time. Meanwhile, M3 drives the design towards a highly efficient aerodynamic design with a large payload volume. M3 is of particular interest as the number of laps flown over battery capacity is effectively a measure of efficiency. This makes the M3 score a measure of how efficiently passengers are carried. The specific number of laps is not relevant as long as the efficiency is unchanged. Therefore there is a strong dependence of M3 score on L/D.

3.2: Sensitivity Analysis

The sensitivity analysis was performed to determine the most important design parameters for M2 and M3. The results of the analysis in Fig. 3 show a very strong dependence on payload weight and maximum g-load that the airframe can withstand for both M2 and M3. This makes intuitive sense since a higher g-load allows tighter turns, minimizing flight time. Additionally, the L/D dependence that was predicted previously is seen in M3, having the greatest effect on score of any design parameter tested for M3.

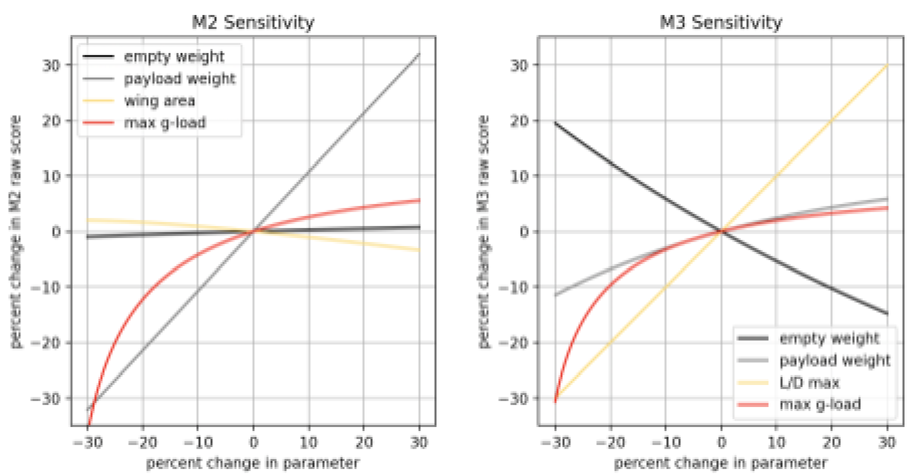


Figure 3: **Sensitivity analysis**

Based on the sensitivity analysis, it was determined that M3 was the most important mission to optimize for given the strong dependence of total score on the number of passengers and aerodynamic efficiency (L/D). Additionally, the maximum g-load has an important effect on both M2 and M3 and therefore will also be prioritized. Payload weight matters for both missions, and is important to the final score, but the total weight carried will be driven by other factors such as maximum wing loading.

3.3: Preliminary Design

The team used the findings from the sensitivity analysis, dimensional constraints from the rules, and the mission scoring functions to write a custom optimization program whose results were validated through analysis and intuitive assessment. A high wing configuration with taper and washout was chosen to increase spiral stability, reduce induced drag, and achieve a high L/D. The taper and twist angle will be varied along the span to achieve a near-elliptical lift distribution without an elliptical planform. The wing will not have dihedral in order to use a continuous spar, increasing wing loading for M2. Spiral stability is achieved through winglets. The wing design has a span of 1.52 m (5 ft) and a chord of 0.41 m to fit the span constraint and maximize blown lift from the propeller. The SG6043 airfoil was chosen after analyzing 400 different airfoils using a Python script developed by the team to optimize for L/D. The maximum sectional L/D is 109 at a C_l of 1.26 and a Reynolds number of 250,000, which is estimated for the cruise speed in M1 and M2. A conventional tail was selected due to the pitch control in the high wing configuration, easier manufacturing, and minimal weight compared to other tail designs. The preliminary design calls for a horizontal tail with a span of 0.71 m and chord of 0.12 m. The vertical tail has a span of 0.39 m and a chord of 0.12 m. The boom is 1.3 m from the leading edge.

A single propeller propulsion system was chosen considering the 20 foot takeoff limit and the energy calculations for M2 which sets the upper limit for energy and thrust requirements. This system leads to a beneficial wing-propeller interaction which reduces induced drag, and increases propeller efficiency. The tail also benefits from the single propeller due to increased dynamic pressure in the slipstream. A 6S 2900 mAh battery, 200 kV motor, and a 16x8 propeller was selected to achieve a thrust of 23 N.

The fuselage will be a rounded rectangular prism with a blunt nose and taper on the back to carry the maximum number of passengers while being as aerodynamically efficient as possible. The fuselage measures 65.7 cm in length, 15.2 cm in height, and 26.0 cm in width. This accommodates a 7.62 by 7.62 by 8.89 cm (3 by 3 by 2.5 in) Medical Supply Cabinet weighing 5 kg in M2 and 80 passengers arranged in a triangular grid in M3. The fuselage skin will be structural using a molded lightweight Kevlar/Nomex sandwich panel with an internal laser-cut plywood frame due to the heavy payloads. The payloads will be inserted through two hatches 15.2 cm (6 in) by 12.7 cm at the sides of the fuselage. Considering the takeoff constraint and ground clearance, a tail dragger landing gear configuration is chosen to provide a greater angle of attack at takeoff.

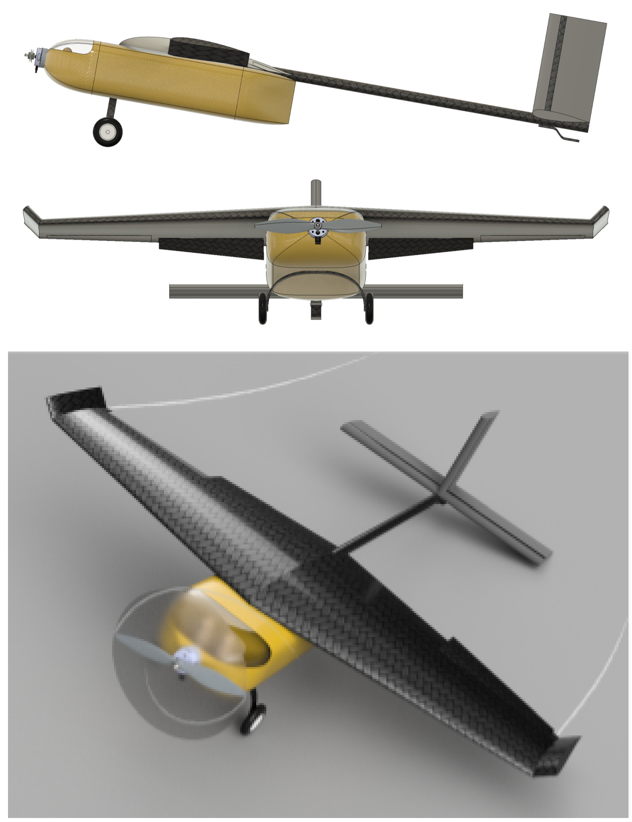


Figure 4: **Preliminary model of aircraft**

Lastly, to ensure the plane fits into the 2.5 ft wide parking spot, the wing will be rotated around its center such that one end rotates towards the front of the fuselage and the other end towards the boom. The orientation of the wing will be held in place by a pin which can be inserted perpendicularly through the rotation point. With this mechanism, the wing will have a continuous spar, allowing for higher wing loading. Furthermore, no additional drag will be generated through this design, and the added weight for the mechanism will be close to the center of gravity, benefiting the stability of the plane.

4. Manufacturing Plan

4.1: Preliminary Manufacturing Flow

Iterative design and prototyping is a critical part of the test procedure outlined in Section 5, which impacts the manufacturing processes chosen. Prototype Zero uses extremely basic manufacturing techniques. Wings are cut out of foam with minimal internal structure. This minimizes construction time and cost, allowing us to verify stability and propulsion systems before fully committing to a design. Prototype One increases manufacturing complexity: wings are a combination of foam and built up sections. Prototype Two is designed to test composite manufacturing processes for the competition aircraft and add full mission functionality. CNC cut Renshape composite molds are made for the fuselage and wings. A wing rotation mechanism, fuselage hatches, and other final details are tested to ensure expected functionality. The competition aircraft will be very similar to Prototype Two with only small changes based on feedback from testing.

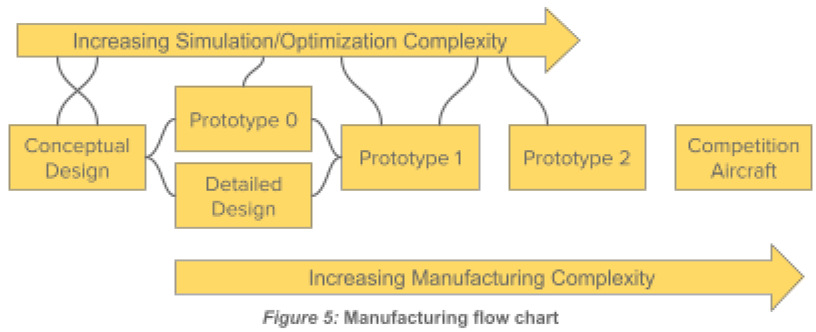


Figure 5: Manufacturing flow chart

4.2: Critical Processes Required

Before a prototype is even built, many parts are tested with Finite Element Models and other computational tools. This process is critical to manufacturing as it can help catch errors before time and money is spent in manufacturing. After this, manufacturing complexity will increase with each prototype, beginning with CNC cut foam wings and leading to full composite structures. 3D printing, laser cutting, and CNC machining will also be used on parts of the aircraft that demand the unique benefits of these manufacturing methods.

5. Test Planning

Numerous tests will be conducted on the individual components of the aircraft prior to the construction and testing of the final aircraft as shown in Table 4. The wings and fuselage will be loaded to failure to ensure structural integrity. The landing gear will undergo testing to examine deformation under known loads. These tests will be used to verify the computational analysis. Extensive ground testing will take place to maximize GM score by optimizing the design and procedure for switching between configurations. An RC Benchmark 1580 test stand will be used to test the propulsion system. Four flight tests are planned to test the design and building techniques. Pilot's feedback as well as a GPS module, altimeter, and a pitot tube will be used to assess the plane's handling qualities, track the plane's flight path, and measure the airspeed.

Test Type		Objective	Method	Sub-Team
Preliminary Design Tests	Thrust test	Choose the most efficient propellor, motor, and battery combination for the propulsion system. Compare with theoretical results from ecalc.	Connect the propulsion system to an RCBenchmark 1580 test stand and test it in a wind tunnel to simulate flying conditions.	Propulsion
Ground Tests	Assembly test	Minimize time spent switching between configurations for GM.	Practice doing ground mission with a completed prototype.	Mechanisms
	Wingtip test	Verify the wing structure's resistance to failure under high g loading.	Lift the plane carrying its MTOW from the wingtips and check for damage.	Aerodynamics
	CG test	Verify that the CG is in the desired position.	Lift the plane from the wingtips at the calculated CG point for the desired static margin and check that the plane is level for all mission configurations	Aerodynamics
	Electronics test	Ensure that all RC electronics systems work properly.	Connect all electronics as they will be in flight and test their functionality. Test the propulsion, control surfaces, and failsafe.	Propulsion
	Full throttle test	Verify that the motors are mounted securely when the throttle is at its max.	With a full prototype, hold the plane in place while the pilot increases the throttle to the max. Check for any damage to the connection	Propulsion
	Structural integrity analysis	Ensure that the plane's structure can withstand expected loads when flying and landing.	Use FEA (SolidWorks) to apply expected loads and observe deformation and stress concentrations	Mechanisms
	Landing gear test	Verify that the landing gear will not break when the plane lands. Compare to FEA results done prior.	Load the plane with its MTOW and perform a 2ft drop test. Check for any damage to the landing gear and any relevant connections	Mechanisms
Flight Tests	Stability analysis	Verify the theoretical stability of the plane design.	Use XFLR5 to assess the aircraft's stability characteristics	Aerodynamics
	Take-off distance test	Ensure that the plane can take off in under 20 feet.	After completing each prototype, an altimeter, GPS module, pitot tube, and pilot input will be used to quantitatively and qualitatively assess the plane's performance at various points of flight. In addition, each prototype will have a different overall goal. Prototype 0 will verify our aerodynamics and propulsion system design. Prototypes 1-3 will verify our manufacturing techniques and help us optimize our plane design with every iteration. The final flight test will be used to verify our competition score by completing each mission and calculating the scores as needed.	All Teams
	Cruise test	Assess the plane's handling and compare actual performance to expected results.		
	Turning test	Assess the plane's turning capabilities and measure turn radii to compare to calculated results.		
	Ground handling	Assess how the plane handles on the ground and upon landing.		

Table 4: **Testing objectives and methods**

1 Executive Summary

In pursuit of the AIAA 2023-2024 DBF competition, the following proposal summarizes the intent of the University of Notre Dame DBF team to design, manufacture, test, and showcase the team's radio-controlled plane's ability to transport the heaviest medical supplies and the largest amount of passengers as quickly, safely, and efficiently as possible. The aircraft must take off in $\leq$ 20', fit in a 2.5' parking space, have a wingspan of 60" or less, and utilize a propulsion battery of $\leq$ 100 Wh. Starting in the parking position, the payloads and propulsion battery pack(s) must be able to be loaded into the aircraft in $\leq$ 5 min prior to each mission. Design requirements are derived from the number of passengers, the medical supply cabinet weight, parking space assembly time, aircraft speed, and propulsion battery capacity.

Through a sensitivity analysis, the highest-scoring aircraft was determined to be the result of a design optimized to primarily maximize the number of passengers and minimize lap time, with a secondary goal of minimizing battery capacity and maximizing wing load. To accomplish this, ND DBF has chosen a full 60" wingspan in order to take off in $\leq$ 20'. Folding wings will be used to fit in the parking space. The aircraft includes a rounded fuselage, a low-mounted Clark-Y airfoil, a centrally-mounted puller motor, and a conventional tail with tail-dragger gear. The first test flight will have an all-wood plane and a rectangular fuselage as proof of concept. For the final design, the rounded fuselage will be manufactured with carbon fiber and the wings with a mix of balsa and lite plywood to optimize weight to load ratio. Consequently, a 99.9 Wh battery was found to be the optimal selection in order to achieve a M2 scoring weight of 1.62 lbs and 24 passengers for M3. A project timeline has been established to begin initial prototype construction in late October and fly in early November. The design will be analyzed and reiterated using data from ground tests and a minimum of 3 flight tests held before the end of March to attain best competition performance.

2 Management Summary

2.1 Team Organization

The Design, Build, Fly team at the University of Notre Dame is comprised of roughly 30 undergraduate members, half of whom are returning from the previous year and half of whom are new. Figure 1 illustrates the team's overall organizational structure. Industry and faculty advisors aid the team by offering constructive feedback in periodic design reviews. The team's non-student pilot also offers key flight insights through these design reviews and test flight debriefs. The chief engineer's role is to guide design squads through each design phase and especially to focus on scoring analysis and system integration. The project manager ensures the team remains within budget, in scope, and on schedule by purchasing supplies, organizing team meetings, and facilitating design communication. Roles of Technical Editor, Media Director, and Director of Finances were introduced this year to redistribute the workload of social media management, sponsor connections, and report writing to more experienced team members. Table 1 highlights the responsibilities of and skills utilized by the team's three technical squads. Each squad's leadership consists of one primary lead and two sub-leads to manage squad deliverables and teach younger members necessary skills. Team members meet twice weekly; once during a Sunday full-team meeting and again for an individual squad meeting during the week.

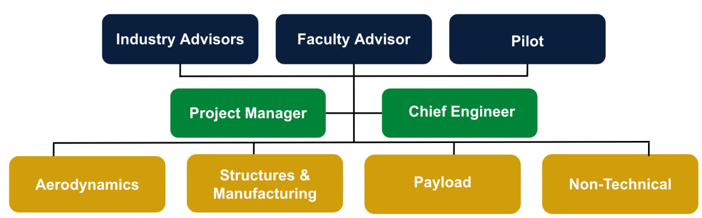


Figure 1: Organization Flow-Chart

Table 1: Team Management Summary

Squads	Responsibilities	Skills Utilized
Aerodynamics	•Overall design and sizing of aircraft features •Performance and stability analysis •Propulsion testing and selection •CAD of all flight surfaces	•Aerodynamic understanding •XFLR5 and Matlab knowledge •Analytical and critical thinking •Design process experience
Payload	•Prototype mission requirement solutions •Evaluate mission mechanism performance •Integrate electrical components within aircraft •CAD of electrical components and payload design	•Electrical system understanding •Circuitry and wiring experience •CAD knowledge •Design process experience
Structures and Manufacturing	•Design and testing of all internal structures •Testing and selection of materials and techniques •Fuselage construction and total aircraft assembly •CAD of fuselage and landing gear	•Aircraft structures understanding •Material design understanding •CAD and FEA knowledge •Manufacturing Techniques
Non-Technical	•Social Media Management (Media Director) •Manage budget & sponsors (Director of Finances) •Delegate and edit report writing (Technical Editor)	•Visual Communication •Networking and financial planning •Documentation and planning

Table 2: 2023-2024 Budget

Categories	Allocated
Construction	**$2,415.00**
Wood	$650.00
Composites	$1,200.00
Landing Gear	$45.00
Monokote	$180.00
Hardware	$140.00
Tools	$200.00
Prototypes and Testing	**$250.00**
Testing	$100.00
Mechanisms	$150.00
Electronics	**$2,200.00**
Batteries	$600.00
ESC	$700.00
Motors	$500.00
Receivers/Telemetry	$225.00
Servos	$100.00
Wires	$75.00
Marketing	**$20.00**
Printing	$20.00
Travel	**$15,100.00**
Airline Tickets	$8,050.00
Rental Cars	$1,200.00
Shipping Plane	$600.00
Gas	$250.00
Lodging	$3,000.00
Food	$2,000.00
Total	**$19,985.00**

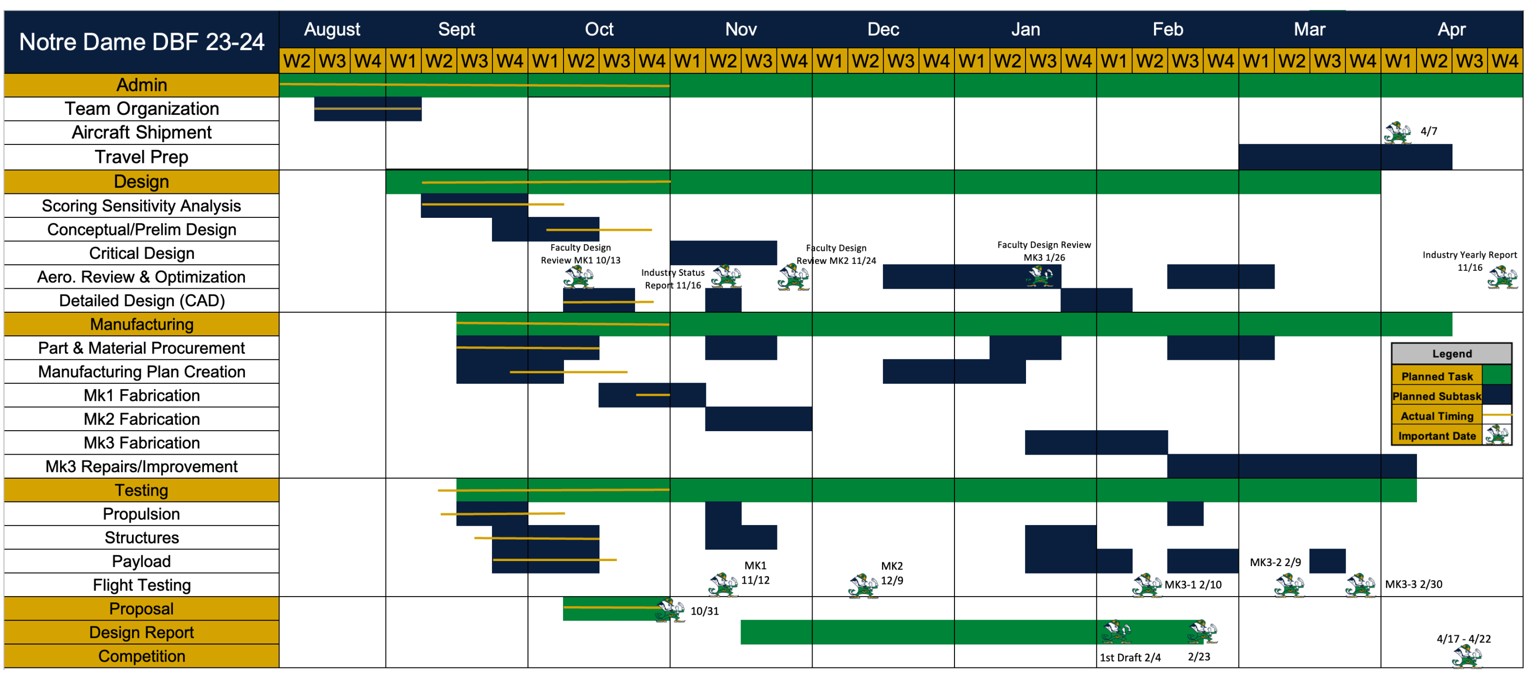
2.2 Budget

The team receives funding solely from corporate sponsors and private donors. The allocated budget is illustrated in Table 2. Expenses are estimated based on spending from past years and material changes, as we are moving from an all-wood plane to a carbon fiber and wood mix. Most of the spending is for travel at 76% of the budget with construction, testing, and electronic components of the plane estimated to be 24%. Manufacturing tools and equipment have been purchased in past years or are accessible through the University of Notre Dame's Engineering Innovation Hub.

2.3 Milestones

The project manager guides the team according to the timeline shown in Table 3. A weekly team meeting is held so squads can discuss their progress, meet with other squads, and establish the tasks to be completed to stay on schedule.

Table 3: 2023-2024 Gannt Chart



3 Conceptual Design

3.1 Mission Outline

There are 3 flight missions and 1 ground mission to demonstrate our aircraft's urban air mobility capability. The Mission details and the design implications are illustrated in Table 4.

Table 4: 2022-2023 Mission Summary

Mission	Description	Scoring	Team Requirements
Ground Mission	•Record time to switch from parking config. to M2 config. to M3 config. back to parking config. •All payloads will start outside of the plane next to the parking spot •Verify that control surfaces are functioning for both mission configurations	$GM = \frac{time_{min}}{time_{team}}$	•Create an aircraft with durable and practical folding mechanism. •Design quick loading and unloading mechanisms for each mission
Mission 1	•Start in parking config., install battery(ies) and crew in ≤ 5 min •Take off in ≤ 20ft and complete 3 laps in 5 minutes	$M1 = 1.0$	•Design aircraft to take off in under 20 ft with payloads and batteries installed. •Design aircraft prepared for flight without battery(ies) and payload installed in parking config. in ≤ 5 min. •Design insert(s) to hold payloads •M2 - Optimize plane speed with maximum payload weight •M3 - Optimize plane speed with maximum # of passengers and minimum battery capacity
Mission 2	•Record medical supply cabinet weight •Start in parking config., install battery(ies), medical supply cabinet, EMTs, patient on gurney, floor insert (if used), and crew in ≤ 5 min •Take off in ≤ 20ft and complete 3 laps in 5 minutes	$M2 = 1 + \frac{(\frac{weight_{payload}}{time})_{team}}{(\frac{weight_{payload}}{time})_{max}}$	
Mission 3	•Record number of passengers •Start in parking config., install battery(ies), passengers, floor insert (if used), and crew in ≤ 5 min •Take off in ≤ 20ft and fly as many laps as possible in 5 minutes	$M3 = 2 + \frac{(\frac{\#laps*\#passangers}{battery\ capacity})_{team}}{(\frac{\#laps*\#passangers}{battery\ capacity})_{max}}$	
Report	•Document full engineering design process	*Score out of 100 points*	•Careful documentation throughout the year •Meet with mentors to discuss reports and airplane performance
Overall Score	*(Design Report Score * (GM + M1 + M2 + M3)) + P*		*P = Participation Score at Competition*

3.2 Scoring Analysis

After completing a comprehensive breakdown of mission requirements into aircraft design requirements, an analysis of the critical scoring parameters was conducted. The goals of this analysis were twofold: first, to find which scoring variables had the greatest impact on the overall score, and second, to preliminarily size the wing and propulsion system to achieve optimal score. A MATLAB script iterated through possible aircraft configurations by wing aspect ratio (AR) and payload weight (PLW), then estimated the weight and coefficient of lift at takeoff. Because the team wanted to factor in the constraint on the aircraft design presented by finite availability of propulsion system configurations, the team compiled a database of manufacturer-provided data for motors, propellers, and batteries. The script used this data to calculate if the given aircraft configuration had any propulsion configurations that met the critical mission constraints outlined in 3.1 of take-off distance and minimum flight time. If the aircraft passed these requirements, it was considered minimally viable for the competition. Each minimally viable configuration was simulated mathematically for M2 and M3 and scored using the scoring equations in Table 4.

The results of the scoring analysis can be seen in Figures 2 and 3 on the right. Each point is a minimally valid aircraft and propulsion configuration. Because hundreds of propulsion systems were considered for each AR and PLW, there are multiple different groupings of speed for the same payload weight. Optimal M2 and M3 score is achieved for an aircraft configuration with slower flight speed but a higher PLW. Therefore, the team will be aiming to optimize for PLW over speed for both M2 and M3.

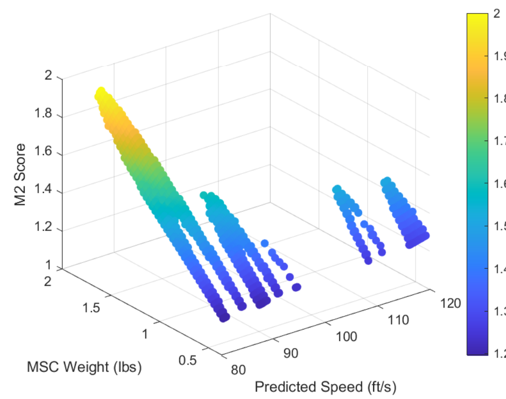


Figure 2: M2 Score sensitivity analysis

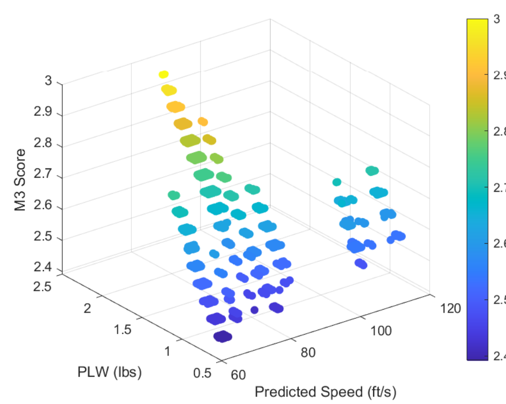


Figure 3: M3 Score sensitivity analysis

3.3 Initial Aircraft Design

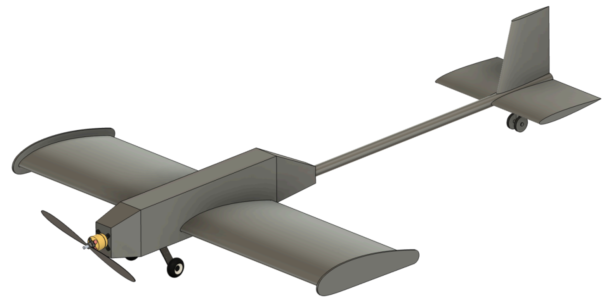


Figure 4: Proposed aircraft isometric view.

A low-wing configuration was selected to reduce drag and increase lift through the utilization of ground effect to satisfy the takeoff distance requirement. The low-wing configuration also maximizes maneuverability and payload volume within the fuselage. The wingspan of the aircraft is 60” with a mean aerodynamic chord of 17.647” and an aspect ratio of 3.4. The wing is untapered with the span fixed at the maximum allowable value in order to maximize wing area for takeoff, and the aspect ratio was selected using the scoring analysis code discussed above. Furthermore, the wing will have 2 degrees of washout and 2 degrees of positive incidence. This will ensure that for missions 2 and 3 the aircraft will produce sufficient lift in level flight to carry the declared amount of payload, and will require a slight nose-down trim during mission 1. A Clark-Y airfoil was chosen for its ease of manufacturing and its high lift-to-drag ratio, which will aid in short takeoff. A conventional tail configuration was chosen for its ease of manufacturing, integration, and favorable stability qualities. Preliminary weight and balance studies were conducted to determine the center of gravity (CG) of the aircraft and position it forward of the wing’s center of lift (CL) to ensure static stability. To increase static stability and achieve a zero pitching moment at zero angle of attack, the horizontal tail will be placed at a -1 degree angle of incidence. The fuselage longitudinal dimension was sized to minimize any unused volume within it, and a boom tail design was implemented to maximize the moment arm between the tail and CG, therefore reducing the size of the empennage and its drag and weight contributions. This resulted in a longitudinal aircraft dimension of 78.353” from the tip of the nose to the trailing edge of the horizontal stabilizer. A fuselage with a rectangular cross-section was chosen for its simplicity of build plus large volume and was given a total length of 40” and a maximum height of 7” to accommodate the chosen scoring payload and electronics.

3.4 Propulsion

The scoring analysis used manufacturer provided thrust data to estimate static thrust and actuator disk theory to calculate the dynamic thrust curve. The analysis indicated that a 19x12 propeller with a Cobra 4130/20 300kV motor will provide adequate thrust to satisfy the takeoff requirement and optimize mission score while using a battery that is under the 100 Wh limit and last at least 6 minutes of flight.

3.5 Payload/Electronics Preliminary Design

The Medical Supply Cabinet will be a 3.5” x 3.5” x 3.5” box manufactured from ABS plastic using additive manufacturing, enabling rapid prototyping and adjustments to the infill for weight modification when necessary. A foam-based restraint mechanism will securely hold the EMTs during M2 and the patients during M3 with a press fit for a low weight penalty. The gurney, also composed of foam, will have dimensions measuring 1.5” x 2.1” x 5.8”. To position 24 passengers, four foam inserts will be engineered for secure placement within the fuselage. The fuselage design will incorporate two hatches to facilitate efficient passenger loading and unloading. All essential electronics will be strategically positioned at the fuselage’s base, separated by a removable floor structure, ensuring versatility for each mission.

4 Manufacturing Plan

After completion of decision matrices for structural aircraft components, the team determined that the aircraft will consist of composite and wooden materials. Figure 5 illustrates the team’s iterative design and manufacturing flow. The fuselage will be manufactured from a carbon fiber wet layup, while the wings and control surfaces will consist of carbon fiber spars and wooden ribs. All wooden-built surfaces will be covered in MonoKote film to improve aerodynamic

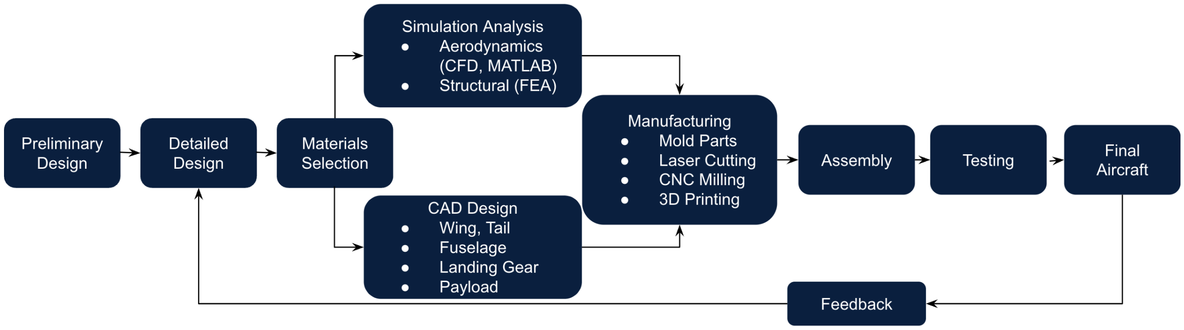


Figure 5: Overall Manufacturing Flowchart

performance and maximize weight efficiency. The team selected to utilize a commercially available carbon fiber rod for the boom tail, given its high strength, stiffness, and low weight. However, due to the complex process of composite manufacturing, the team has chosen to build the MK1 aircraft almost entirely out of plywood and balsa sheeting. Composite manufacturing methods will be implemented for the following aircraft iterations. This will allow the team to rapidly prototype aircraft components in early design stages to quickly test and improve overall design. The team will leverage access to a multitude of fabrication tools found in the Notre Dame Engineering Innovation Hub to build the aircraft, most critically the vacuum pump and 3D printer for carbon fiber layups and the laser cutter for wooden construction.

5 Testing Plan

The design squads will conduct several tests to verify the aircraft's and its components' performance. The tests, identified in Table 5, are intended to measure strength, functionality, and performance. Before aircraft assembly, static thrust testing is conducted, as well as testing of the landing gear structural response. As described in the table, the ground tests enable the team to identify any problems and apply changes before flight testing. The flight tests verify the intended aircraft performance and the required 20-foot takeoff distance for the three missions. They also identify areas of possible improvement for future iterations. Safety protocols are followed throughout each test to ensure the safety of each team member, the surrounding facilities, and the aircraft.

Table 5: Test Plan

Test	Design Squad	Method	Objective
Propulsion Tests			
Static Thrust Testing	Aerodynamics	Use a propeller test stand to measure thrust, battery current, power, and RPM of different propeller and motor combinations.	Choose a suitable propeller and motor combination that produces the desired thrust.
Ground Tests			
Wing Tip Test	Aerodynamics	Load the aircraft to the maximum weight and lift vertically by the wingtips.	Ensure security of the wings and structural integrity of the aircraft under high g loading.
Control Surfaces	Aerodynamics	Apply full range of motion of each control surface via the transmitter.	Ensure that the control surfaces have full range of motion and move in the intended direction.
CG Test	Aerodynamics	Lift the aircraft at either wing tip and observe stability. Make necessary adjustments and repeat until stable.	Test aircraft stability and ensure the CG is within intended limits.
Loading Test	Structures	Attach aircraft to ground mission test stand and apply weights to the fuselage at the CG.	Verify the fuselage and wing structure are strong/dependable under high centered loading.
Assembly Test	Payload	Simulate each ground mission and record the corresponding times required. Repeat until the desired times are achieved.	Minimize the assembly time for each ground mission.
Endurance Test	Payload	Apply 90% throttle to the motor mounted to the test stand for 6 minutes.	Ensure the aircraft has 6 minutes of endurance time.
Signal Range Test	Payload	Apply continuous control surface movement while simultaneously moving the transmitter away from the aircraft.	Ensure that the receiver functions properly at a distance.
Component Tests			
Landing Gear Test	Structures	Conduct drop tests within minor heights and analyze the structural response.	Confirm the strength of the landing gear for takeoff and landing.
Materials Test	Structures	Apply load to materials (carbon fiber, fiberglass, lite plywood) using a load frame (hydraulic press).	Evaluate strength and rigidity of materials for component material selection.
Structural Test	Structures	Use SOLIDWORKS (FEA) to apply expected loads on aircraft components.	Establish aircraft structual components can combat loadings during flight and ground missions.
Flight Tests			
Flight Test #1	Aerodynamics	Perform delivery flight with the crew only.	Ensure stability and full control of the aircraft and to provide a standard to improve upon.
Flight Test #2	Aerodynamics	Load crew, EMTs, patient, gurney, and medical supply cabinet and perform the medical transport flight.	Ensure desired mission performance and identify any possible improvements.
Flight Test #3	Aerodynamics	Load crew and intended number of passengers and perform urban taxi flight.	Analyze aircraft performance and identify any possible future improvements.
Takeoff Distance Test	Aerodynamics	Locate the 20 foot takeoff distance and verify the aircraft clears the ground within the marked distance for each flight test.	Ensure the aircraft continuously takes off in less than 20 feet.

University of Missouri - Columbia

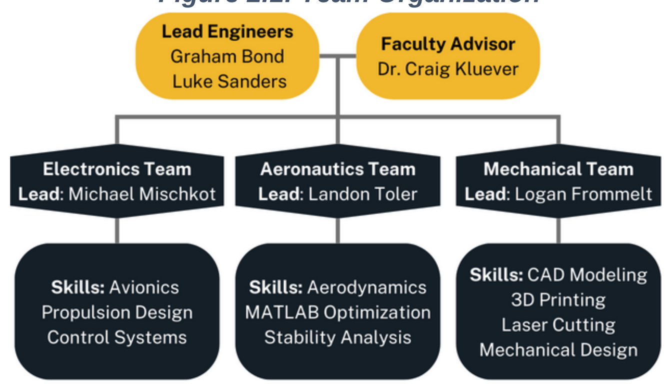
AIAA Design, Build, Fly Proposal

2023 – 2024

1. Executive Summary

This proposal details the approach of the **Mizzou AeroTigers**, representing the University of Missouri – Columbia, to design, analyze, manufacture, test, and fly a scale aircraft at the 2024 AIAA Design, Build, Fly Competition in Wichita, Kansas. This aircraft must be capable of executing missions centered around *Urban Air Mobility*, including a Medical Transport Flight and an Urban Taxi Flight, which require a short takeoff length of 20 ft and the ability to fit in a parking spot with a width of 2.5 ft. After decomposing mission objectives and performing a sensitivity study on design parameters, an optimization program was developed to produce the highest-scoring aircraft. This year's design, **TIGER** (Tomorrow's Infrastructure Gateway and Emergency Rescue), will be a single-motor aircraft with conventional empennage, a high elliptical wing, and the ability to rotate its wing 70° to fit within a parking spot. It will be capable of carrying a Medical Supply Cabinet weighing **6.2 lbs,** completing a lap in **20 seconds** during M2, and will be capable of carrying **60 passengers 9 laps** with a minimum of **20.8 Wh** of stored energy. To execute this design, a project schedule, manufacturing plan, and testing plan have all been developed, based on the key milestones of having a maiden test flight in December, submitting a holistic design report in February, and attending the Fly-Off in April.

Figure 2.1: Team Organization

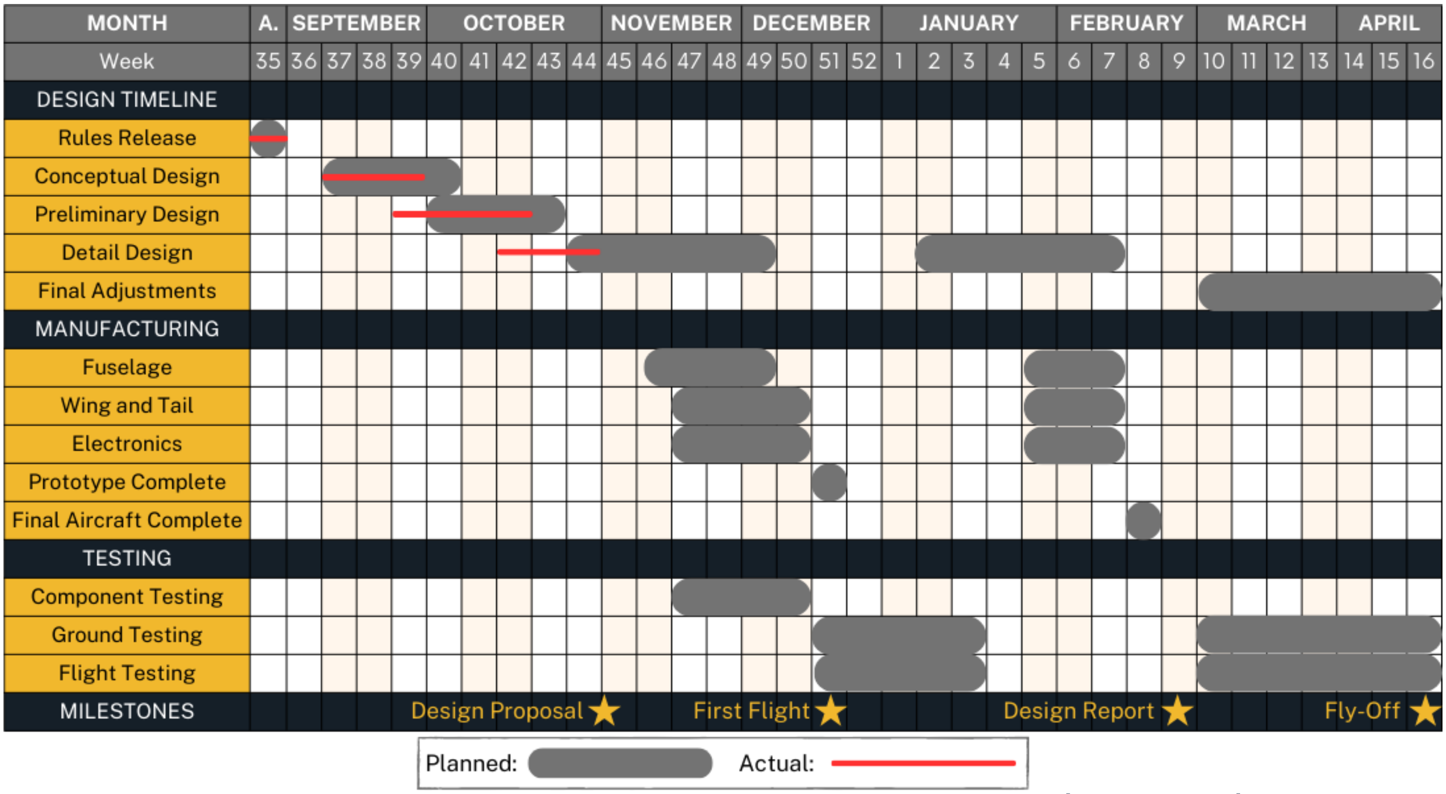


2. Management Summary

2.1 Team Organization: The Mizzou AeroTigers is an entirely student-led organization consisting of three teams: Electronics, Aeronautics, and Mechanical. The teams are organized as shown in **Figure 2.1** and each has a student leader responsible for ensuring the team's timely success. The Electronics team is responsible for the design, testing, and validation of the propulsion, control, and energy storage systems. The Aeronautics team is responsible for the preliminary sizing, planform design, and aerodynamic analysis of the aircraft, which are critical to the optimization of mission deliverables. The Mechanical team is responsible for the design, SolidWorks modeling, and implementation of aircraft structures and mechanisms. All teams are involved in the manufacturing of their respective components and in the writing of this proposal and the design report. Two Lead Engineers supervise and manage the project by creating timetables, integrating the work of the three teams, acquiring funding, recruiting new members, and leading general body meetings.

2.2 Schedule of Project Milestones: Figure 2.2 presents the AeroTigers' timeline to prepare for the Fly-Off. Maintaining scheduled deadlines is key to developing a high-scoring aircraft with ample time for prototyping and testing before the Fly-Off. The AeroTigers' conceptual and preliminary design phases are already complete; section three details these phases and the results. Currently, the detailed design phase is in progress, involving the generation of comprehensive CAD models for manufacturing. Next, prototype manufacturing is scheduled to begin in mid-November, aiming for the first test flight to occur in mid-December. The data and experience gained from each flight will be used to improve the aircraft, with the final design scheduled to be fully manufactured by the end of February. The manufacturing strategy is further detailed in section four, while the testing procedures and planned testing schedule are contained in section five.

Figure 2.2: Competition Gantt Chart



2.3 Budget: The Mizzou AeroTigers' anticipated budget for the 2024 competition is detailed in **Figure 2.3**. The anticipated costs will be financed through a combination of fundraising, corporate outreach, and support from the University. This support will cover manufacturing, testing, and anticipated travel costs. This funding will enable the team to bring 12 students, including leadership and key contributors, to the in-person Fly-Off in Wichita. The AeroTigers have already acquired the necessary manufacturing tools, including 3D printers, soldering equipment, and laser cutters.

Figure 2.3: Budget

CATEGORY	ITEM	ANTICIPATED COST (USD)
Electronics ($1,930)	Motors, Propellers	$450
	Transmitter, ESC	$520
	Batteries	$960
Structures ($1,615)	Carbon Fiber Spars	$1,040
	MonoKote Film	$200
	Landing Gear, Hardware	$100
	Filament/Birch Plywood	$275
Travel ($1,900)	Lodging (4 nights)	$1,400
	Gas (Wichita, KS)	$500
Total Anticipated Cost		**$5,445**

3. Conceptual Design Approach

3.1 Mission Decomposition: This year's challenge is to develop an aircraft specializing in *Urban Air Mobility*. The aircraft must comply with a **5 ft** total wingspan constraint, fit within a **2.5 ft** parking spot, and weigh less than **55 lbs**. Three flight missions will be conducted to gauge the effectiveness of the aircraft design, and one ground mission will evaluate the efficiency of preparing the aircraft for flight from its parking configuration. **Figure 3.1** defines important design parameters and the scoring function for each mission, where $\mathbf{M_n}$ is the individual mission score, **W** is the payload weight, **L** is the number of laps, **P** is the number of passengers, **C** is battery capacity, and **t** is the mission completion time. To compute a total score, the individual mission scores will be summed and multiplied by the design report score, of which 100 points are possible. Flight order is determined by design report score and is paramount to having enough time to complete all missions at the Fly-Off. A small additional score for participation is also included.

Figure 3.1: Mission Decomposition

MISSION	OBJECTIVE	SCORING	DESIGN PARAMETERS
M1: Delivery Flight	• Prepare for flight in under 5 minutes • Complete 3 laps in under 5 minutes	$M_1 = 1.0$	• Ensure takeoff in under 20 ft • Balance CG in unweighted configuration
M2: Medical Transport Flight	• Complete 3 laps in minimum time • Carry heaviest medical supply cabinet • Carry EMTs, Patient on Gurney	$M_2 = 1.0 + \frac{[W/t]_{MU}}{[W/t]_{Max}}$	• Maximize in-flight velocity • Maximize wing strength
M3: Urban Taxi Flight	• Complete maximum laps in 5 minutes • Use minimum battery capacity • Carry maximum number of passengers	$M_3 = 2.0 + \frac{[L^*P/C]_{MU}}{[L^*P/C]_{Max}}$	• Minimize drag for battery efficiency • Balance speed and battery capacity to optimize number of laps • Maximize fuselage storage size
GM: Configuration Demonstration	• Minimize time for inserting and removing each loading configuration	$GM = \frac{t_{min}}{t_{MU}}$	• Design inserts for efficient removal • Design wing for parking configuration

3.2 Sensitivity Study: A sensitivity study was performed in MATLAB to analyze the impact of key scoring and design variables. **Figure 3.2** depicts how each mission objective impacts the scoring function. Lap speed is critical for M2 and M3, and has the largest impact on overall score, while takeoff weight is critical for both M2 payload weight and M3 passenger count. GM time has an inverse, nonlinear relationship with score. M3 Battery capacity has a sawtooth pattern, reflective of the fact that minimum thresholds of battery capacity must be met to complete each lap. Therefore, capacity should be optimized to its minimum necessary value to complete five minutes of laps, as excesses in battery capacity hurt the overall score. Completing less than the maximum number of laps also harms efficiency, as takeoff amperage draw is higher than amperage draw during flight. **Figure 3.3** depicts how wing aspect ratio and takeoff weight impact the overall score at a constant thrust value. Larger aspect ratios decrease the maximum takeoff weight but also decrease drag, allowing higher M2 and M3 flight speeds. The results from the sensitivity study were then used as inputs for generating the optimized preliminary design, with the overall process shown in **Figure 3.4.**

Figure 3.2: Sensitivity of Scoring Variables

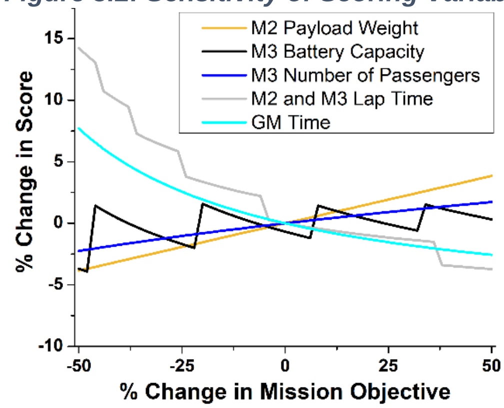
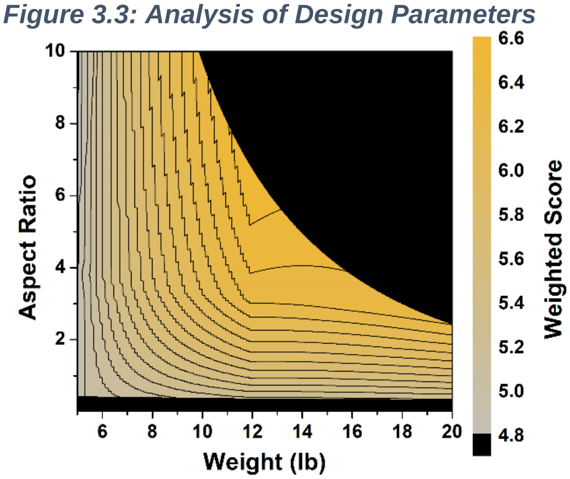
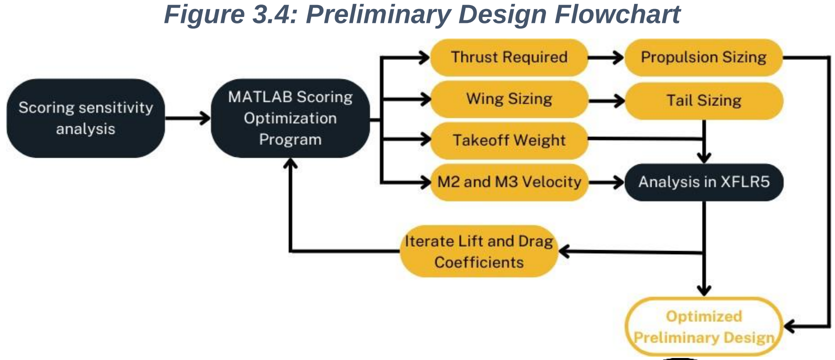


Figure 3.3: Analysis of Design Parameters



3.3 Preliminary Design: Based on the mission decomposition, an effective design must maximize strength, stability, and in-flight velocity while minimizing drag and configuration time. Thus, a monoplane with a high, elliptical wing was selected to optimize the M3 lift-to-drag (L/D) ratio, prevent interference in the parking configuration, and improve stability at a high weight. Tricycle landing gear and conventional empennage were selected

Figure 3.4: Preliminary Design Flowchart



for weight, balance, and ease of manufacturing. The Wortmann FX 60-126 airfoil was selected out of available low-speed airfoils to maximize L/D at the M3 velocity and due to its relatively low thickness.

The preliminary design process was iterative and combined the scoring function generated from the sensitivity study with MATLAB's optimization toolbox to output the highest-scoring aircraft design available. The generated design was then modeled in XFLR5 to output 3D lift and drag coefficients and stability metrics, which were iterated back into the MATLAB program until a converged solution was found. To maximize M3 efficiency, the program included a way to calculate the velocity for maximum L/D and the corresponding thrust required. From this analysis, key results included an aspect ratio of **6.8**, a takeoff weight of **12 lbs**, and a takeoff thrust of **24.4 lbs**. Based on the takeoff weight, a **6.2 lb payload** can be carried in M2 to complete laps at **up to 196 ft/s**, and **60 passengers** can be carried in M3 at an optimized velocity of **80 ft/s**.

Major restrictions on the propulsion system include the 20 ft takeoff requirement, high takeoff weight, and M3 efficiency. Many motors were compared based on power requirements and amperage draw during takeoff and M3 flight. The **Scorpion HK-4015-1070 kV** was selected, as it can output the required takeoff thrust of 24.4 lb while drawing only **33 A**. In total, an estimated **20.8 Wh** of energy is required to complete all five minutes of M3, equivalent to a 6S 1000 mAh LIPO battery. This motor will be placed in a tractor configuration and will have its propeller size and amperage draw optimized experimentally.

A blended rectangular fuselage was selected to maintain a high fineness ratio while storing the maximum number of passengers. Due to the door width restriction of 6 inches, twelve passenger dolls will be optimally arranged in five individual passenger inserts that are installed through each of the five doors along the side of the aircraft fuselage. To minimize ground mission time, the dolls will be passively held in place by the insert geometry, requiring little assembly effort from the ground crew member. Similar EMT and medical supply inserts will be used for M2. Each insert is shown next to the conceptual model of the aircraft in **Figure 3.5.** The medical supply cabinet will be manufactured from concrete and rebar to achieve the desired weight. Preliminary stability analysis, optimized for M3, has placed an angle of incidence of 1.5° on the wing and -5° on the tail and has located the CG at 35% MAC, creating a static margin of 17% MAC. The M2 and M3 payloads will have their CGs centered in the same place to maintain consistency, while the battery, ESC, and motor will all be placed in the front of the aircraft.

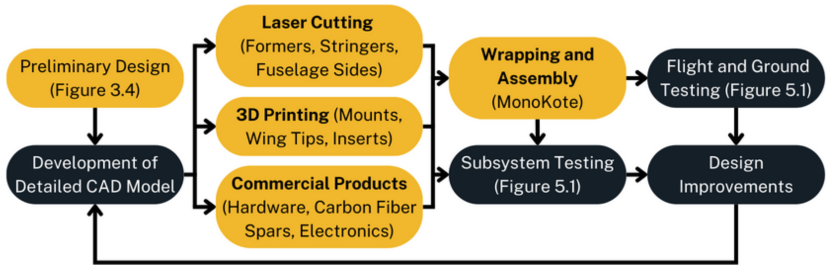
Figure 3.5: Aircraft Conceptual Model

To shift into the parking configuration, shown in **Figure 3.6**, the wing will hinge about a reinforced vertical shaft that connects the fuselage with the primary wing spar. It locks at 0° and 70° and will be held in place with a magnetic key that can be accessed on the fuselage side panel opposite the doors. The carbon fiber wing spars and vertical shaft will be sized based on FEA and experimentation.

Figure 3.6: Aircraft in Parking Configuration

4. Manufacturing Plan

Figure 4.1: Manufacturing Flowchart



The manufacturing flow is outlined in **Figure 4.1**. Weight, strength, and precision all must be considered throughout manufacturing. With a rotating scissor-wing mechanism, the strength of the wing-to-fuselage connection is critical. Each section of the aircraft will be broken down into individual components and modeled in SolidWorks. The primary framework, including ribs, formers, and fuselage sides, will be cut from 1/8-inch plywood using a 60W CO2 laser cutter. More complex components, including the wing rotation mechanism, wing tips, and payload inserts, will be 3D-printed using PLA with the infill optimized for strength and minimal weight. At important locations, including the wing box, wing rotation mechanism, and fuselage, high-strength composite tubes will be used to support the high loads during flight. After each subsystem is manufactured, the aircraft will be assembled with a MonoKote exterior skin. The final competition aircraft will be designed and assembled in the same way with improvements made to the initial design from experience and testing.

5. Testing Plan

Before aircraft assembly, each team will subject their designs to thorough testing and validation. The electronic subassembly will be installed on a test bench to validate the wiring configuration. The propulsion system will be evaluated on a test stand to optimize thrust control and battery discharge rate. Various rotating wing mount prototypes will be loaded to failure to optimize the part's strength and infill volume. Once the first full aircraft prototype assembly has been completed, each structure will be evaluated for strength and performance, with an emphasis on the technical inspection requirements. Ground testing will include a wing tip test, a fail-safe verification, a taxiing assessment, and a measurement of GM time. Flight testing will validate the 20 ft maximum takeoff distance, assess battery endurance, and collect GPS data. M3 velocity will be optimized by comparing throttle input and current draw in flight. The purpose, methodology, and due dates for each test are displayed in **Figure 5.1.** To maintain timely progress, the prototype aircraft will undergo its maiden flight in December and comprehensive testing throughout January. In March, the final aircraft will be subjected to simulated competition runs, requiring the completion of a technical inspection, ground mission, and all three flight missions. Each flight date will allow the pilots to familiarize themselves with the aircraft, fine-tune the control systems, and optimize mission performance.

Figure 5.1: Testing Plan

CATEGORY	TEST	METHOD	GOAL	DUE DATE
Component Testing	Static Thrust Test	Measure thrust, battery usage, and power on a test stand	Select propeller/battery and create thrust model	12/04/23
	Electronics Bench Test	Attach all electronic systems on test bench	Ensure working avionics and propulsion subsystems	12/18/23
	Wing Mount Test	Continuously add weight to rotating wing shaft until failure	Ensure reliability of wing connection during flight	12/18/23
Ground Testing	Landing Gear Test	Drop loaded aircraft onto landing gear	Ensure reliability of landing gear	1/08/24
	Wing Tip Test	Hold each mission-configured aircraft by its wingtips	Ensure structural stability and locate static margins	1/08/24
	Configuration Test	Test GM speed and consistency of changing configurations	Select ground crew and optimize GM score	1/08/24
	Taxi Test	Test movement of aircraft on ground	Ensure landing gear functionality and balance	1/15/24
	Technical Inspection	Perform thorough inspections of the aircraft's construction	Demonstrate ability to pass technical inspection	1/15/24
Flight Testing	Takeoff Distance Test	Measure takeoff distance for different weights and thrusts	Determine throttle required for 20 ft takeoff	1/15/24
	Flight Propulsion Test	Collect data in-flight to correlate thrust with velocity	Generate throttle curve and optimize M3 velocity	1/15/24
	Flight Endurance Test	Measure battery usage in-flight with M3 configuration	Optimize M3 battery capacity and score	1/15/24
	Mock Flight Missions	Practice each flight mission	Ensure stability, optimize M2 velocity and overall score	1/22/24