2025 Design, Build, Fly Competition Summary

The 2024-25 AIAA/Textron Aviation/RTX Design, Build, Fly Competition Flyoff was held at the Tucson International Modelplex Park Association in Tucson, AZ on the weekend of April 10-13, 2025. This was the 29th year of the competition. Of the 159 proposals submitted and judged, 112 teams were invited to submit a design report for the next phase of the competition. 111 teams submitted design reports and 96 teams attended the flyoff (22 international teams). Over 1200 students, faculty, and guests were present. This was a record year for the number of teams and students attending the fly-off. Of the 96 teams in attendance, 92 successfully completed tech inspection. The weather was hot and dusty but flying conditions were generally good, which allowed for non-stop flying. Of the 267 official flight attempts, 164 resulted in a successful score with 78 teams achieving at least one successful flight score and 24 teams successfully completing all missions (one ground and three flight missions). The quality of the teams, their readiness to compete, and the execution of the flights was exceptional.

The contest theme this year was an X-1 Supersonic Flight Test Program. The first mission was a Delivery Flight requiring the aircraft to complete three laps within five minutes. The second mission was a Captive Carry Flight including fuel tanks and an X-1 Flight Test vehicle, with score based on weight of the fuel tanks and time to fly three laps. The final mission included in-flight Launch of the X-1 Flight Test vehicle, with score based on number of laps flown prior to launch of the X-1 and the ability of the X-1 to release from the airplane and fly autonomously to a target area, with a bonus score base on the X-1 vehicle's weight and its landing position within the target area. Teams were also required to complete a ground mission demonstrating the efficiency of converting a production bomber airplane into a flight test platform. The team's final score is the product of the sum of the flight and ground mission scores and total report score plus participation score. More details on the mission requirements and scoring breakdown may be found at the competition website: http://www.aiaa.org/dbf.

First Place went to FH Joanneum, Second Place went to Royal Melbourne Institute of Technology, and Third Place went to Santa Clara University. A full listing of the results is included below. The Best Paper Award, sponsored by the Design Engineering TC for the highest design report score, went to the University of New South Wales with a score of 97.58.

For the fourth year, the Stan Powell Memorial Award recognized a team that exhibited the Most Meaningful Lessons Learned during the competition. This year, it was awarded to Virginia Polytechnic Institute and State University. Working through multiple issues that resulted in two failed flight missions, they rallied Sunday to post a very successful score for Mission 3.

We owe our thanks for the success of the DBF competition to the efforts of many volunteers from Textron Aviation, RTX, 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 RTX, and to the AIAA Foundation for their financial support as well as to our Gold sponsors this year – General Atomics, Mathworks, Stoke Space and The University of Arizona Aerospace and Mechanical Engineering. Special thanks go to RTX 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

2025 Design, Build, Fly Competition Summary

BY TEXTRON AVIATION

COLLINS AEROSPACE | PRATT & WHITNEY | RAYTHEON

2025 Design/Build/Fly Competition Final Results

Rank	Team	Part	Mission Scores					Report			2025 DBF
	University	P	GM	M1	M2	M3	Total	Prop	Design	Total	Score
1	FH JOANNEUM	3	0.92	1.00	1.69	2.73	6.34	81	81.28	81.29	**518.23**
2	Royal Melbourne Institute of Technology	3	1.00	1.00	1.60	2.36	5.96	89	79.83	81.16	**486.36**
3	Santa Clara University	3	0.85	1.00	1.36	2.26	5.47	74	89.57	87.20	**479.90**
4	The University of Akron	3	0.42	1.00	1.97	2.51	5.89	64	83.50	80.55	**477.78**
5	Rensselaer Polytechnic Institute	3	0.08	1.00	1.93	3.00	6.01	87	75.07	76.80	**464.60**
6	The University of Texas at Austin	3	0.65	1.00	1.88	2.11	5.64	76	82.65	81.58	**463.44**
7	Virginia Polytechnic Institute and State University	3	0.63	1.00	1.42	2.35	5.40	70	87.80	85.19	**463.16**
8	University of Ljubljana	3	0.59	1.00	1.69	2.04	5.32	76	88.17	86.35	**461.96**
9	The University of Sydney	3	0.46	1.00	1.58	2.28	5.32	88	86.00	86.32	**461.94**
10	University of California, Los Angeles	3	0.17	1.00	1.42	2.22	4.82	84	92.43	91.13	**441.97**
11	University of Southern California	3	0.35	1.00	1.28	2.11	4.75	84	89.36	88.50	**423.14**
12	University at Buffalo	3	0.28	1.00	2.00	2.26	5.54	79	74.05	74.73	**416.95**
13	The University of Kansas	3	0.21	1.00	1.55	2.22	4.99	70	85.07	82.76	**416.03**
14	The Pennsylvania State University	3	0.08	1.00	1.55	2.15	4.78	79	85.07	84.16	**405.19**
15	Embry-Riddle Aeronautical University - Prescott	3	0.06	1.00	1.66	2.22	4.95	73	82.52	81.04	**403.99**
16	Columbia University	3	0.96	1.00	1.15	2.04	5.15	82	77.02	77.76	**403.78**
17	University of Illinois Urbana-Champaign	3	0.21	1.00	1.32	2.61	5.14	82	76.67	77.50	**401.20**
18	University of Maribor	3	0.22	1.00	1.48	2.57	5.27	68	75.87	74.65	**396.62**
19	The Hong Kong Polytechnic University	3	0.44	1.00	1.29	2.11	4.83	79	80.70	80.38	**391.58**
20	Universidad Pontificia Bolivariana	3	0.51	1.00	1.20	2.07	4.79	83	80.25	80.66	**389.11**
21	The University of Texas at Dallas	3	0.09	1.00	1.37	2.04	4.49	77	85.67	84.34	**382.10**
22	University of Oklahoma	3	0.20	1.00	1.34	2.22	4.76	74	80.47	79.49	**381.73**
23	Texas A&M University	3	0.24	1.00	1.21	2.11	4.56	66	71.30	70.50	**324.53**
24	University of Kentucky - Paducah	3	0.11	1.00	1.18	2.11	4.40	68	65.57	66.00	**293.16**
25	University of Michigan - Ann Arbor	3	0.88	1.00	1.23	0.00	3.11	77	90.42	88.44	**278.48**
26	University of Massachusetts Amherst	3	0.75	1.00	1.37	0.00	3.12	75	84.67	83.26	**262.73**
27	Georgia Institute of Technology	3	0.00	1.00	1.74	0.00	2.74	77	86.62	85.17	**236.26**
28	Universidade da Beira Interior Faculdade de Engenharia	3	0.22	1.00	1.36	0.00	2.58	66	86.02	82.98	**217.18**
29	Colorado State University	3	0.05	1.00	1.44	0.00	2.49	76	87.50	85.83	**216.72**
30	North Carolina State University	3	0.12	1.00	1.38	0.00	2.51	89	82.53	83.49	**212.48**
31	The Hong Kong University of Science and Technology	3	0.21	1.00	1.42	0.00	2.63	81	76.60	77.20	**205.71**
32	San Diego State University	3	0.22	1.00	1.71	0.00	2.93	71	67.98	68.49	**203.73**
33	University of Florida	3	0.16	1.00	1.22	0.00	2.38	84	81.72	82.08	**198.59**
34	San Jose State University	3	0.10	1.00	1.37	0.00	2.48	80	78.50	78.78	**198.04**
35	Washington University in St. Louis	3	0.13	1.00	1.11	0.00	2.24	83	83.17	83.09	**188.75**
36	Aviation and Aerospace University, Bangladesh	3	0.12	1.00	1.06	0.00	2.18	70	86.57	84.10	**186.45**
37	Khalifa University of Science and Technology	3	0.25	1.00	1.13	0.00	2.38	75	72.70	73.09	**177.32**
38	University of Notre Dame	3	0.17	1.00	1.09	0.00	2.27	78	74.50	74.98	**172.88**
39	Military Institute of Science and Technology	3	0.22	1.00	1.07	0.00	2.29	65	75.50	73.96	**172.20**
40	The University of Hong Kong	3	0.11	1.00	1.22	0.00	2.33	72	70.92	71.03	**168.31**
41	The Ohio State University	3	0.06	1.00	1.30	0.00	2.35	72	69.77	70.06	**167.84**
42	Utah State University	3	0.15	1.00	1.08	0.00	2.23	68	74.10	73.16	**166.31**
43	Trine University	3	0.06	1.00	1.16	0.00	2.23	63	75.05	73.25	**166.24**
44	Purdue University (Main Campus)	3	0.05	1.00	1.04	0.00	2.08	78	73.00	73.77	**156.71**
45	Missouri University of Science and Technology	3	0.00	1.00	1.30	0.00	2.30	73	65.17	66.29	**155.32**
46	Rowan University	3	0.12	1.00	1.12	0.00	2.24	72	66.33	67.21	**153.25**
47	University of Colorado Boulder	3	0.13	1.00	1.14	0.00	2.27	77	63.58	65.53	**151.44**
48	Clarkson University	3	0.77	1.00	0.00	0.00	1.77	77	79.13	78.87	**142.50**
49	Johns Hopkins University	3	0.07	1.00	1.01	0.00	2.08	78	58.03	60.98	**129.83**
50	California State University, Long Beach	3	0.04	1.00	1.00	0.00	2.05	68	60.03	61.27	**128.47**
51	University of Washington-Seattle	3	0.34	1.00	0.00	0.00	1.34	85	89.50	88.83	**122.25**
52	University of New South Wales	3	0.13	1.00	0.00	0.00	1.13	86	97.58	95.83	**110.95**
53	The University of Alabama	3	0.28	1.00	0.00	0.00	1.28	74	85.30	83.67	**110.01**
54	University of Maryland, College Park (UMCP)	3	0.38	1.00	0.00	0.00	1.38	88	73.92	76.09	**107.65**
55	Rutgers University - New Brunswick	3	0.24	1.00	0.00	0.00	1.24	76	85.87	84.34	**107.61**
56	Alexandria University	3	0.27	1.00	0.00	0.00	1.27	73	81.75	80.45	**105.01**

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2025 Design/Build Fly Competition Final Results (cont)

Rank	Team	Part	Mission Scores					Report			2025 DBF
	University	P	GM	M1	M2	M3	Total	Prop	Design	Total	Score
57	Embry-Riddle Aeronautical University, Daytona Beach	3	0.14	1.00	0.00	0.00	1.14	74	90.70	88.22	103.42
58	Universidad de Antioquia	3	0.13	1.00	0.00	0.00	1.13	73	88.73	86.31	100.15
59	University of California, Irvine	3	0.22	1.00	0.00	0.00	1.22	62	82.10	79.10	99.46
60	Auburn University at Auburn	3	0.10	1.00	0.00	0.00	1.10	81	83.90	83.50	94.91
61	University of Maine	3	0.21	1.00	0.00	0.00	1.21	64	74.37	72.80	90.82
62	National University of Science and Technology POLITEHNICA Bucharest	3	0.06	1.00	0.00	0.00	1.06	67	81.60	79.37	86.90
63	DAYANANDA SAGAR COLLEGE OF ENGINEERING	3	0.00	1.00	0.00	0.00	1.00	78	84.50	83.53	86.53
64	George Washington University	3	0.07	1.00	0.00	0.00	1.07	63	77.92	75.61	84.10
65	VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE	3	0.10	1.00	0.00	0.00	1.10	73	73.12	73.05	83.61
66	West Virginia University	3	0.03	1.00	0.00	0.00	1.03	71	78.75	77.66	83.11
67	Stanford University	3	0.00	1.00	0.00	0.00	1.00	66	81.73	79.32	82.32
68	Case Western Reserve University	3	0.09	1.00	0.00	0.00	1.09	64	68.17	67.50	76.85
69	John Brown University	3	0.04	1.00	0.00	0.00	1.04	66	70.37	69.64	75.35
70	North Dakota State University	3	0.00	1.00	0.00	0.00	1.00	72	67.30	68.01	71.01
71	The City College of New York	3	0.23	1.00	0.00	0.00	1.23	65	50.92	53.07	68.27
72	Saint Louis University	3	0.08	1.00	0.00	0.00	1.08	66	59.57	60.50	68.05
73	University of Arkansas	2	0.76	0.00	0.00	0.00	0.76	84	84.03	84.06	66.28
74	Massachusetts Institute of Technology	3	0.16	1.00	0.00	0.00	1.16	76	43.67	48.52	59.32
75	University of California, San Diego	3	0.06	1.00	0.00	0.00	1.06	61	47.23	49.29	55.16
76	University of Nebraska Lincoln	3	0.05	1.00	0.00	0.00	1.05	61	45.08	47.41	52.84
77	University of Georgia	3	0.00	1.00	0.00	0.00	1.00	62	47.47	49.64	52.64
78	Texas Tech University	3	0.00	1.00	0.00	0.00	1.00	64	44.68	47.56	50.56
79	University of Tennessee Knoxville	3	0.13	1.00	0.00	0.00	1.13	65	28.33	33.84	41.13
80	National University of Singapore	3	0.44	0.00	0.00	0.00	0.44	72	87.90	85.58	40.58
81	Seoul National University	3	0.17	0.00	0.00	0.00	0.17	75	84.95	83.46	17.47
82	Cornell University	3	0.16	0.00	0.00	0.00	0.16	84	77.58	78.47	15.20
83	Rochester Institute of Technology	3	0.08	0.00	0.00	0.00	0.08	81	75.83	76.62	9.09
84	University of North Carolina at Charlotte	3	0.06	0.00	0.00	0.00	0.06	74	79.63	78.79	7.66
85	University of Missouri - Columbia	2	0.06	0.00	0.00	0.00	0.06	72	69.92	70.28	5.91
86	University of California Merced	2	0.05	0.00	0.00	0.00	0.05	68	36.90	41.52	3.98
87	Birla Institute of Technology and Science , Pilani, KK Birla Goa Campus	3	0.00	0.00	0.00	0.00	0.00	77	75.57	75.78	3.00
88	University of South Alabama	3	0.00	0.00	0.00	0.00	0.00	68	55.15	57.00	3.00
89	University of Hartford	3	0.00	0.00	0.00	0.00	0.00	69	51.45	54.04	3.00
90	California State Polytechnic University Pomona	2	0.00	0.00	0.00	0.00	0.00	67	63.33	63.85	2.00
91	University of Vermont	2	0.00	0.00	0.00	0.00	0.00	70	25.18	31.89	2.00
92	Vaughn College of Aeronautics and Technology	2	0.00	0.00	0.00	0.00	0.00	62	22.73	28.62	2.00
93	Boston University	1	0.00	0.00	0.00	0.00	0.00	79	59.00	62.06	1.00
94	University of South Carolina	1	0.00	0.00	0.00	0.00	0.00	70	59.37	60.95	1.00
95	University of Missouri - Kansas City	1	0.00	0.00	0.00	0.00	0.00	67	53.07	55.10	1.00
96	University of Idaho	1	0.00	0.00	0.00	0.00	0.00	62	45.00	47.55	1.00
97	University of Arizona	0	0.00	0.00	0.00	0.00	0.00	67	32.03	37.30	0.00
98	Yıldız Teknik Üniversitesi	0	0.00	0.00	0.00	0.00	0.00	66	78.33	76.49	0.00
99	Iowa State University	0	0.00	0.00	0.00	0.00	0.00	69	74.33	73.52	0.00
100	Mukesh Patel School Of Technology Management and Engineering (Mumbai)	0	0.00	0.00	0.00	0.00	0.00	78	67.10	68.80	0.00
101	Ghulam Ishaq Khan Institute of Engineering Sciences and Technology	0	0.00	0.00	0.00	0.00	0.00	64	68.83	68.12	0.00
102	Cairo University	0	0.00	0.00	0.00	0.00	0.00	82	60.87	63.99	0.00
103	University of California, Davis	0	0.00	0.00	0.00	0.00	0.00	74	59.58	61.68	0.00
104	Gonzaga University	0	0.00	0.00	0.00	0.00	0.00	67	60.22	61.25	0.00
105	Colorado School of Mines	0	0.00	0.00	0.00	0.00	0.00	68	56.58	58.29	0.00
106	The University of Tennessee Chattanooga	0	0.00	0.00	0.00	0.00	0.00	68	53.97	56.12	0.00
107	Western Michigan University	0	0.00	0.00	0.00	0.00	0.00	61	46.33	48.53	0.00
108	Tribhuvan University	0	0.00	0.00	0.00	0.00	0.00	75	43.83	48.44	0.00
109	Clemson University	0	0.00	0.00	0.00	0.00	0.00	75	39.25	44.62	0.00
110	National Autonomous University of Mexico	0	0.00	0.00	0.00	0.00	0.00	61	34.13	38.11	0.00
111	University of Pennsylvania	0	0.00	0.00	0.00	0.00	0.00	65	22.33	28.74	0.00
112	James Madison University	0	0.00	0.00	0.00	0.00	0.00	61	0.00	9.17	0.00

1 Executive Summary

This proposal outlines NC State's plan for designing, manufacturing, and testing its "Highway to Howl" (H2H) aircraft and test vehicle "Thunderwolf" to compete in the 2024-2025 AIAA Design, Build, Fly (DBF) Competition. The objective is to design, build, and test a remote-controlled fixed-wing aircraft to simulate the NASA X1 test through three flight missions and a ground mission. The scoring for these four missions is determined by lap time, weight of external fuel tanks, weight of the test vehicle, and landing location of the glider. Trade studies, an optimization code, and sensitivity analysis were developed to determine the optimal aircraft configuration.

The H2H is a high-wing twin-boom aircraft with a U-tail, tricycle landing gear, and single-puller propeller. To achieve a high payload weight, a wingspan of 70.9" is used with a Rhodes St. Genese 30 airfoil and a rectangular wing. The H2H will carry a payload weight of 10.3 lbs and complete 3 laps in around 168 seconds in Mission 2 (M2). For Mission 3 (M3), the H2H will fly 4 laps then release the Thunderwolf on the fifth lap to conduct the required flight envelope. The Thunderwolf is a flying delta-wing with elevons for control and is deployed by a servo lock and key.

2 Management Summary

2.1 Organizational Structure

The North Carolina State AIAA DBF team is a fully student-led design team consisting of 33 undergraduate members. The team is advised by two faculty members, three graduate members, and is led by seven seniors who fill administrative and technical positions. Each technical lead advises a subteam of underclassmen focusing on a specific technical aspect as shown in Table 1. This organizational structure allows for a sustained flow of information between technical leads while allowing underclassmen to learn and contribute. Figure 1 visualizes the implemented organizational structure with administrative roles shown in gray and technical positions in red.

Table 1 Team Technical Leads

Technical Lead	Responsibility	Skills needed
Aerodynamics	Required aerodynamics analysis for sizing and desired performance	Fundamental Aerodynamics and derive parameters
Propulsion	Complete calculations to determine motor and propeller needed	Analysis of required mechanical power vs electrical power
Stability & Controls	Perform stability analysis to be able to get stability derivates and determine control surface sizing	Knowledge of stability software, understanding of stability and control theory
Structures	Design airframe and conduct testing to ensure structural stability	Structural analysis and FEA knowledge
CAD & Simulation	Model and run simulations on the aircraft	CAD and FEA knowledge
Payload	Lead payload design and figure out how the payload will affect aircraft characteristics	Assembly Processes knowledge, Lab experience, and CAD

For the administrative roles, the Team Lead is responsible for setting deadlines, tracking deliverables, and team task management. The Financial Lead is responsible for setting and maintaining a budget. The Systems Engineer is in charge of subsystem integration into the aircraft. The Communications Lead establishes and maintains relations with professors for design advice and access to testing facilities. The last two administrative roles, the Safety Engineer and the Rules Compliance Lead, ensure that the development of the aircraft is safe and follows AIAA 2024-2025 rules. The senior design team meets twice weekly to discuss progress, while the entire DBF student body meets twice weekly to collaborate on design decisions, manufacturing, and testing.

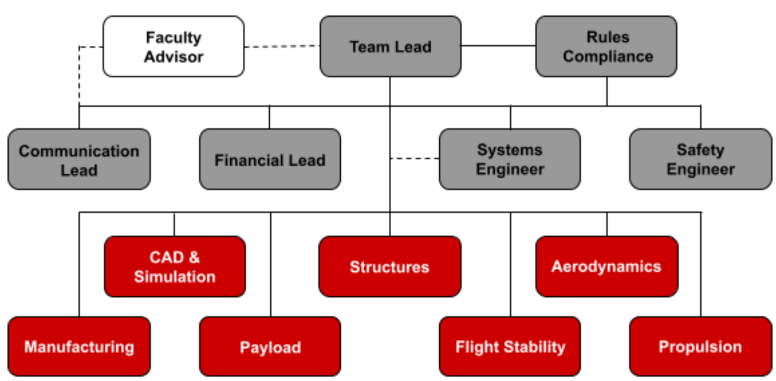

Fig. 1 Team Organizational Structure

2.2 Schedule

The proposed schedule for the design and manufacture of the project is outlined in Fig. 2. The Team Lead will hold other leads accountable and will ensure completion of the necessary deliverables throughout the year.

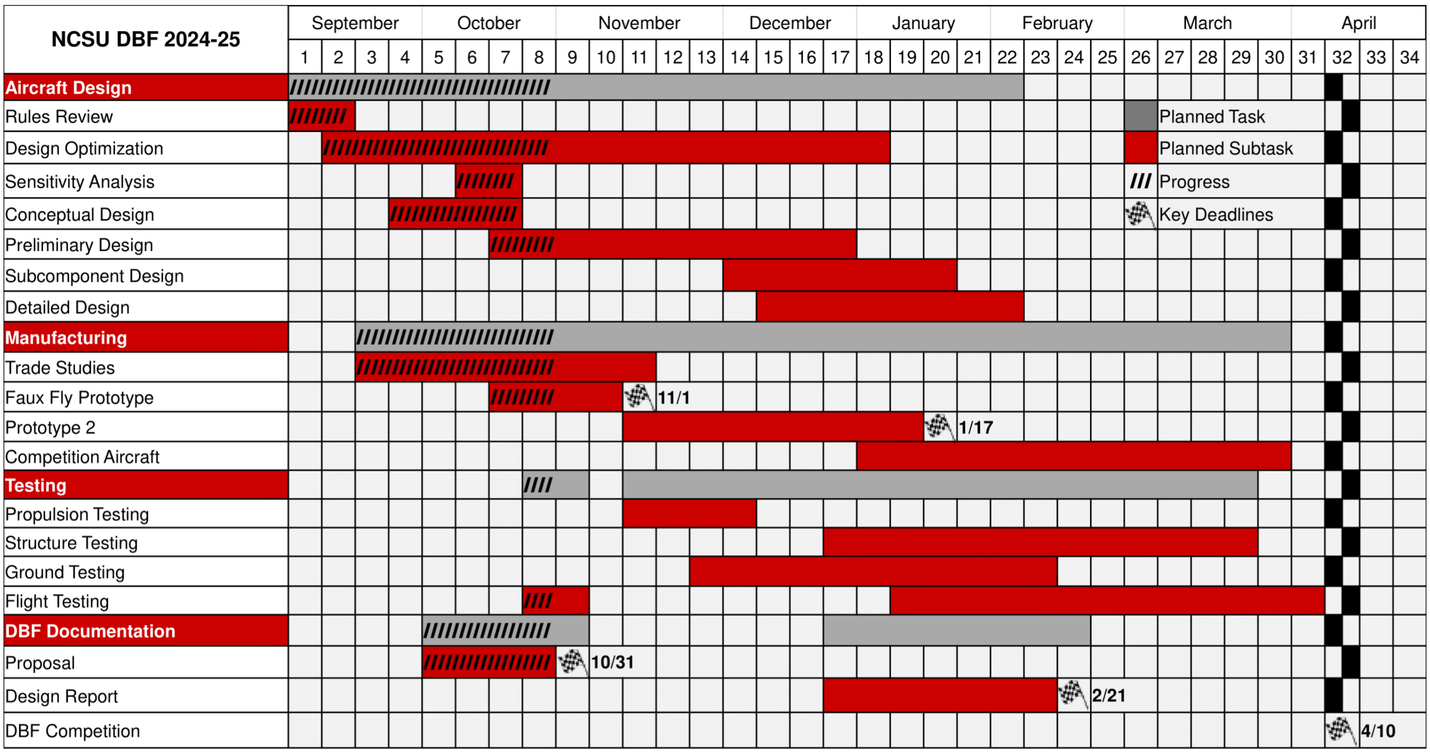

Fig. 2 Team Gantt Chart

2.3 Budget

The NC State team receives funding from NC State's Engineer Your Experience (EYE) fund, NC State's Education and Technology Fees fund, and the Team Competition NC Space Grant. NC State's team budget is outlined in Table 2. Expenses are based on the previous year's DBF team expenses and the estimated travel costs to Tucson, Arizona. As seen in Table 2, roughly 65% of the budget is allocated towards travel. The rest of NC State's budget will be used for constructing and testing the aircraft. No manufacturing tools will be purchased as NC State provides these to the team and reuses items from previous years.

Table 2 2024-2025 NC State DBF Budget

Category	Item	Allocated
Travel	Airfare	$4,000.00
	Lodging	$2,500.00
	Rental Car	$1,500.00
	Shipping	$400.00
	Packaging	$50.00
Electronics	Receiver	$150.00
	Servos	$550.00
	Motor	$500.00
	Battery	$400.00
	Electronic Speed Controller	$100.00
	Wiring	$50.00
	Lights	$50.00
Structures	Balsa Wood	$600.00
	Breather/Peel Ply/Bags	$300.00
	Fiberglass	$200.00
	Carbon Fiber	$850.00
	XPS Foam Board	$100.00
	Propellers	$100.00
	Landing Gear	$150.00
	3D Printing Filament	$50.00
	Adhesives	$150.00
	Ultracote	$150.00
	Hardware	$100.00
Total Cost		**$13,000.00**

3 Conceptual Design Approach

3.1 Analysis of Mission Requirements

The competition recreates the X1 flight test conducted by NASA in 1948. The competition consists of a ground mission (GM) and three flight missions. The scoring, description, and requirements for each mission are displayed in Table 3.

Table 3 Mission Description and Requirements

Mission	Scoring	Description	Sub-system Requirements
M1	$M1 = 1.0$	• Start in the parking configuration. Install propulsion battery packs within 5 minutes. • Complete 3 laps of the course within 5 minutes and successfully land.	• Aircraft must be easily configurable to be set up within the staging window. • Aircraft must be stable and fast enough to complete 3 laps in the flight window.
M2	$M_2 = 1 + \frac{\left(\frac{Fuel\ Weight}{Time}\right)_{Team}}{\left(\frac{Fuel\ Weight}{Time}\right)_{Max}}$	• Record fuel tank weights. • Install battery packs, test glider, and fuel tanks in 5 minutes. • Record time to fly 3 laps within 5-minute flight window.	• Aircraft must optimize fuel weight carried and minimize lap time. • Aircraft pylons must be strong enough to carry payload weight securely. • Propulsion system must provide enough power to account for increased aircraft weight.
M3	$M_3 = 2 + \frac{\left(\#\ Laps\ Flown + \left(\frac{Bonus\ box\ score}{X1\ vehicle\ weight}\right)\right)_{Team}}{\left(\#\ Laps\ Flown + \left(\frac{Bonus\ box\ score}{X1\ vehicle\ weight}\right)\right)_{Max}}$	• Install battery packs, test glider, and fuel tanks in 5 minutes. • Complete as many laps as possible before releasing the test glider between 200-400 ft of altitude. Aircraft must then complete another lap before landing. • Test glider must land within 5-minute flight window and inside the landing zone for bonus points.	• Aircraft must have a high top speed to optimize lap time. • X1 test glider must be autonomously controlled. • X1 test glider must be light weight. • X1 test glider must complete 180-degree turn in stable flight and have a functioning LED flasher. • Glider deployment mechanism must drop the glider safely without impact to either the glider or main aircraft.
GM	$GM = \frac{(Mission\ Time)_{Min}}{(Mission\ Time)_{Team}}$	• Record time to switch from "clean" configuration to test configuration. •Verify control surfaces are working properly. • Demonstrate release of test glider from aircraft and light on glider turns on.	• Aircraft must be easy to set up to ensure aircraft is configured in minimum time. • LED light on glider must turn on when dropped.

3.2 Trade Studies

Prior to design optimization, the pylon attachment method, tail configuration, tail arm configuration, and glider deployment mechanism (GDM) were selected via the trade studies shown in Table 4. Each option was rated on a scale of 1-10 in weighted categories with 10 being the best possible. A U-tail gives better yaw authority in M2 and M3 while keeping the vertical tails as clear as possible from the glider during separation. The U-tail is attached to the wings by twin booms to minimize aft CG shift and vibrations while retaining structural strength. The pylons are mounted to the wings with Dual-Lock tape for removal speed during the GM and manufacturing simplicity. Finally, the GDM uses a servo lock and key method for its manufacturing simplicity and low weight. After each matrix was completed, the weighting of each category was varied to verify that the winning design option was not sensitive to slight weighting changes.

Table 4 Pugh Matrices

Tail Configuration	Scoring Weight	Conventional Tail	n-Tail	U-Tail	T-Tail
Points of Failure	15%	8	2	6	5
Yaw Authority	35%	7	8	9	7
CG Effects	10%	7	4	5	6
Wake Effects from Wing	15%	6	3	6	2
Manufacturability	25%	7	4	8	5
Weighted Result	100%	6.10	4.50	6.55	5.05

Pylon Attachment	Scoring Weight	Dual-Lock Tape	Hose Clamp	Rib Hook
Loading Capacity	35%	8	9	9
Weight	20%	10	8	8
Aero. Effects	10%	8	8	6
Structural Effects	25%	9	8	7
Manufacturability	10%	10	6	8
Weighted Result	100%	8.85	8.15	6.66

Tail Arm Configuration	Scoring Weight	Close Twin-Boom	Medium Twin-Boom	HT Tip Twin-Boom	Extended Fuselage
Vibrations	25%	3	6	7	7
Structural Strength	25%	8	8	4	5
CG Effects	20%	9	8	5	3
Manufacturability	30%	7	7	8	3
Weighted Result	100%	6.65	7.20	6.15	4.50

Glider Deployment Mechanism	Scoring Weight	Servo Lock/Key	Solenoids	Spindle Servos	Spring-Loaded Clamp
Deployment Success	35%	6	5	5	7
Deployment Speed	5%	5	8	5	8
Weight	35%	10	3	6	2
Manufacturability	25%	10	9	7	10
Weighted Result	100%	8.35	5.45	5.85	6.05

3.3 Design Optimization Code

The optimization code sets payload weight, wing and tail dimensions, wing airfoil, and wing location as optimization variables and used DBF's mission scoring equations as its objective function. For every iteration of the design optimization model, the aircraft's performance and stability were calculated and used to determine its competition score. Using MATLAB's design optimization toolbox, iterations of the aircraft's design were optimized for the highest score possible.

3.4 Preliminary Design

3.4.1 Transport Aircraft (H2H)

The Computer-Aided Design (CAD) model of the H2H, with fuel tanks and glider attached, is displayed in Fig. 3. The optimization code outputted a wingspan of the maximum 72.0", which will be reduced to 71.0" as a buffer against manufacturing errors. The wing has a chord of 12.6" with no taper to maximize wing area and lifting surface for M2. The wing also has an aspect ratio of 5.70 to optimize lift over drag ratio (M3). The optimization code returned the Rhode St. Genese 30 as the best-performing airfoil likely because it has a high L/D of 67 at a cruise angle of attack of 5°. The airfoil also features a flat bottom, which decreases manufacturing complexity. The twin booms are 35.4" in length and connected to an optimized horizontal tail with a span of 46.5" and a chord of 5.83". The horizontal tail's high aspect ratio reduces drag during flight, but it primarily increases roll stability for M2. The longer span gives the option of converting the elevator to elevons if flight tests reveal more roll authority is needed. The optimization code returned a vertical tail span and chord of 5.83". The fuselage is a rounded square cross-section with a length of 21.7" and side of 3.94". It is sized to fit a 350kV motor with a 20"x13" propeller, 6S 4500mAh 95C battery, 150A ESC, receiver, and the GDM.

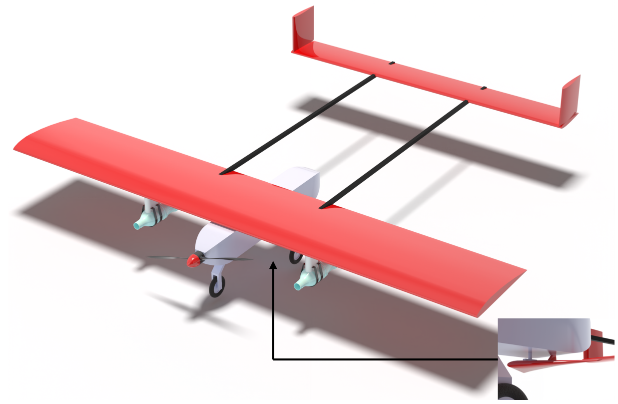

Fig. 3 CAD Model

3.4.2 Fuel Tanks

The optimization code outputted a total payload weight of 10.3 lbs. Using the minimum 16.9 fl oz bottle to reduce drag for M2 and M3, a payload material with a density of 309 lb/ft^3 achieves the optimal payload weight while using the full volume. The fuel tanks will carry a mixture of resin and lead to meet the payload density requirement. In addition, the pylon design seen on the left in Fig. 4 maintains structural strength while reducing drag. The fuel tank will be secured to the pylon by two standard hook-and-loop straps for ease of removal. They will be mounted cap-forward as Computational Fluid Dynamics (CFD) analysis showed less drag in that configuration. The pylon will attach and detach from the wing using 3M Dual-Lock tape on both the pylon and the wing. Dual-Lock tape ensures an equal stress distribution from the payload on the wing skin.

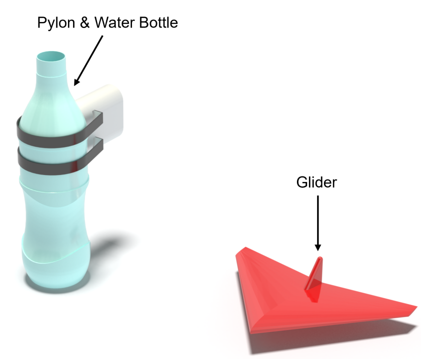

Fig. 4 CAD Models of Pylon and Glider

3.4.3 Glider (Thunderwolf)

With the maximum weight limit of 0.55 lbs in mind, the glider configuration, seen on the right in Fig. 4, was chosen to be a flying delta wing. This configuration consists of two actuating control surfaces (elevons), requiring no more than two micro-servo actuators. The gliding wing will also produce less parasitic drag when attached to the main aircraft to increase speed in M3. This configuration also allows for rapid prototyping and design iterations.

Flying wings must have multiple key design aspects in order to fly in a stable and steady mode. Most importantly, the wing must have a positive pitching moment at a zero angle of attack and positive pitch stiffness. To create a positive moment, the flying wing will require large amounts of sweep and negative twist. These features will result in negative local lift generation near the tips of the glider, which induces a positive pitching moment at zero angle of attack. Obtaining positive pitch stiffness is achieved by placing the center of gravity in front of the neutral point of the glider. Roll and yaw stability are relatively simple to achieve. Yaw stability is maintained by the implementation of a centrally positioned vertical tail surface, akin to a shark fin, instead of outwardly placed winglets. This decision was made to reduce any adverse effects related to winglets such as increased structural complexity, aeroelastic instability, and manufacturing complexity. With the following design decisions in mind, the dimensions of the glider are as follows: A span of 12.0", large sweep of at least 30°, around 9° of twist. and a low aspect ratio of 5. Though this may produce additional induced drag, more lift will be generated, which is required for maintaining a small wingspan. A slight dihedral of around 2° will be implemented in order to maintain roll stability. Finally, the central vertical tail will be tapered and swept to increase the vertical tail moment arm by moving the aerodynamic center aft, and it will have a span of 2.00".

3.4.4 Glider Deployment Mechanism

The GDM will consist of a servo lock and key. To release, the servo will turn a key until it aligns with a mated hole in the glider. The hole will be at the glider's CG to reduce instability from the glider during flight. The key arm will extend the glider far enough from the fuselage to create the necessary 0.25" clearance. In addition, the glider will have a normally closed reed switch connecting the power supply to the onboard flight control computer (FCC). A magnet onboard the aircraft will power the reed switch and keep the switch open pre-deployment. Once deployed, the magnet's absence will set the switch to its normally closed state and route power to the flight controller and lights. Waiting to power the FCC until just after deployment will cause the glider to only need a 200 mAh 2-cell LiPo battery, saving on weight.

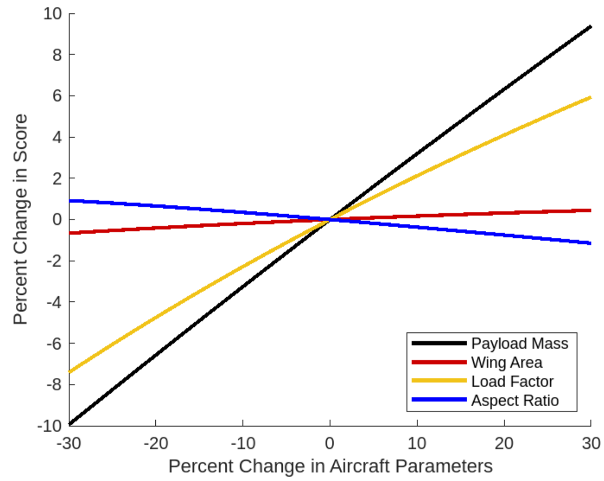

Fig. 5 Mission 2 Sensitivity

3.5 Sensitivity Analysis

In order to validate the preliminary design, a sensitivity analysis was conducted to find the most impactful score variables and verify the design optimization scoring results. Optimization variables were directly varied ±30% and inputted back into the optimization code to calculate the altered score. The resulting percent changes in score were plotted in Figs. 5 and 6. This sensitivity analysis verifies the team's design optimization code is optimizing for the correct flight envelope. For M2, the code optimizes for maximum payload mass and wing area while retaining maximum speed. For M3, since the payload is not utilized for the mission score, its impact on the sensitivity analysis is null. However, a higher load factor is most impactful as it results in tighter turns and thus, faster lap times. These results confirm expectations for variable influence as higher wing area is inversely related to aspect ratio. A decrease in wing area means a decrease in lift and the amount of payload that can be carried.

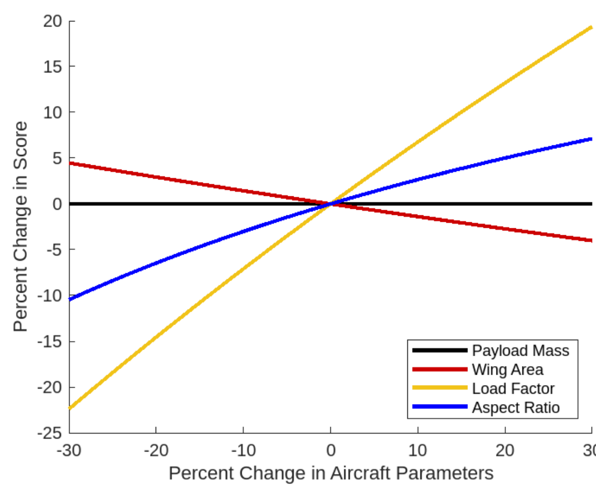

Fig. 6 Mission 3 Sensitivity

3.6 Mission Targets

In M1, the H2H will successfully fly 3 laps in approximately 210 seconds. To complete M2, the H2H will fly 3 laps with 10.3 lbs of payload in approximately 168 seconds. In M3, the H2H will complete 4 laps, release the glider, and finish the fifth lap with 20 seconds to spare. The ground crew member will finish GM within 140 seconds.

4 Manufacturing Plan

As described in the previous sections, the manufacturing process influenced many design decisions. Figure 7 displays the team's steps to complete the aircraft. The first H2H prototype will feature the discussed preliminary design to test the stability and control of the aircraft with and without fuel tanks. This will also test the aerodynamic qualities of the pylons in M2. It will include loose-tolerance hand manufacturing, fiberglass layups, and will not contain the glider systems used in M3.

The second H2H prototype will test M3 systems such as the reed switch and GDM. The payloads will also contain the full weights used in M2. Iterations of the Thunderwolf will be manufactured using low-density PLA and additive manufacturing. If there are any stability or performance issues from the first H2H prototype, there will be wing and tail changes. The competition aircraft will consist of tight-tolerance machining, carbon fiber spars, and a two-layer carbon fiber layup overtop the wing. The reinforcement of the carbon fiber spars and layup will provide structural support for the bending moments on the wings due to G-forces and the fuel tanks in M2. The empennage will use the same manufacturing processes as the wing, with carbon fiber tubes being used for twin booms on each prototype. For all three prototypes, sections of foam will be CNC wire-cut into the airfoil shape and glued together to form the full wing.

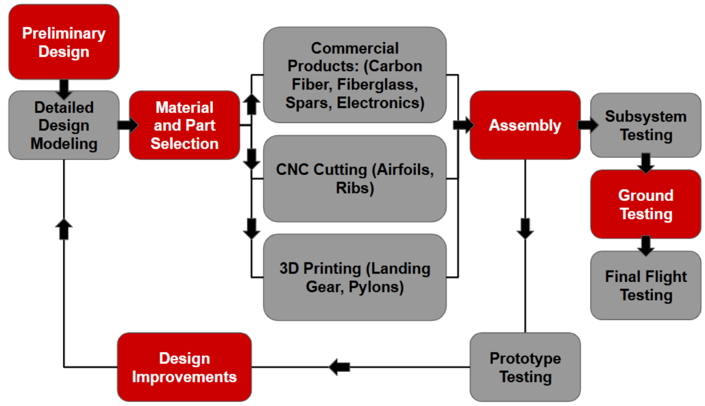

Fig. 7 Manufacturing Flowchart

5 Test Planning

Once the first prototype is constructed, the tests shown in Table 5 will be performed with the exception of glider-related tests for the first prototype. Preliminary testing of the prototypes will provide feedback on all components for future iterations. Practice flights will also be conducted with an experienced RC pilot to gather feedback and identify potential issues. Flight tests will be conducted to verify the aircraft can complete all required missions and requirements.

Table 5 Test Plan Chart

Test Type		Objective	Method	Sub-Team
Preliminary Design Tests	Cruise Thrust Test	Verify endurance and efficiency of propulsive systems.	Attach propulsion system to TTYO Flight Stand 15 and test performance.	Propulsion
	Realflight Iron Bird Simulation	Ensure receiver works with transmitter.	Connect transmitter to RealFlight Simulation with Preliminary Aircraft Design model.	Aerodynamics, CAD and Simulations, Stability and Controls
		Verify preliminary flight performance for the pilot.	Perform Design Build Fly missions in RealFlight, verifying movement of control surfaces.	Stability and Controls
Ground Verification Tests	Payload Test	Verify payload is secure and structurally stable.	Attach pylons and fuel tanks, simulate flying with shaking and drop tests	Payload
	Assembly Test	Minimize the time assembling the aircraft and ensure pylons are detachable.	Assemble full aircraft with payload while timed. Conduct Ground Mission timed, ensure desired time is achieved.	Manufacturing, Structures
	Pylon Attachment Test	Ensure attachment of pylons.	Attach and detach pylons to ensure strong hold for flight.	Manufacturing, Structures
	Wing Loading (with pylons)	Verify wing structure can withstand payload.	Lift aircraft by wings using a flat surface across the wings.	Structures
	CG Tip Test	Ensure CG is at intended location.	Lift aircraft by wings along the CG X axis, adjust until CG location is found.	Stability and Control
	Glider Drop Test	Ensure glider safe seperation from aircraft and electronic systems turn on.	Ensure glider is secured and FCC is turned off. Activate Glider deployment, ensure separation, ensure activation of FCC and LEDs.	Payload
	Stability Controls Test	Verify the control surface system.	Attatch power connector to receiver. Verify control surfaces move in intended direction.	Stability and Controls
Flight Tests	Cruise Test	Verify cruise speed with and without tank attachments.	Fly in cruise speed, measuring vertical speed.	Propulsion, Stability and Controls
	Turning Test	Verify aircraft can turn with a minimum bank angle of 20 degrees.	Perform Bank angle turn of a minimum of 20 degrees, measuring stability, along with vertical speed.	Propulsion, Stability and Controls
	Glider Deployment Test	Verify stable glider deployment.	Perform Mission 2 and ensure glider is deployed in stable trim flight before banking 180 degrees.	Payload, Stability and Controls
	Full Systems Test	Verify all systems, aircraft and glider, are in full operation.	Fly full-intensity mission attempts.	All Leads

1. Executive Summary

This proposal outlines the Royal Melbourne Institute of Technology (RMIT) Design, Build, Fly (DBF) team's plan for the design, manufacturing, and testing of its aircraft, "Black Widow", for the 2024–25 AIAA DBF competition. The competition consists of four missions focused on payload capacity and the deployment of a secondary vehicle, "X-1" that must autonomously land. The team is structured into three sub-teams—Aerostructures, Avionics, and Systems—each assigned specific roles to streamline the design, build, and testing processes. Weekly meetings and a Gantt chart will assist in keeping the team organised and on schedule. Performance in the competition is assessed based on lap time, fuel mass, and the successful autonomous deployment and landing of the X-1 vehicle.

To maximise the overall score, the team conducted a score sensitivity analysis, prioritising the highest possible fuel weight (W_F) and the lightest X-1 weight (W_X), while balancing lap count and lap time. The analysis yielded mission targets of a 9-kg (19.8-lbs) W_F and a 33-s lap time for Mission 2 (M2), and a 0.125-kg (0.276-lbs) W_X with 6 laps for Mission 3 (M3). Ground mission (GM) time is expected to be minimised to 30 s by using the minimum required number of fuel bottles. The design was further refined through a series of trade studies, resulting in a high-wing monoplane configuration with a tractor motor, conventional tail, and taildragger landing gear. The aircraft features a rectangular wing with a 1.82 m (6 ft) wingspan, a 0.80 m (2.62 ft) chord, and winglets. The fuselage was sized around the battery and tail arm, measuring 2 m (6.56 ft) in length, 88.9 mm (3.50 in) in height, and 94.0 mm (3.80 in) in width. The propulsion system was optimised to maximise thrust given the high fuel weight, with a battery capacity of 97.7 Wh. A comprehensive manufacturing plan has been developed, detailing the next steps in design, CAD modelling, electronics selection, and both simulation and physical testing. The testing outline includes a range of tests intended to validate the design and simulation models, with specific deadlines to monitor progress.

2. Management Summary

2.1. Team Organisation

The RMIT 2024–25 DBF team consists of nine undergraduate members and two graduate students. The team is fully student-led, whilst academic advisors provide guidance and technical expertise at certain meetings and design reviews. Leadership is shared between the chief and deputy chief engineer, who handle both logistical and technical responsibilities. They organise meetings, manage the budget, arrange travel from Australia to the US, and ensure that team tasks and deadlines are met. In addition to this, they oversee the integration of the design process and testing of aircraft components. The team is divided into three core sub-teams: aerostructures, avionics, and systems, as shown in Figure 1. Each sub-team has a designated leader who is responsible for task distribution, organising sub-team meetings, and ensuring progress is well-documented. The specific roles and responsibilities of each sub-team are detailed in Table 1.

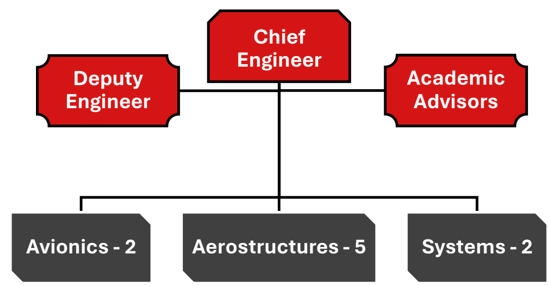

Figure 1: Organisational Chart

Sub-Teams	Roles	Skill Sets
Aerostructures	• Design the overall aircraft • Conduct stability and control analyses • Conduct lift and drag simulations • Plan and execute fight- and ground-mission tests	• Model-aircraft design • Knowledgeable in the use of FEA and CFD tools • Composite and other advanced manufacturing • Skilled in Solidworks and XFLR5 • Aircraft performance and stability
Avionics	• Conduct motor and propeller selection and testing • Avionics selection for main aircraft and the X-1	• Understanding of aircraft propulsion systems • Aircraft stability and landing automation
Systems	• Conduct a mission sensitivity analysis • Ensure aircraft adheres to requirements	• Thorough understanding of the rules • Excel and MATLAB knowledge

Table 1: Sub-Team Roles and Skills

2.2. Schedule

The team's schedule, represented by the Gantt chart in Figure 2, is reviewed during weekly full-team meetings to ensure progress is on track with the timeline. In addition, each sub-team holds weekly meetings to assign and manage specific tasks. To facilitate effective communication between sub-teams, working-day sessions are held every Monday, allowing for quick collaboration across the team.

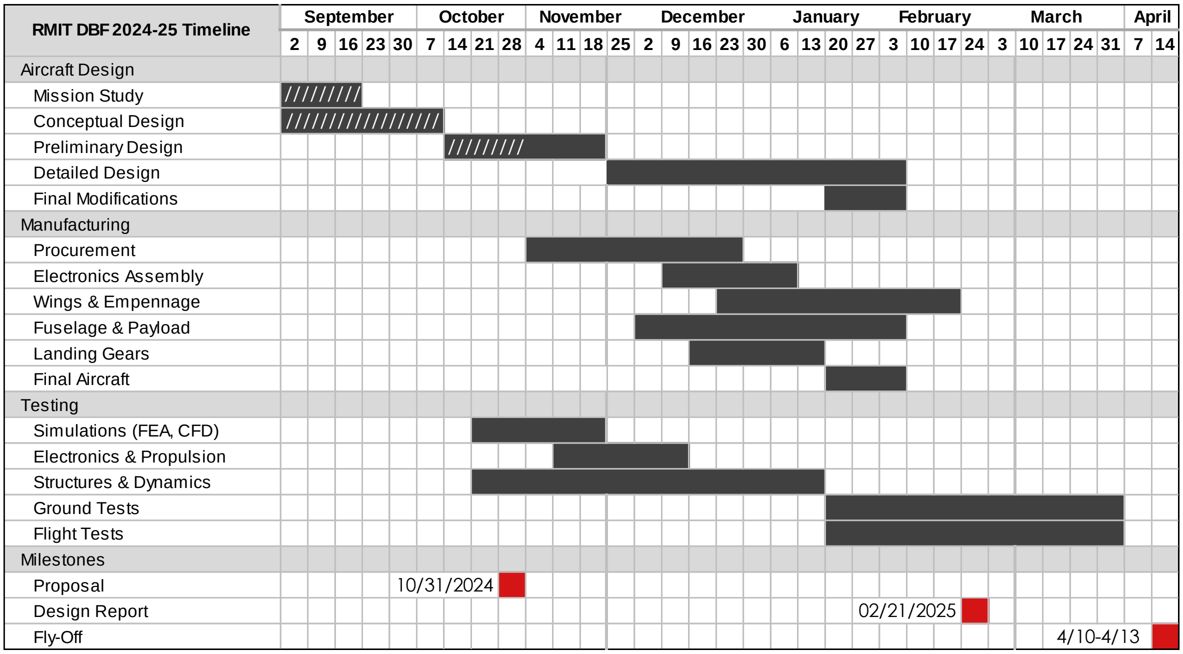

Figure 2: Schedule

2.3. Budget

The team's projected budget is outlined in Table 2. Funding will come from a combination of support from RMIT and external sponsorships, with an expected 70:30% split. Budget estimates are informed by previous competition experiences, with adjustments made to reflect the current team size. Being an Australian team, travel costs represent the largest portion of the budget. This is followed by material expenses, primarily for composites, as the team specialises in this method of construction. Additionally, the team benefits from access to RMIT's advanced-manufacturing tools, including CNC mills and 3D printers.

Item	Description	Cost Total
Materials	Composite Fabrics, Resin, Rods, Adhesives	$4,480
	Balsa Wood and Foam	$400
	Motor, Propellor, Servo, ESC, Batteries	$1,400
	Screws, Nuts, Bolts, Tape, etc.	$200
Competition	Bottles, Payload Weights, X-1 Test Vehicles	$1,400
	Workshop Events	$1,350
Travel	Melbourne-to-Tucson Flights	$24,000
	Accommodation for the Team	$12,180
	Meals for the Trip Duration	$4,770
	Transportation (Car Hire)	$3,390
	TOTAL COST (USD)	**$53,570**

Table 2: Budget

3. Conceptual Design Approach

3.1. Mission Overview

The competition consists of three flight missions and one ground mission, themed around the "X-1 Supersonic Flight Test Program". An analysis of the mission requirements, as detailed in **Error! Reference source not found.**, indicates that for M2, the aircraft design should p rioritise high wing loading and air speed to maximise payload capacity while minimising flight time. For M3, the focus shifts toward minimising drag and achieving the lightest possible X-1 vehicle configuration.

Mission	Scoring	Requirements	Sub-System Requirements
M1: Delivery	1.0	• Ready aircraft for flight in under 5 min. • Complete three laps in under 5 min.	• The aircraft's wingspan must be no more than 1.82 m (6 ft). • The aircraft must have a quick and simple process to switch to flight configuration. • The aircraft must be durable, reliable, and achieve stable flight under varying conditions. • The aircraft must weigh no more than 24.94 kg (55 lbs).
M2: Captive Carry	$1+\dfrac{\left(\frac{W_F}{T_{M2}}\right)_{Team}}{\left(\frac{W_F}{T_{M2}}\right)_{Max}}$	• Ready aircraft, load fuel bottles, and mount X-1 in under 5 min. • Complete three laps in the fastest time. • Carry the heaviest fuel weight, in a minimum of two external bottles of ≥474 ml (16+ fl oz) each.	• The aircraft must withstand high wing loading and air speed. • The pylons must withstand heavy weight payloads under high g loads. • The motor must provide sufficient thrust to take off at a reasonable speed for a heavy weight configuration.
M3: Launch	$2+\dfrac{\left(N_{Laps}+\frac{BP}{W_X}\right)_{Team}}{\left(N_{Laps}+\frac{BP}{W_X}\right)_{Max}}$	• Ready aircraft, load fuel bottles (may be empty), and mount X-1 for flight in under 5 min. • Complete as many laps as possible in 5 min.	• Aircraft drag, including that of the external fuel bottles, must be minimised for power efficiency. • The propulsion package must be expertly selected for power efficiency. • X-1 drop mechanism must be reliable and quick to install.

		• Carry the lightest flight-capable X-1 vehicle. • Release the X-1 at the last lap, with flashing lights, at 61-122 m (200–400 ft). • The X-1 shall autonomously reach stable flight, complete a 180° turn, and come to rest in the highest point bonus box within the 5-min mission time.	• X-1 body, and avionics must be as light as possible while fulfilling mission requirements. • X-1 must complete the landing procedure quickly
GM: Loading	$\frac{(T_{GM})_{min}}{(T_{GM})_{team}}$	• Insert the fuel pylons, bottles, and X-1 in the least amount of time • Ensure fuel bottles are secure and X-1 lights turn on upon release	• Pylons, fuel bottles, and the X-1 must have a quick and easy installation method.
Total Score = (Proposal Score × 0.15 + 0.85 × Report Score) × (GM + M1 + M2 + M3) + Participation Score			

Table 3: Mission Requirements Breakdown

3.2. Sensitivity Study

Following the breakdown of the mission requirements, a score sensitivity analysis was conducted for M2 and M3. The main objective of this analysis was to discover what parameters have the greatest impact on the mission score. Using this information, the wing and propulsion parameters can be estimated to achieve the best score. A MATLAB script was used to establish the relationship between each scoring parameter and the corresponding mission score. The results of this study are shown in Figure 3.

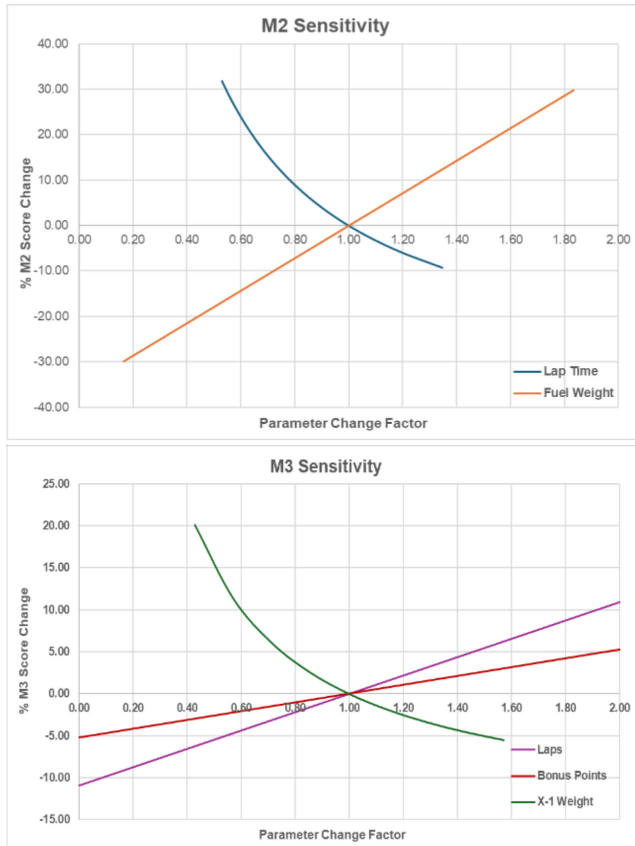

Figure 3: Mission Sensitivity Results

For the GM, reducing load time increases the mission score. To achieve this, no internal bottles will be used and the minimum of two external bottles will be loaded. For M2, although mission score exponentially increases against lap time (T_{M2}), this is only applicable at cruise speeds (V_c) of 61+ m/s (200+ ft/s), which are unachievable given the battery-capacity limit. In contrast, a high W_F could be achieved with the necessary wing area, leading to a high M2 score. Thus, the team chose to prioritise W_F for M2. For M3, the score increased exponentially as W_X decreased, meaning optimal scores are achieved at a very low W_X. Although bonus points (BP) only contributed a ±5% change in score, achieving zero BP negated all the score gained from a low W_X. Increasing the number of laps in M3 (N_{Laps}) increased the mission score, yet this relation contradicted the high W_F required for M2. This is because a high W_F means a large wing area and a low aspect ratio (AR), leading to high total drag and thus a lower possible V_c for M2 and M3. To find whether a low AR was worth the decrease in N_{Laps}, an analysis of the impact of AR on M2 and M3 scores was studied for a fixed wing loading. The results showed that a low AR led to a much higher mission score despite the decrease in V_c. Thus, the most optimal aircraft is one with high W_F, lower V_c, low W_X, and an X-1 that reliably receives non-zero BP.

3.3. Design Approach

Based on the sensitivity analysis and trade study, specific mission objectives and component specifications were established, with maximising W_F as the top priority. Given the lack of a takeoff-length requirement, a maximum takeoff weight (MTOW) of 15 kg (33.07 lbs) was set, leading to an estimated empty weight of 6 kg (13.23 lbs) and a W_F of 9 kg (19.84 lbs), following historical payload ratios. This was determined through an iterative process that varied wing area and target weight while optimising wing loading. Iterations continued until power and thrust limits were reached, which computed using conservative zero-lift drag (C_{d_0}) values and propulsion efficiencies to ensure the aircraft would be flight-capable. M2 lap time was also estimated to be 33 s, based on the chosen weight and given battery limitations.

With the focus on a larger wing area to support a high W_F, a conservative estimate of six laps was predicted for M3, based on the maximum V_c and a 6-min flight duration for safety. A weight estimate for the X-1 model and its avionics, which included a 1S LiPo battery, flight controller, GPS, and speed sensor, returned a low target weight of 0.125 kg (0.276 lbs). Drawing from the team's previous experience with automated flight, a goal of 2.5 BP was set for the X-1 landing. For the GM, the team expects a fast completion time of 30 s, based on past success. These mission goals serve as a baseline, with the team aiming to push the boundaries of both the aircraft and the X-1 during testing to maximise the overall mission score.

3.4. Trade Studies

A series of trade studies, results of which are shown in Table 4–6, were conducted to establish the baseline design of the aircraft. Key figures of merit were identified for each component, allowing for effective comparisons between potential designs. Each trade study has a reference configuration that the other designs are scored around, allowing for easier comparison.

3.4.1. Wing Configuration and Planform

		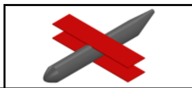		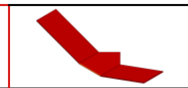	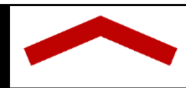		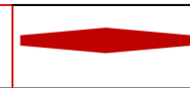
Figures of Merit	**Factor**	**Biplane**	**Monoplane**	**Flying Wing**	**Swept-Back**	**Rectangular**	**Tapered**
Manufacturability	3	0.4	1	0.5	0.2	1	0.5
Stability	1	1	1	0.8	0.6	1	0.8
Manoeuvrability	2	1.2	1	1.1	1.3	1	1.3
Drag	2	0.5	1	1.3	1.1	1	1.3
Lift	3	1.4	1	1.1	1	1	1.1
Total Score		9.8	**11.0**	10.4	9.0	**11.0**	10.8

Table 4: Wing-Configuration and Planform Trade Study

The selection of the wing planform and configuration was heavily influenced by manufacturability, considering both time constraints and prior experience. With the high lift requirements for the MTOW, lift performance was equally crucial. A monoplane design was chosen, as alternative wing configurations offered no significant advantages. While swept-back wings were considered, they are difficult to manufacture and only beneficial at higher speeds, which the sensitivity analysis showed was not the optimal path. Although tapered wings offered some drag reduction, the rectangular planform was ultimately preferred for its manufacturing simplicity.

3.4.2. Wing Location & Tail Configuration

							
Figures of Merit	**Factor**	**Low-Wing**	**High-Wing**	**Mid-Wing**	**T-Tail**	**Conventional Tail**	**V-Tail**
Manufacturability	2	0.8	1	0.4	0.8	1	0.7
Stability	2	0.3	1	0.6	0.6	1	0.7
Manoeuvrability	2	1.4	1	1.3	1	1	0.8
Structural Integrity	1	1.8	1	1.3	0.7	1	1
Ergonomics	3	0.6	1	0.8	0.8	1	0.8
Total Score		8.6	**10.0**	8.3	7.9	**10.0**	7.8

Table 5: Wing-Location and Tail-Configuration Trade Study

With the fuel bottles and X-1 mounted on the underside of the aircraft, ergonomics were a key factor in selecting the wing placement. A high-wing configuration was favoured due to its ease of manufacturing, enhanced stability, and the convenience it provides for quick loading during the GM and staging. Additionally, it ensures sufficient ground clearance for takeoff and landing. A conventional tail was selected for its simplicity, proven effectiveness in previous competitions, and lower weight compared to alternative designs.

3.4.3. Propulsion & Landing Gear

			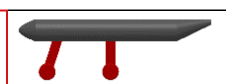	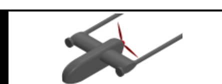	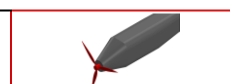	
Figures of Merit	**Factor**	**Taildragger**	**Tricycle**	**Pusher**	**Tractor**	**Dual**
Manufacturability	2	1	0.8	0.5	1	0.4
Weight	3	1	0.7	1	1	0.5
Ergonomics	1	1	1.3	1	1	0.7
Stability	2	1	1.3	-	-	-
Drag	2	1	0.7	-	-	-
Efficiency	3	-	-	1.2	1	0.4
Thrust	2	-	-	0.8	1	1.3
Total Score		**10.0**	9.0	10.2	**11.0**	6.8

Table 6: Propulsion and Landing-Gear Trade Study

Assuming the fuel bottles are mounted under the wing, a taildragger landing configuration would allow for a better load angle for the GM, minimising mission time. In contrast, the tricycle design raised concerns of weight and drag, which are influential factors on M2 and M3 scores. For propulsion, a pusher configuration complicates fuselage manufacturing due to the single boom tail, while a dual-motor setup interferes with GM loading and is overall less efficient. Therefore, a traditional single-motor tractor configuration was selected.

3.5. Preliminary Design

The team used the mission goals and dimensional constraints from the rules to size the main aircraft components. The outcome is summarised in Table 7. The wing area was maximised through chord length to fulfil the needs of the MTOW. After analysing a series of airfoils in XFLR5, the MH 116 was chosen for its high lift coefficient (0.5) at zero angle of attack (AoA) and its consistent pitching-moment coefficient vs AoA. Calculations for a conventional tail revealed the necessary tail geometry for stability and control of the aircraft. The battery was selected to be closest to the 100-Wh limit with the highest cell count available. The optimal motor and propeller configuration was selected from manufacturer databases based on the proposed flight parameters and verified through eCalc.

Due to the absence of internal payload, the fuselage was designed around the battery to minimise size, thereby reducing both C_{d_0} and weight. The fuselage is designed to be 2 m (6.56 ft) long, 88.9 mm (3.50 in) high, and 94.0 mm (3.80 in) wide. To allow for easy battery installation and management of the X-1 drop mechanism, access hatches will be placed above the motor and beneath the wing. The fuselage skin will be constructed using carbon fibre, with internal ribs added to enhance structural integrity.

Mission Parameter		Propulsion		Wing		Tail	
M2 T_{M2}	99 s	**Propeller**	18×12×3	**Wing Area**	1.44 m^2 (15.5 ft^2)	**Horizontal Tail Span**	1.20 m (3.94 ft)
M2 W_F	9 kg (19.84 lbs)	**Motor**	4130-300kv	**Aspect Ratio**	2.25	**Horizontal Tail MAC**	0.40 m (1.31 ft)
M3 N_{Laps}	6	**Battery**	8s 3300 mAh	**Wingspan**	1.82 m (6 ft)	**Vertical Tail Span**	0.46 m (1.50 ft)
M3 BP	2.5	**Power Loading**	179.1 W/kg	**Mean Chord**	0.80 m (2.62 ft)	**Vertical Tail MAC**	0.33 m (1.08 ft)
M3 W_X	0.125 kg (0.276 lbs)	**Max Thrust**	96.6 N (21.7 lbf)	**Airfoil**	MH 116	**Tail Arm Length**	1.30 m (4.27 ft)
GM T_{GM}	30 s					**Airfoil**	NACA 0005

Table 7: Design Parameters

The pylons and bottle attachment must be simple and secure to meet M2 and GM objectives. The fuel-bottle volume will be minimised to reduce drag and improve ground clearance. To achieve the high predicted W_F at a low volume, lead ball bearings were chosen as ballasts for their cost-to-density ratio. Therefore, a total bottle volume of 840 ml (28.4 fl oz) was selected to be filled with lead, allowing the team to achieve the required W_F for M2. The pylons will be mounted under the wing, near the fuselage, to minimise wing-bending moments, and with sufficient clearance for the X-1. A sliding rail mechanism will attach the pylons, which will have a cage structure for quick mounting of the bottle.

The X-1 will follow a traditional monoplane design with a lightweight polystyrene wing and tail, and a carbon-fibre fuselage to reduce W_X. Ultra-lightweight avionics, including a flight controller and GPS, were chosen for automated flight while keeping W_X low. A servo claw will drop the X-1, with a metal strip activating the avionics and landing program upon release. A flying wing design will also be explored during early testing; however initial weight estimations are in favour of a traditional monoplane. A preliminary CAD model of the aircraft, undercarriage and X-1 glider is shown in Figure 4.

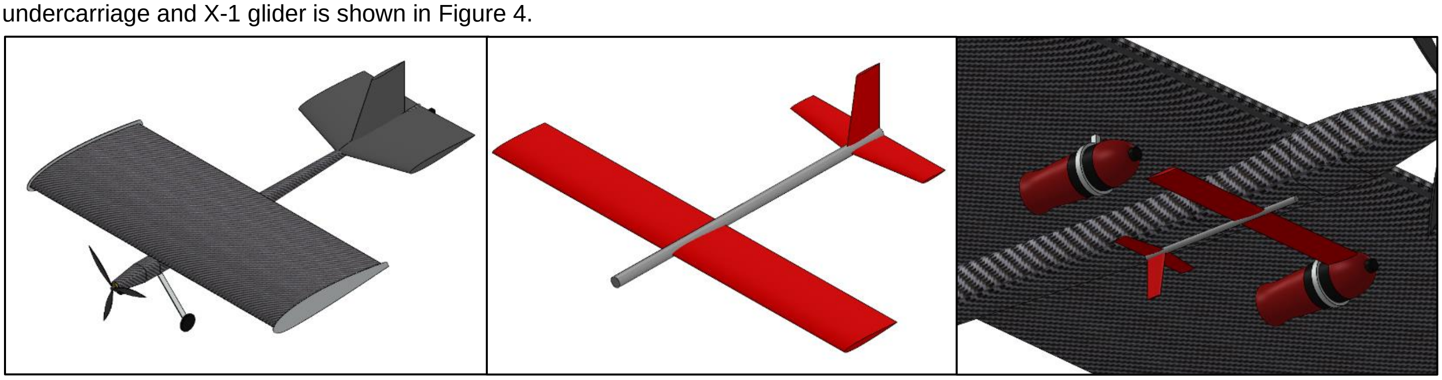

Figure 4: Aircraft Conceptual CAD

4. Manufacturing Plan

4.1. Preliminary Manufacturing Plan

Manufacturing is a critical part of the competition. Due to the large size of the wing and tail, complex manufacturing is required for the aircraft to be light and strong enough to be successful. Given the size of the RMIT team it would be difficult to build prototype aircraft along with a high-quality final aircraft. Instead, the decision is made to invest time in manufacturing a single, complex aircraft more quickly, to allow for more flight testing. Figure 5 shows how manufacturing testing, including techniques and materials, is conducted in parallel with detailed design. In doing so, materials and manufacturing techniques can inform the design process, allowing manufacturing to start quickly after design. The X-1 and avionics follow similar progressions, with materials/electronics being tested early in the design process to assist with the final design. Once a final design is achieved, they can be assembled and tested on their own before being added to the full assembly of the aircraft.

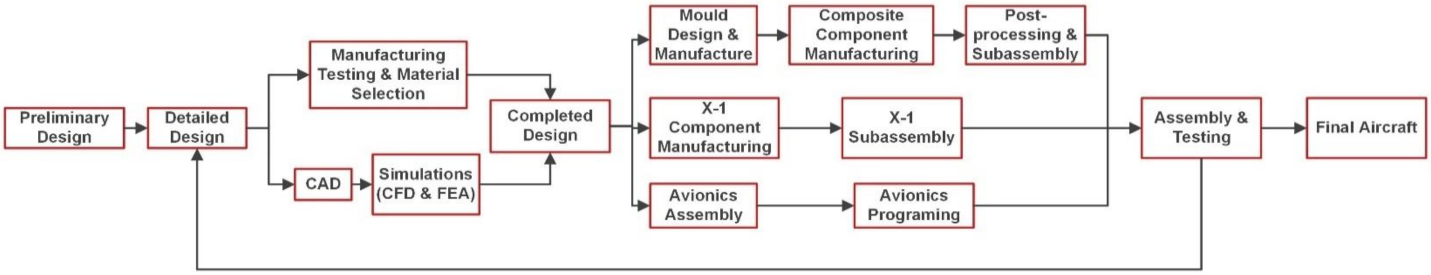

Figure 5: Manufacturing Plan

4.2. Critical Processes Required

A large emphasis is placed on composites manufacturing due to the ability to make strong and light weight components consistently. RMIT University has dedicated composite manufacturing facilities and a wealth of experience, making it possible to build composite structures in the time between the rules being released and the fly-off date. Techniques such as resin infusion and foam-core wrapping are currently being tested as methods for the final aircraft. Once the final aircraft has been designed, moulds for the composite components can be designed and manufactured, with the composite parts themselves being constructed afterwards

5. Testing Outline

Numerous tests are scheduled for the aircraft and its individual components, many of which are outlined in Table 8. These tests aim to verify and validate theoretical models, establish team deadlines, and enhance design aspects before finalisation. A structural test on the fuselage and body will identify and address any weak points before flight testing, ensuring theoretical load analyses are validated. Motor tests will take place in a wind tunnel, evaluating different motor and propeller configurations to determine the optimal setup. Ground and payload tests will provide critical data to strengthen and improve the efficiency of the pylon and X-1 drop mechanisms. Finally, flight mission tests, supported by aircraft sensors and pilot feedback, will assess overall performance and highlight areas for improvement.

Sub-Team	Test	Objective	Method	Due Date
Propulsion Tests				
Avionics	Static Thrust Test	Select the most applicable and efficient propeller, motor, and battery for the aircraft propulsion. Results will be compared with theoretical values from eCalc.	Use a motor test stand in a wind tunnel to determine propulsion and power capabilities.	11/18/24
Ground Tests				
Aerostructures	Structural Tests	Verify that the wing, fuselage, and landing gear can withstand high g loading and satisfy the competition tech inspection.	Lift the aircraft from its wingtips at MTOW and check for damage. Drop the aircraft from short heights and check for damage.	1/13/25
Aerostructures	CG Test	Verify the CG is at the intended location.	Lift the aircraft from its wingtips for each mission configuration and determine CG.	1/13/25
Aerostructures	Payload Test	Verify the pylons and X-1 loading mechanism can withstand high g loading.	Apply 1.5 x max load on the pylons and X-1 mechanism and check for damage.	12/30/24
Systems	X-1 Test	Verify the X-1 executes required drop manoeuvre and performs autonomous mission.	Drop the X-1 from test aircrafts and observe response.	12/30/24
Systems	GM Test	Minimise the payload loading time for GM.	Simulate the GM. Repeat to minimise time.	3/31/25
Avionics	Electronics Test	Ensure the electronics function correctly, including receiver-transmitter connection at range.	Connect the electronics as required in flight and test their function as needed.	1/13/25
Flight Tests				
Full Team	First Flight	Ensure the aircraft can takeoff, cruise, and land. Determine the required trim for the aircraft.	Fly the aircraft for the desired objective and observe aircraft structural response. Use an altimeter and pitot tube to measure performance data and find improvements. Implement improvements in subsequent mission tests, ensuring to meet requirements and increase mission score where possible.	1/20/25
Full Team	M1 Test	Complete M1, verifying stability and control of the aircraft.		3/31/25
Full Team	M2 Test	Complete M2, verifying flight with intended payload and flight performance. Improving for a higher score where possible.		3/31/25
Full Team	M3 Test	Complete M3, verifying predicted flight performance and X-1 drop and landing. Improving for a higher score if possible.		3/31/25

Table 8: Test Plan

University of Maryland, College Park
AIAA Design, Build, Fly 2024-2025 Competition Proposal

1.0 - Executive Summary

This proposal encapsulates the design, manufacturing, and testing plan for “TerpJet” by team “AeroTerps” from the University of Maryland, College Park. The primary objective is to execute an X-1 Supersonic Flight Test Program by carrying fuel tanks and launching an X-1 test vehicle from the designed aircraft.

In designing TerpJet, the team identified carrying capacity as the most critical mission parameter, thus focusing the design to minimize aircraft empty-weight and maximize total lift. Accordingly, TerpJet will be a mid-wing, bi-propeller, monoplane with a reduced fuselage size. This minimizes weight, drag, and assembly time for Mission 2 and improves staging time for the ground mission. The wings feature flaps and ailerons on trailing edges, with a carbon fiber hard point built into each wing for attaching to the fuel tank pylons. The plane has a conventional empennage with a vertical and horizontal stabilizer. TerpJet is designed to have an empty weight of 13 lbs and to carry two external fuel tanks, each weighing 15.77 pounds. The aircraft’s design components and analysis are discussed in further detail in *Section 3.3* .

For the design of the X-1 glider, the team primarily focused on controllability to consistently land within the 2.5-point bonus zone. This translates to designing for 3-axis passive stability and minimizing turn radius. Subsequent focuses include minimizing X-1 weight and loading time. Accordingly, the X-1 will be constructed with flat plate airfoils using carbon fiber sheets. X-1 design components and analysis are discussed in further detail in *Section 3.4*.

As per the project timeline, manufacturing of the full-scale prototype began in mid-October, with its maiden test flight planned for mid-November. This gives us ample time to iterate upon system designs. *Section 2* of this proposal will describe the team structure, schedule, and budget, followed by the proposed design in *Section 3*. *Sections 4* and *5* will conclude this proposal with manufacturing and testing plans.

2.0 - Management Summary

2.1 - Organization

The University of Maryland Design, Build, Fly team is a combination of a capstone course and a student-run club with a faculty advisor and organized leadership shown in the organization chart (Fig. 1). The Team Lead and Chief Operating Officer organize meetings and administer the schedule. The treasurer manages inventory while ensuring adherence to fiscal constraints. The Chief Engineer and Assistant Chief Engineer manage the integration of subsystems while ensuring the technical capability of all designs. Design, Manufacturing, and Flight Test Leads serve as liaisons between subteams and executives while leading respective phases. Additionally, the Pilot acts as a “sub-design lead”, advising design decisions based on a flight experience. Finally, there are five sub-teams, each with individual Subteam Leads and 3-7 members, allocated to the skills and responsibilities listed in Table 1. There are bi-weekly General Body

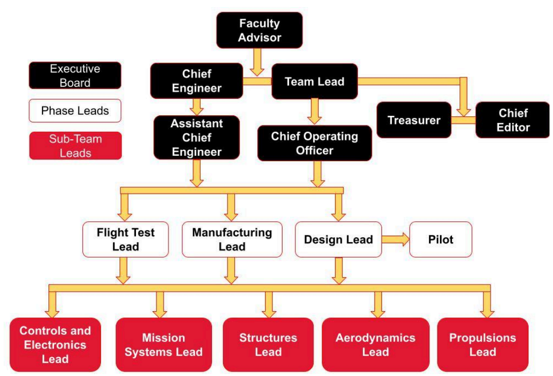

Fig. 1 Team Org Chart

Table 1 Sub-Team Responsibilities and Skills

Sub-Team	Responsibilities	Required Skills
Mission Systems	Score Sensitivity, Team Strategy, High Level Design of X-1 & Fuel Tanks	Systems Engineering, Conceptual CAD, Programming
Aerodynamics	Airfoil, Planform, Nose cone and generally drag reduction	Aerodynamics Theory, XFLR5, Profili 2.0, CFD, Wind Tunnel Testing
Controls & Electronics	Control Surfaces, Tail Sizing, X-1 Autopilot, Wiring	Control Theory, Programming, Electrical Engineering
Propulsions	Motor, ESC, Battery Selection	Propulsion Theory, Thrust Stand Testing, Electrical Engineering
Structures	Design Airframe to meet structural requirements	CAD, FEA, Materials & Mechanics Theory, DFA/DFM

Meetings for the entire team as well as weekly subteam meetings for the specifically delegated work. Additional build sessions are hosted as required to stay on schedule.

2.2 - Schedule

The proposed project schedule is outlined in the Gantt Chart shown in Table 2. Referencing this chart ensures that team members execute responsibilities for fulfilling milestones and meet project deadlines. Major milestones include two internal design reviews, as well as flight testing of one small-scale and two full-scale prototypes. This fuels an iterative design process where designs are improved based on feedback from subject matter experts, and test results.

Table 2 Team Gantt Chart

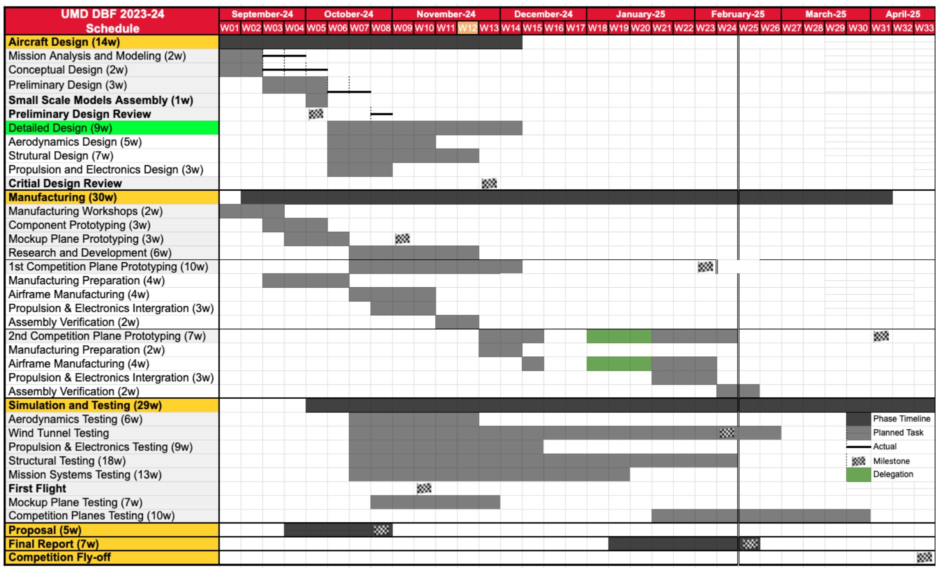

Table 3 Budget

Category	Item	Est. Cost
Manufacturing ($700)	3D Printing Materials	$450
	Tools	$250
Propulsion, Control, & Electronics ($2,150)	Servos	$200
	Receivers	$200
	Controllers	$350
	Motors	$500
	Batteries	$500
	Propellers	$200
	Misc. Electronic Components	$200
Structures ($1,400)	Prototyping Materials	$300
	Composite Materials	$600
	Part Comissions	$500
Mission Systems ($200)	Payload	$100
	Glider Parts	$100
Flight Test ($250)	Miscellaneous	$250
Travel ($7,500)	Lodging	$2,000
	Flight & Luggage	$4,000
	Car Rental	$400
	Fuel	$100
	Food	$1,000
Total		$12,200

2.3 - Budget Description

AeroTerp's 2025 anticipatory budget is listed in Table 3. The budget encompasses costs associated with manufacturing, materials, and travel (including shipping the competition plane via air). The gross proceeds total $17,500 - coming from the UMD Aerospace Department ($13,000), Northrop Grumman ($2,000), and Boeing ($2,500). Expenses are reduced by utilizing campus resources, through the use of manufacturing labs/tools and an in-house wind tunnel. The team is currently operating with a 30% budget margin.

3.0 - Conceptual Design Approach

3.1 - Analysis of Mission Requirements

The objective of this competition is to design, build, and fly an RC airplane to execute the "X-1 Supersonic Flight Test Program." This includes the following missions: Flight Mission 1 (M1) requires flying 3 laps of the course in 5 min; Flight Mission 2 (M2) requires flying 3 laps with externally mounted fuel tanks and the X1; Flight Mission 3 (M3) requires flying laps with externally mounted fuel tanks and the X1, to be dropped in the

Table 4 2025 Mission Summary

Mission	Scoring	Mission Objectives	Considerations
M1	$= 1$	• Attach batteries in < 5 min • Fly 3 laps in < 5 min • Successful landing	• Flight capable aircraft
M2	$= 1 + \frac{\left[\frac{fuel\ weight}{time}\right]_{UMD}}{\left[\frac{fuel\ weight}{time}\right]_{Max}}$	• Attach batteries, fuel, pylons, X-1 in < 5 min • Fly 3 Laps as fast as possible • Carry as much payload (fuel) as possible	• CG Shift from payload • Increased AoA required • Higher Moments of Inertia • Structurally-capable of carrying fuel tanks
M3	$= 2 + \frac{\left[\#laps + \frac{bonus\ score}{x1\ weight}\right]_{UMD}}{\left[\#laps + \frac{bonus\ box\ score}{x1\ weight}\right]_{Max}}$	• Attach batteries, fuel, pylons, X-1 in < 5 min • Fly as many laps as possible • Release X-1 on final lap • X-1 must turn on and keep on strobe light • X-1 should be as light as possible • X-1 should stabilize, turn 180° and land in bonus zone	• Must climb to 200ft • X-1 aero effects on aircraft • Clearance for X-1 drop • Functional release mechanism • X-1 should have high LWR and Glide Ratio • X-1 should be resistant to wind and variations in drop conditions • X-1 should withstand impact
GM	$= \frac{mission\ time_{Min}}{mission\ time_{UMD}}$	• Load pylons as fast as possible • Load fuel and X-1 as fast as possible • Control surfaces must stay operational	• Ground clearance desired • Easy to load pylons, fuel tanks and X-1

final lap; and the Ground Mission (GM) requires installing pylons, fuel tanks, and the X-1 to TerpJet. Further mission analysis is included in Table 4.

3.2 - Score Sensitivity for Design Parameters Analysis

The team started with a score sensitivity analysis to determine the impacts of different mission parameters on scoring. Shown in Fig. 2, the percent change of each mission parameter is plotted against the percent change for the mission score. The data shows that maximizing payload weight is worth the tradeoff in flight time, given its greater impact on mission score. The Mission 3 X-1 bonus score and X-1 weight have the highest impacts on the overall team score, distinguishing them as a top priority. Finally, Ground Mission loading time, which is independent of all other scoring parameters, should be minimized.

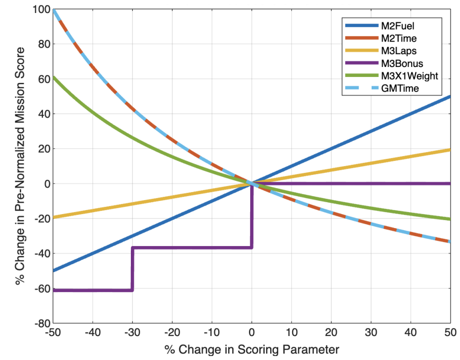

Fig. 2 Scoring Parameter Sensitivity Plot

The design parameters of TerpJet are most consequential to Mission 2. Fig. 3 shows the percent change of several aircraft parameters plotted against the percent change for Mission 2 score. As expected, increasing aircraft empty weight and drag negatively impacts the score. Reducing empty weight increases the aircraft's agility, aiding in lap completion and maneuverability. Meanwhile, increasing propwash velocity, propeller radius, and wing chord length will improve scores. These considerations were taken into account to design TerpJet, as covered in *Section 3.3*.

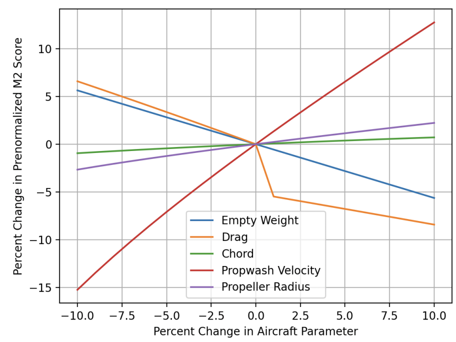

Fig. 3 Aircraft Parameter Sensitivity Plot

3.3 - TerpJet Preliminary Design

A trade study was conducted between three airframe configurations: a "conventional" design with an 8-inch diameter fuselage for an internal tank; a "minimal fuselage" design, where the 4-inch fuselage is only large enough for necessary electronics (i.e. no internal tank); a "twin-boom" design (no internal tank) where electronics are split between two separate 3-inch fuselages, shielding external fuel tanks from oncoming airflow. A significant portion of this analysis utilized a dynamics simulator developed by the team in 2022 to compare the nonlinear differential dynamics beyond cruise (e.g. takeoff, climbs, turns). The simulator has been validated against several planes in flight tests and at prior competitions and can predict mission parameters (e.g. lap time, payload capacity) within a 2% error margin when given relevant design parameters. The output, shown in Table 5, predicts the mission performance of each design. In addition to the mission performance shown in the table, the team considered manufacturability, cost, team heritage/available design resources, and expected stability/risks. 1/3rd scale models were also flight-tested on Sept. 29th (Fig. 4) to better understand handling characteristics. After weighing all factors in a decision matrix, the minimal fuselage airframe was the best option to be further developed.

Table 5 Factors Considered in Configuration Trade Study

	Conventional	Min. Fuselage	Twin Boom
M2 Payload (lb)	24	31	30
M2 Time (s)	79	76	76
M3 Laps	10	11	11
GM Time (s)	55	38	40
Mfg Time (wks)	~4	~2	~6
Cost ($)	~$1,700	~$1,500	~$2,000
Heritage/Resources	Best	Middle	Worst
Stability/Risks	Best	Middle	Worst

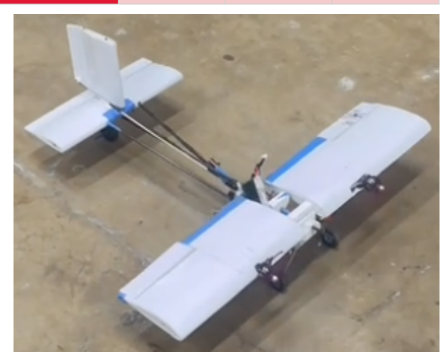

Fig. 4 Minimal Fuselage Flight Test Model (⅓ scale)

Fig. 5 Full Aircraft CAD Model

As shown in *Section 3.2*, maximizing carrying capacity benefits mission scoring. Toward this objective, the empty weight should be minimized while maximizing lift. This logic leads to the minimal fuselage design pictured in Fig. 5. TerpJet consists of an XPS-foamboard with wood-plate bulkheads, a wing attachment point, and a carbon fiber longeron to connect the empennage. Taildragger landing gear is selected for ample propeller clearance and low tail-strike possibility. These landing gears are mounted to reinforced wing/empennage attachment points, to minimize loads on the spars/longerons. Two external fuel tanks, each weighing upwards of 15.77 lbs, will be mounted to the wing spar via a system of removable pylons attached to hard points. A hatch is located atop the fuselage for battery accessibility, while the X-1 is mounted beneath. At present, the empty weight of TerpJet is estimated to be roughly 13 lbs, and cruise velocity is estimated to be 110 ft/s with empty fuel tanks (M3) or 105 ft/s with filled fuel tanks (M2).

In determining an airfoil, the team used XFLR5 to obtain aerodynamic data (at Reynolds Numbers 420,000 for cruise and 200,000 for takeoff, and angles of attack between -10° to 20°) for a set of 30 airfoils recommended by the UIUC Low Reynolds Flow Research Laboratory. A weighted decision matrix, accounting for lift & drag coefficients, stall angle of attack, and manufacturability was used to downselect the SD7062 airfoil for the main wing. At present, the wingspan is 66 inches and the chord length is 11 inches, giving an aspect ratio of 6. The team plans to conduct simulations in Profili 2.0 and XFLR5 to investigate the effectiveness of different planform and winglet designs for downwash reduction. Due to its available design resources and flight heritage, the team selected a conventional empennage. This will be placed 30 inches behind (leading edge to leading edge) the wing. A NACA-0009 airfoil will be used for both the horizontal (chord: 9in, span: 8in) and vertical (chord: 9in, span: 20.5) stabilizer. The team will continue investigating control surface sizing methodologies of previous top-scoring DBF teams. With that information, yaw, pitch, and roll rates from varying control surface sizes can be calculated to find the optimal size for each flight mission, considering shifts in required AoA and CG between missions.

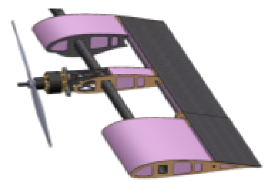

Fig. 6 Wing Section CAD Model

Fig. 7 Wing Mount CAD Model

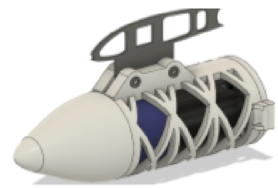

Fig. 8 Pylon/Hardpoints CAD Model

The aircraft structure is designed to concentrate the various aerodynamic and mission-required loads onto a main forward wing spar. As shown in Fig. 6, the wing will be made from two hollow carbon fiber spars, one square, and one circular. These were selected for their light weight and ability to resist maximum expected torsion and bending loads based on hand calculations. The wing structure will also use XPS-foamboard wrapped in carbon fiber skin to maintain the airfoil shape. The wing attachment point, shown in Fig. 7, is also designed to maintain high structural integrity.

As shown in Fig. 8, two hardpoints, made from carbon fiber plates, will be fitted directly onto the wing spar. These hardpoint plates will extend below the wing, where pylons can be secured using detent quick-release pins. The pylons will be 3D printed with carbon fiber reinforced nylon and will have an opening to easily slide and secure the 34 oz Pepsi bottles. The bottles will be primarily filled with lead shot pellets, selected for their high density (0.41 lb/in^3). The remaining gaps between pellets will be filled with salt, preventing vibration of the lead shot pellets and adding additional weight. The lead-to-salt ratio can be varied at the competition to provide different mission fuel weights, to be determined as per the team's competition strategy.

In designing the electrical subsystem, the team selected components with years of successful flight heritage. The TBS Crossfire Diversity Nano Receiver was selected; when paired with a TBS Crossfire Micro Module connected to a Radiomaster TX16S Mark II transmitter, it will provide a long-range, high-penetration 900MHz radio connection. An Matek Servo power distribution board with an onboard battery eliminator circuit will regulate battery voltage and signal outputs for up to six servos. Each of the five control surfaces will be actuated by an ES-3054 17-gram servo. The aircraft will have two propulsion batteries (6S 2250 mAh LiPos with a 75C discharge rating) that is compatible with its two Scorpion SII-4020 630kV motors. These motors were selected using a weighted decision matrix that considered peak current, maximum watts, cost, weight, and motor kV. Two HobbyWing SkyWalker 120A V2 electronic speed controllers were selected for their heat sinks, programmable motor functions, and high continuous current rating (significantly higher than motors require). The TerpJet's electronics will be stored in the 3D-printed nose cone. The propulsion motors will be 16 inches from mid-span for space-efficiency and weight distribution.

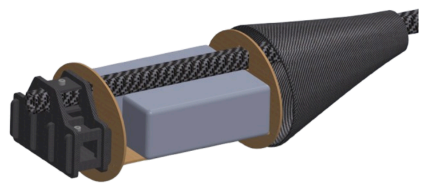

Fig. 9 Fuselage (interior) CAD Model

3.4 - X-1 Glider Preliminary Design

The X-1 must be completely autonomous, without a receiver or propulsion system. For M2 and M3, the X-1's wing must be >0.25in below the aircraft's fuselage and between two fuel tanks. In M3, the X-1 must be dropped between the lap line and upwind turn, at an altitude of 200-400ft. Then, it must complete a 180° turn and descend to land in the bonus zone. A strobe light on the X-1 must turn on upon release, and stay on post-landing. The X-1 is further constrained with a maximum weight of 0.55 lbs. For M3, it would be beneficial to land the X-1 in as little time as possible, and to drop the X-1 from 200 ft altitude, to maximize the time the carrier aircraft is flying laps. Finally, X-1 loading time should be minimized for optimal ground mission scoring.

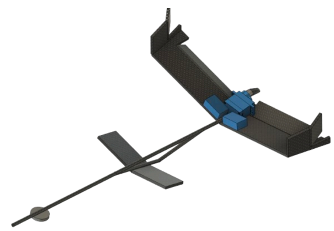

Fig. 10 Canard-Wing X-1 Glider Design

The "Canard-Wing" X-1 configuration, shown in Fig. 10, was designed with a glide ratio of 8.6, a lift-to-weight ratio of 2, and a turning radius of 105ft. This design allows for three-axis passive stability axes; having the wing behind CG allows winglets to double as dual vertical stabilizers while increasing the lift curve slope, thus inducing a high pitch down moment at high AOA's, and therefore pitch stability. Only one servo is required to control ailerons and induce a turn. Expecting low Reynolds numbers (around 40,000), where drag on thick airfoils significantly increases, the team decided to use flat plate airfoils. The generalized control strategy is to overshoot the 180° turn in order to point the velocity vector of the X-1 toward the 2.5-point bonus zone (the exact point of entry will be determined by wind velocity). After entering the bonus box, the X-1 will enter a controlled dive to the ground. Alongside flight testing, the team is using a programmed dynamics simulator with Monte-Carlo methods to model performance given randomized initial conditions (drop location & velocity) and wind velocities.

X-1 electronics were selected to meet bare minimum requirements while minimizing weight. This led to the selection of the SpeedyBee F405 Wing Mini Flight Controller, BZ-121 GPS module, SG90 servo, EvansDesigns Strobe Light (Pico), and a 200mah 2s LiPo. The release mechanism will unlatch a pin, allowing the X-1 to fall from TerpJet.

4.0 - Manufacturing Plan

The manufacturing plan (see Fig. 11) begins with the "Workshop" phase, most importantly covering lab safety. Then, inventory will be taken to identify gaps in current supplies and capabilities, including initial prototypes to test the conditions of existing tools. The team will research the benefits of different manufacturing processes. In the Manufacture and Assembly phase, the team fabricates major aircraft components. Designs will take shape by 3D printing complex components, laser-cutting airfoil ribs, hot-wire cutting foam wings, water-jetting carbon fiber plates, and assembling using epoxy. Once assembled, the Prototype Aircraft undergoes testing (see *Section 5*) to identify potential failure points using RCA (Root Cause Analysis), and prompt improvements cyclically until the prototype meets all requirements. In the Competition Aircraft phase, the final aircraft is assembled to competition standards, and an abundance of spare parts are manufactured. The Manufacturing Lead will be responsible for implementing this plan, ensuring the focus and readiness of the team.

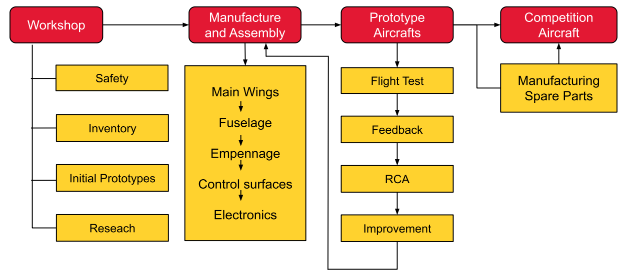

Fig. 11 Manufacturing Flow Chart

5.0 - Testing Plan

The test plan shown in Table 6 provides a tentative schedule for the validation of design choices. Ground testing evaluates structural integrity, electronics, and mechanical assemblies. Wind tunnel testing will be conducted in appropriate university labs to acquire flow quantities, forces, and moments of interest for the prototype and main aircraft. To collect the flight data needed to characterize the aircraft's performance, the aircraft will be equipped with a Pixhawk flight controller to quantify performance metrics such as velocity, stability, turn/climb rates, etc. These electronic components will be removed before the Fly-off, as per competition regulations. The team has prepared documentation to plan, execute, and report flight tests through a series of templates that involve flight cards, safety checklists, procedures, and after-action reports. In addition, two team members already have a Part 107 certification demonstrating knowledge of the Federal Aviation Administration's regulations for unmanned aerial systems, and one more member is expected to complete this certification by the end of the year.

Table 6 Testing Plan

	Test Objectives	Purpose	Method	Deadline
Aerodynamics	Lift and Drag	Verify lift and drag forces acting on the prototype and main aircraft to satisfy mission parameters	Wind Tunnel Testing	11/27/2024
	Control Surfaces	Acquire the aircraft's attitude based on control surface deflection while ensuring full range of control	Wind Tunnel Testing	11/27/2024
Electronics	Electronic Speed Control	Ensure the ESC operates in satisfactory condition during flight	Ground Testing	12/20/2024
	Arming Fuse	Verify the fuse can handle the maximum draw of the current	Ground Testing	12/20/2024
Mission Systems	Complete Glider Deployment	Confirm the aircraft can deploy the glider and autonomously fly its designed flight path.	Flight Testing of the Prototype and Main Aircraft	03/28/2025
	Glider GPS Tracking	Analyze the behavior of the glider's GPS	Flight Testing of the Prototype	12/20/2024
Propulsion	Thrust Production varying Wind Speed	Analyze thrust performance that is varied with wind speed	Small Scale Wind Tunnel Testing	11/10/2024
	General Motor/Propeller Thrust attached to Aircraft	Acquire aircraft speed generated based on thrust produced by the motor/propeller	Flight Testing of the Prototype	12/20/2024
Structures	Wing Tip Loading	Confirm the aircraft can satisfy the wing tip loading test	Ground Testing	12/06/2024
Flight Testing	Taxi	Verify the aircraft's ability to taxi on the ground	Ground Testing	12/06/2024
	Assembly	Improve assembly process for competition	Ground Testing	12/06/2024
	First Flight	Confirm the aircraft can fly in its basic configuration before making any other advancements	Flight Testing of the Prototype	12/20/2024
	Mission Flight	Validate aircraft's ability to perform each mission successfully while finding ways to optimize mission scoring	Ground and Flight Testing of the Prototype and Main Aircraft	03/28/2025
	Competition Flight	Simulate competition procedures to ensure the aircraft is prepared for competition	Ground and Flight Testing of the Main Aircraft	04/04/2025