SUAS 2025 Technical Design Report

Nanyang Technological University (Archimedes Autonomous Vehicles)

Jiayan Zhao, Darren Suen, Tz Yuan Li, Tz Lung Li, Aloysius Chia, Tingli Hu

***Abstract*—UAS 2.0 is a modular and lightweight quadrotor platform developed by Archimedes Autonomous Vehicles for SUAS 2025. Building on operational experience from RobotX 2024, it integrates a precision winch delivery system, a stereo vision–LiDAR perception suite, and a robust power distribution architecture. Designed around an 18-minute flight window, UAS 2.0 focuses on high-value tasks including waypoint navigation, mapping, and a single airdrop. This report details its design, validation methodology, and future developments.**

***Index Terms*—Unmanned Aerial System (UAS), autonomous flight, PX4, stereo vision, SLAM, LiDAR, airdrop delivery, SUAS 2025.**

I. Competition Strategy

AAV approaches SUAS 2025 with a strategy calibrated to the current capabilities and inherent limitations of UAS 2.0, while maintaining an engineering-driven commitment to operational safety, reliability, and scoring efficiency. Recognizing the system's endurance limitation, the team adopts a targeted mission focus designed to maximize achievable points within a single 18-minute flight window, without compromising mission continuity.

A comprehensive trade-off analysis was conducted to map expected mission points, system constraints, and task complexities, thereby guiding carefully selected mission priorities. The outcome prioritizes:

- Autonomous flight (50 pts),
- Mapping (100 pts), and
- Object detection and single airdrop (up to 100 pts).

Given the platform's validated endurance of 18 minutes (post-battery margin), the team acknowledges the impracticality of executing multiple airdrop cycles. Therefore, the strategy deliberately omits secondary airdrops and instead redirects energy and operational time toward:

- Ensuring mapping area coverage completeness,
- Maximizing object detection pass efficiency, and
- Reducing operator intervention to the minimum permissible (200 pts potential operator score).

The competition strategy is also risk-aware, factoring the team's limited in-field flight hours at the SUAS venue, historical data from past endurance trials, and the absence of RTK GPS, which mandates reliance on stereo-visual SLAM corrections to mitigate GPS drift.

This pragmatic and focused approach is consistent with the team's longer-term goal of using SUAS 2025 as a platform validation testbed, laying the groundwork for a fully reconfigured, extended-endurance UAS 3.0 system in subsequent iterations.

II. Design Strategy

The design of UAS 2.0 embodies a pragmatic evolution from the team's prior RobotX 2024 UAS 1.0, with deliberate subsystem enhancements aimed at fulfilling the SUAS 2025 mission within the platform's inherent endurance, payload, and integration constraints. Informed by a system engineering approach, each subsystem was critically assessed against the SUAS task requirements, risk factors, and operational timelines, resulting in the following configuration.

Fig. 1 shows the overall design of our unmanned aerial system 2.0 (UAS 2.0). The UAS weighs 7 kg, which is comparatively lightweight relative to past SUAS systems. The Holybro X650 quadrotor frame achieves portability and is easy to disassemble to fit in travel-size suitcases. T-Motor MN4014 400KV motors, 17*5.8 carbon fiber propellers and AIR 40A ESCs provide a maximum thrust of 3.3 kg each at full throttle. This gives the

UAS an approximate 2:1 thrust-to-weight ratio. These motor feature upgraded stator bearings to minimize eddy current loss for enhanced efficiency and endurance.

Fig. 1: 3D model of UAS 2.0 .

A. Power Distribution System

The power distribution system of UAS 2.0 is shown in Fig. 2. A 6S 22,000 mAh LiPo battery supplies power to the entire system via 4 branches. Firstly, it supplies the full battery voltage to the four ESCs controlling the motors. Secondly, it powers the Pixhawk 6X flight controller at 5V through a power brick, and the flight controller further powers its connected peripherals, including GPS, telemetry, RC receiver, and LiDAR. A DC-DC converter is used to step the voltage down to 12 V for the third and fourth branch. The third branch powers both the control board and the servo motor used in the winch system. The fourth branch powers the onboard computer, which subsequently supplies power to the stereo camera used in the vision system.

The 6S 22,000 mAh battery provides sufficient capacity for 25 min flight endurance and a maximum speed of 20.1 m/s.

A critical aspect of designing the power distribution system is selecting appropriate voltage regulators. As shown in Fig. 3a, the power brick is compatible with the flight controller and provides a stable voltage output with minimal ripple. For the 12 V supply, we selected an ultra-light DC-DC converter capable of delivering a continuous current of 5 A, which meets the power requirements of both the onboard computer and the servo motor, as illustrated in Fig. 3b. Overall, the power distribution system is well-designed, taking into account the power demands of all system components, and demonstrates strong stability and performance.

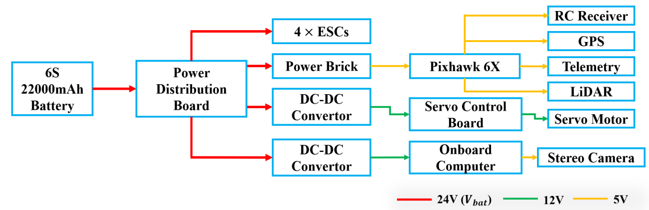
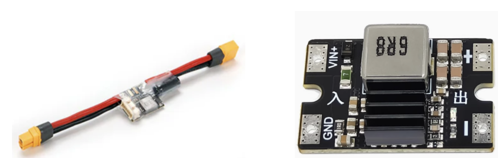


Fig. 2: Diagram of power distribution system.



(a) Power brick (b) DC-DC converter

Fig. 3: Voltage regulators used in power distribution system.

B. Control System

The Holybro Pixhawk 6X (Fig. 4a) runs the open-source PX4 autopilot firmware for attitude and position control.

(a) Pixhawk 6X (b) M9N GPS

Fig. 4: Main parts of control system.

The flight controller adopts a cascaded P–PID control architecture, as illustrated in Fig. 5, [1]. Sensor data from the accelerometer, magnetometer, and barometer onboard the Pixhawk 6X, along with external compass and GPS position data provided by the M9N GPS module (Fig. 4b), are fused using an Extended

Kalman Filter (EKF) to estimate the state of the system and provide accurate feedback for the control loop. By tuning the PID parameters, accurate and stable pose control of the system can be achieved.

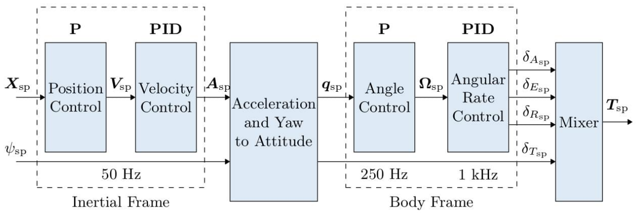


Fig. 5: Control architecture.

C. Communication System.

The communication system of UAS 2.0 is shown in Fig. 6. There are two main ways to communicate with the drone: via a radio controller or through a PC. The radio controller used is the RadioMaster TX16S Mark II, renowned for its high quality and reliable performance. A RadioMaster PR1 ELRS receiver operating at 2.4 GHz is connected to the flight controller to receive input commands from the radio controller.

For PC-based communication, the computer runs the Mission Planner and connects to the flight controller using the MAVLink protocol to monitor the drone's real-time status. This connection is established via a pair of 433 MHz SiK Telemetry Radios (V3). The low frequency offers better range and reliability, making it suitable for long-distance communication and meeting the requirements of the competition. In parallel, the PC also runs a Ubuntu virtual machine to remotely access the onboard computer via SSH. This connection is used to run mission scripts and monitor key mission information, such as the results of the object detection algorithm and the mapping process. A SIM7600G-H 4G Dongle is connected to the onboard computer to enable this data transmission over the cellular network.

Communication between the flight controller and the onboard computer is handled via MAVROS. The onboard computer executes the object detection algorithm, which takes input from both the stereo camera data stream and the system state provided by the flight controller. Based on this data, it generates high-level commands to the flight controller, which then executes low-level control by generating PWM signals to control the motors. Additionally, the winch system is activated by the onboard computer when the conditions for the airdrop task are satisfied.

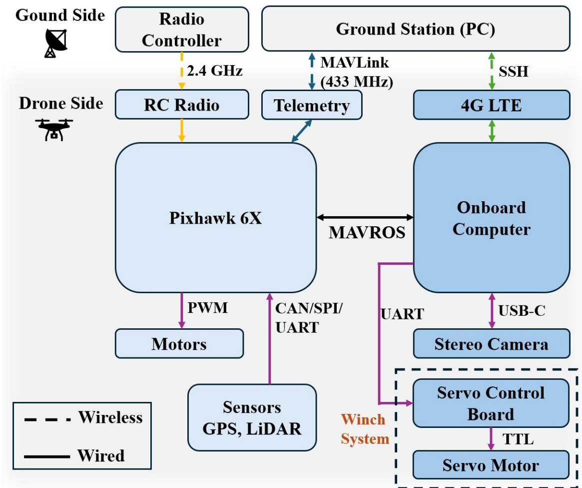


Fig. 6: Diagram of communication system.

The hardware components mentioned above are shown in Fig. 7 .

(a) TX16S Mark II (b) PR1 ELRS

(c) SiK Telemetry Radios (V3) 433MHz (d) SIM7600G-H 4G Dongle

Fig. 7: Main parts of communication system.

D. Vision System

The vision system utilizes the ZED 2i camera, as shown in Fig. 8a. It is a high-resolution stereo depth camera designed for 3D perception, spatial mapping, and AI-based applications. It integrates numerous sensors, such as an IMU, barometer and magnetometer to enhance positional tracking. The camera supports real-time depth estimation and 3D point cloud generation, making it ideal for autonomous navigation and SLAM applications.

To ensure high processing speed and minimal latency, a high-performance edge computing unit is required. The NVIDIA Jetson Orin NX 16 GB is used as the onboard computer in our vision system, as shown in Fig. 8b. It delivers up to 100 TOPS of AI performance under default settings and features an 8-core ARM Cortex-A78AE CPU, a 1024-core Ampere GPU with 32 Tensor Cores, and 16 GB of LPDDR5 memory. It is optimized for edge AI applications such as robotics, computer vision, and autonomous systems, supporting complex neural networks and real-time data processing with low power consumption.

On the software side, the onboard computer runs YOLOv8 [2] for real-time object detection and manages the airdrop task. It also executes a customized mapping algorithm [3] tailored to the competition's mapping requirements.

(a) ZED 2i

(b) Jetson Orin NX 16GB

Fig. 8: Main parts of vision system.

E. Obstacle Avoidance System

An LDRobot LD-06 LiDAR is used for obstacle avoidance, as shown in Fig. 9. The LD06 LiDAR is a compact and lightweight 2D LiDAR sensor developed by YDLIDAR, designed primarily for indoor and short-range applications. It features a 360-degree scanning range with a sampling rate of up to 4500 points per second and a detection range of up to 12 meters. With its low power consumption, high accuracy, and simple UART/USB communication interface, the LD06 is well-suited for obstacle avoidance, mapping, and SLAM tasks in small robotics platforms.

The obstacle avoidance algorithm is embedded in the PX4 autopilot firmware [4]. PX4 implements obstacle avoidance using a local planning algorithm based on the 'Local Planner' module, which utilizes real-time depth or distance data from sensors such as LiDAR or stereo cameras. It generates a safe trajectory in 3D space by constructing a local cost map and evaluating potential flight paths that avoid obstacles while maintaining progress toward the mission goal.

Fig. 9: LDRobot LD-06 LiDAR.

F. Winch System

The overall design concept of the winch system is compact, lightweight, and safe. The structure of the customized winch system is shown in Fig 10. The actuator used in the system is the Waveshare ST3215-HS, as shown in Fig. 11a, which weighs only 70 g and offers a maximum torque of 20 kg·cm and a maximum rotational speed of 106 RPM. This servo motor supports programmable control to define any angle as the midpoint and can also operate in continuous rotation mode (speed closed-loop control) or as a stepper motor. It includes a built-in acceleration and deceleration function, which ensures smoother and more stable motion. A Waveshare Serial Bus Servo Driver Board is used to control the servo motor, as shown in Fig. 11b.

The airdrop task is designed with two key considerations in mind: time efficiency and operational safety. First, the airdrop duration should be minimized to conserve energy and maximize the drone's flight range. The airdrop time T_{drop} can be estimated using Eq. (1), where D is the altitude of the drone (in meters), n is the servo motor's rotation speed (in RPM), and r is the radius of the winch wheel (in meters). For our system, the drone's altitude is set to 18 m, and the wheel radius r is chosen as 0.05 m, resulting in an airdrop time of approximately 34.4 s. Secondly, to ensure safety during the airdrop, the winch wheel is securely mounted and mechanically constrained. The system is configured so that the beacon and tether are released and allowed to fall freely when they are approximately one meter above the ground, thereby reducing the risk of the tether becoming entangled with the drone structure and avoiding potential hazards.

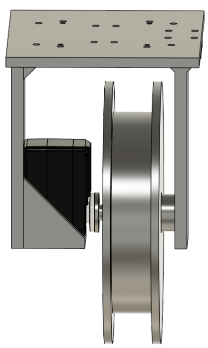


Fig. 10: The 3D model of the winch system used for precision airdrops.

$$T_{drop} = \frac{D \times 60}{n \times \pi \times 2r} \tag{1}$$

(a) ST3215-HS (b) Servo Driver Board

Fig. 11: Electrical parts of winch system.

III. Testing Strategy

A well-designed testing plan plays a crucial role in the development of an autonomous system. It provides a structured and systematic approach to validate each component, ensure system integration, and identify potential failures early in the development cycle. Our testing strategy is structured into the following three main phases.

A. Simulation Testing

Initially, we employed eCalc, a specialized calculator that incorporates aerodynamics, to conduct a preliminary feasibility assessment of the selected propulsion system. This was essential to ensure that the chosen system would provide stable and reliable flight, adequate flight duration, and sufficient payload capacity.

Following this initial validation, we utilized Autodesk Fusion 360 to analyze the structural integrity of our design. Fusion 360 is a comprehensive tool that allows for detailed stress and load analysis, ensuring that our drone's structure can withstand the operational demands.

Once the structural design was finalized, we proceeded to validate the control effectiveness of the drone's position and attitude controllers using a combined simulation approach with Software In The Loop (SITL) and Gazebo. SITL integrates the actual flight control software with a simulated environment, allowing for realistic testing without physical hardware. Gazebo, on the other hand, is a versatile robotics simulator that provides a 3D environment for our simulations. In addition to controller validation, this simulation also served to verify the rationality and correctness of the integrated object detection and mapping algorithms. These algorithms are essential for the drone's autonomous operation, enabling it to navigate and map its environment effectively.

These steps ensure that our drone design is not only theoretically sound but also practically viable and reliable for its intended applications.

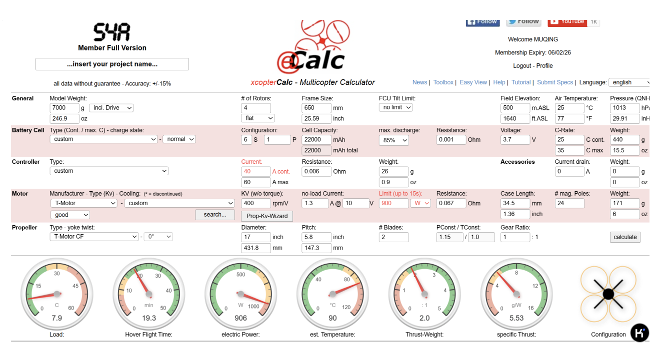


Fig. 12: Example of simulation testing (eCalc).

B. Module Testing

Before proceeding with the system integration phase, it is imperative to conduct thorough testing on each individual module of the system to ensure its reliability and performance. This allows us to identify and rectify any potential issues or weaknesses in the components before they are assembled into the complete system. All key modules, such as the propulsion system, control system, and power distribution system, have been subjected to independent testing. This meticulous process ensures that each component functions correctly in isolation, paving the way for seamless integration and reliable performance within the complete system.

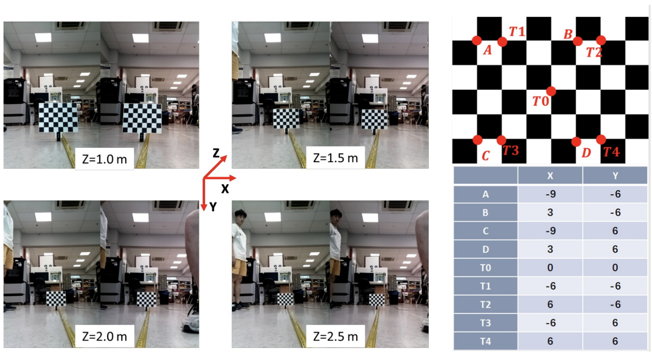


Fig. 13: Example of module testing (camera calibration).

C. System Integration Testing

After simulating and testing individual modules separately, the team then conducted flight tests to ensure effective integration of systems. Precaution was taken to ensure that UAS flights were operated in accordance with the unmanned aircraft (UA) regulations stipulated by the Civil Aviation Authority of Singapore governing outdoor UA operations.

Before each flight, testing objectives are clearly established to keep the testing process focused and efficient. The system integration testing is conducted in three distinct phases. The initial phase involves manually controlling the drone to test its takeoff and hovering capabilities, which helps verify the communication link between the radio controller and the drone, as well as the performance of the propulsion system.

The second phase shifts the drone into autonomous mode to evaluate the reliability of the positioning system. This includes assessing the accuracy of waypoint following and the effectiveness of speed control. The precision of these systems is crucial for the drone's ability to navigate as intended.

Once the UAS is verified to be working reliably, the task specific algorithms are then run during the final phase of testing. The UAS' performance is observed and feedback is taken to further improve the program.

Each of these phases is repeated multiple times before the competition, with the test results driving iterations and improvements in the algorithms. This rigorous testing regime is essential to ensuring that the drone performs optimally in the actual competition. By systematically addressing each aspect of the drone's functionality, we can identify and resolve any issues that may arise, thereby enhancing the overall reliability and performance of our UAS.

Fig. 14: Example of system integration testing (autonomous flight).

ACKNOWLEDGEMENTS

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Associate Professor Xie Ming — for his supervision of the team and technical advice on autonomous systems and machine vision.

The team would also like to thank Adalia Lee for producing the media for the team, and Nur Sharlynn Esham and Sushruth Muthukrishnan for their assistance in maintaining the website. Team Archimedes expresses our appreciation to our sponsors listed in Appendix A for their continuous support.

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APPENDIX A
SPONSORS

A. Title Sponsors

Nanyang Technological University, School of Mechanical and Aerospace Engineering (MAE) — For the lab facilities to our project.

B. Gold Sponsors

Singapore Maritime Foundation (SMF) — For travel bursary.

APPENDIX B
COMPONENT SPECIFICATIONS (UAS 2.0)

Component	Vendor	Model / Type	Specifications	Custom / Purchased	Cost (SGD)	Year
Onboard Computer	seeed studio	NVIDIA Orin NX 16GB	128GB SSD, 128-bit LPDDR5 DRAM	Purchased	$1166	2024
Stereo Camera	Amicus Engineering	ZED 2i with Polariser	4mm lens, 5m focal length	Purchased	$1524.91	2024
LiDAR	AliExpress	LD-06 TOF	360 degrees	Purchased	$122.22	2025
Flight Controller	Holybro	Pixhawk 6X v2A	STM32H753 Processors	Purchased	$348.91	2024
GPS	Holybro	M9N	IST8310 Compass	Purchased	$71.33	2024
Power Distribution Board	Holybro	PM02D Power Module	2S-12S, 20g	Purchased	$32.41	2024
Servo Driver Board	Waveshare	Serial Bus Servo	ST/SC, 70g	Purchased	$7.63	2025
Telemetry	Holybro	SiK Telemetry Radio V3 (pair)	500m range, 100mW, 433MHz	Purchased	$76.52	2024
Radio Receiver	Holybro	RP1 ELRS Nano Receiver	CRSF, 2.2g	Purchased	$25.93	2024
4G LT*3E Dongle	Waveshare	SIM7600G-H 4G	GNSS Positioning, Global Band Support	Purchased	$100.84	2025
Radio Controller	Holybro	RadioMaster TX16S Mark II (Mode 2)	ELRS, V4.0 Hall Gimbal, 2km range @ 22dbm	Purchased	$272.38	2024
Battery	Hobbysquare	Tattu 22000mAh Lipo	22.2V, 25C, 6S1P, 2.55kg	Purchased	$420	2024
ESC	T-MOTOR	AIR 40A 2-6S (x4)	621Hz, 26g	Purchased	$207.48	2024
Servo Motor	Waveshare	ST3215-HS	20kg·cm, 106 RPM	Purchased	$24.44	2025
Brushless Motor	T-MOTOR	MN4014 Fixed Wing (x4)	KV400, 30A, 900W, 3.3kg Thrust	Purchased	$502.76	2024

Component	**Vendor**	**Model / Type**	**Specifications**	**Custom / Purchased**	**Cost (SGD)**	**Year**
Propellor	T-MOTOR	17*5.8 CF (2 pairs)	432mm, 6kg Thrust, 8600RPM	Purchased	$189.36	2024
Carbon Fibre Frame	Holybro	X650 V2	-	Purchased	$258.12	2024
Flange Plate	Waveshare	Metal Flat Key Shaft	-	Purchased	$4.40	2025

APPENDIX C
OUTREACH ACTIVITIES

Since adopting the name **Archimedes Autonomous Vehicles** in May 2024, the team has undergone a significant structural transformation—from a project-based initiative to a full-fledged student club open to students across nine faculties at Nanyang Technological University. As we transition from RobotX 2024, we are expanding our capabilities in the maritime robotics domain, with participation in SUAS 2025 representing a strategic step in this direction. With UAVs and UASs playing an increasingly vital role in maritime operations, the team is committed to contributing meaningfully to this evolving landscape.

We are deeply grateful to the maritime robotics community and our sponsors for their continued support. We believe in the importance of building long-term relationships and remain committed to sharing our knowledge and experience as a way to give back to the broader community.

A. Lab Visits

As part of our STEM outreach campaign, Team Archimedes regularly hosts lab visits for students ranging from elementary to tertiary levels, as well as for educators and policymakers. These visits serve as opportunities to inspire the next generation of maritime robotics talent, exchange insights, and foster international collaboration.

Fig. 15: Lab Visit by Kamnoetvidya Science Academy, Thailand.

Fig. 16: Lab visit by educators from Singapore's Ministry of Education (MOE).

B. Industrial Partnership and Appreciation

Team Archimedes is deeply appreciative of our industry partners and sponsors, whose support has been instrumental in sustaining our technical progress and outreach initiatives.

Fig. 17: Singapore Maritime Foundation's New Year Conversations 2025.

To deepen our understanding of real-world maritime challenges, the team actively engages with industry leaders. During Singapore Maritime Week, our members were invited by the Singapore Maritime Foundation (SMF) to learn about advanced systems deployed by the Maritime and Port Authority of Singapore (MPA), including Autonomous Surface Vehicles (ASVs), Remotely Operated Vehicles (ROVs), and Skyports Drone Services' UAS shore-to-ship delivery operations at the Maritime Drone Estate.

Fig. 18: ASV deployed by MPA onboard Mata Ikan.

Fig. 19: Skyports' shore-to-ship UAS delivery demonstration at the Maritime Drone Estate.

C. Local Exchanges

Team Archimedes actively engages in knowledge exchange with other maritime robotic and engineering student teams in Singapore. Notably, we have established rapport with Bumblebee from the National University of Singapore (NUS) and Nautical Knights from the Singapore Institute of Technology (SIT), fostering a collaborative learning environment among local institutions.

Fig. 20: Jersey exchange with Team Bumblebee at NUS Robotics Fair.

Fig. 21: Engagement with SIT's Nautical Knights during IMDEX Asia.