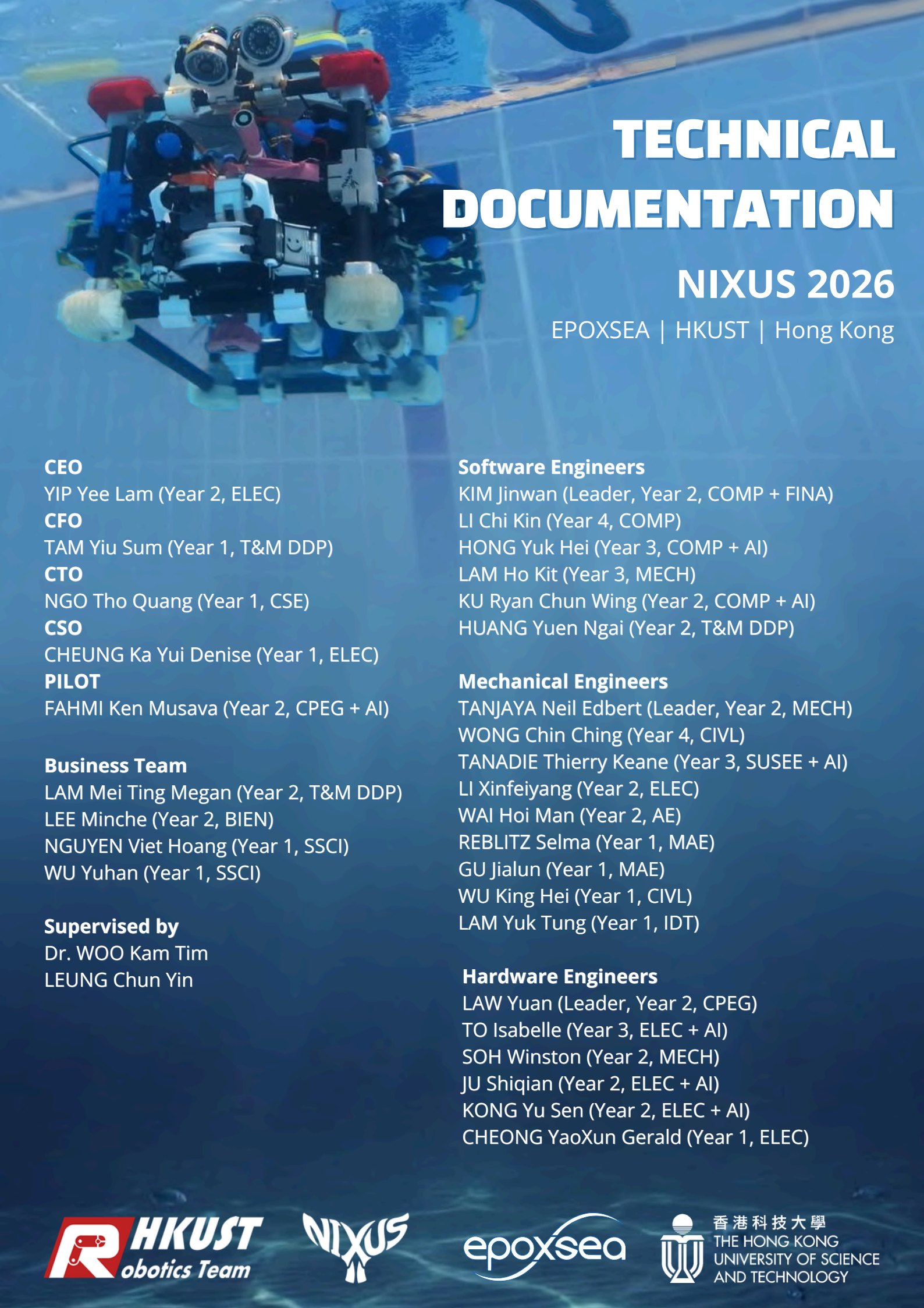




TECHNICAL DOCUMENTATION

NIXUS 2026

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Abstract

EPOXSEA is a 30-member, multidisciplinary team from the Hong Kong University of Science and Technology (HKUST). We are dedicated to advancing ocean exploration and promoting environmental stewardship through underwater robotics. For the 2026 MATE ROV Competition, we present NIXUS, a compact and agile ROV designed to operate reliably in polar environments.

NIXUS integrates multipurpose manipulators and a software-based control architecture for real-world missions. These include collecting basket stars and coral specimens from a coral garden, replacing an eDNA sensor at the Holyrood subsea observatory, and connecting wind-turbine power to an offshore oil platform. To extend our reach, we also developed an improved vertical float that ensures reliable data collection beneath ice-covered environments. Together, NIXUS and the float demonstrate well-coordinated system performance in extreme conditions while supporting marine biodiversity monitoring and offshore energy infrastructure tasks.

This technical documentation describes the design rationale and system configuration of NIXUS, outlines the iterative prototyping and troubleshooting process, and provides an outlook of our management and operational structure. It further presents how the vehicle and supporting systems were developed to meet the technical and operational challenges of the 2026 MATE ROV Competition.



Figure 1: EPOXSEA team photo

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Teamwork

Company Profile

EPOXSEA is a collaborative, multidisciplinary team of 30 representing 8 nationalities. Based at the Hong Kong University of Science and Technology (HKUST), we are committed to developing innovative and sustainable ROVs that support marine biodiversity conservation and scientific research.

Our mission is to expand humanity’s understanding of the ocean while contributing to an equitable and sustainable blue economy. By combining our expertise in engineering, environmental science, and data analytics, we aim to create practical, technology-driven solutions that advance marine research and generate meaningful environmental impact.

Company Organization

EPOXSEA operates through a streamlined hierarchical structure that supports clear communication, efficient teamwork, and effective project coordination. The team is divided into four core departments—Mechanical, Hardware, Software, and Business—each responsible for a key aspect of the ROV and the company’s overall operations.



Figure 2: EPOXSEA organizational structure

Role	Responsibilities
CEO	Oversees team development and hosts regular meetings and pool tests
CTO	Ensures the team’s technical designs comply with the MATE ROV Competition 2026 standards
CFO	Manages budgeting and financial transparency
Safety Officer	Enforces safety protocols to maintain a secure and healthy working environment
Department Leads	Oversee project coordination and mentor junior members.

Table 1: EPOXSEA roles and responsibilities

Project Schedule

To maintain organization, accountability and technical excellence, EPOXSEA’s work is divided into three key phases across the year:

1. Recruitment and Onboarding

From September to November 2025, EPOXSEA conducted an intensive recruitment and training programme to build a capable and committed team. Trainees first received foundational engineering training, after which shortlisted candidates were given advanced, ROV-specific instruction. This process helped us comprehensively assess both technical ability and teamwork, ensuring that new members were ready to contribute effectively. In addition to technical training, we organized team-building activities to help new recruits integrate into EPOXSEA’s culture of cooperation, innovation, and continuous learning.

2. ROV Designing and Manufacturing

After the team was formed, we entered the main development stage. Each department contributed to specific aspects of the vehicle’s development: the Mechanical department focused on structural design and mission-specific mechanisms; the Hardware team developed and tested printed circuit boards

(PCBs) and electrical systems; and the Software team coded and integrated the control and vision systems. At the same time, the Business department prepared documents and reports to maintain consistency, transparency, and clear communication across the team. This phase allowed each department to contribute its expertise while working toward a shared goal, ensuring that the ROV design aligned with competition requirements and progress deadlines.

3. Testing and Refining

Once the initial prototype was assembled, regular testing became a central part of our development

process. Pool tests were conducted twice a week to evaluate maneuverability, buoyancy, and system responsiveness under simulated mission conditions. These tests helped us identify problems early and make targeted improvements across all departments.

Following the MATE ROV Hong Kong Regional, the team continued refining the ROV and shifted its full focus to preparing for the international competition. Through this iterative process, we were able to improve the vehicle’s performance and overall reliability while strengthening our readiness for the next stage of competition.

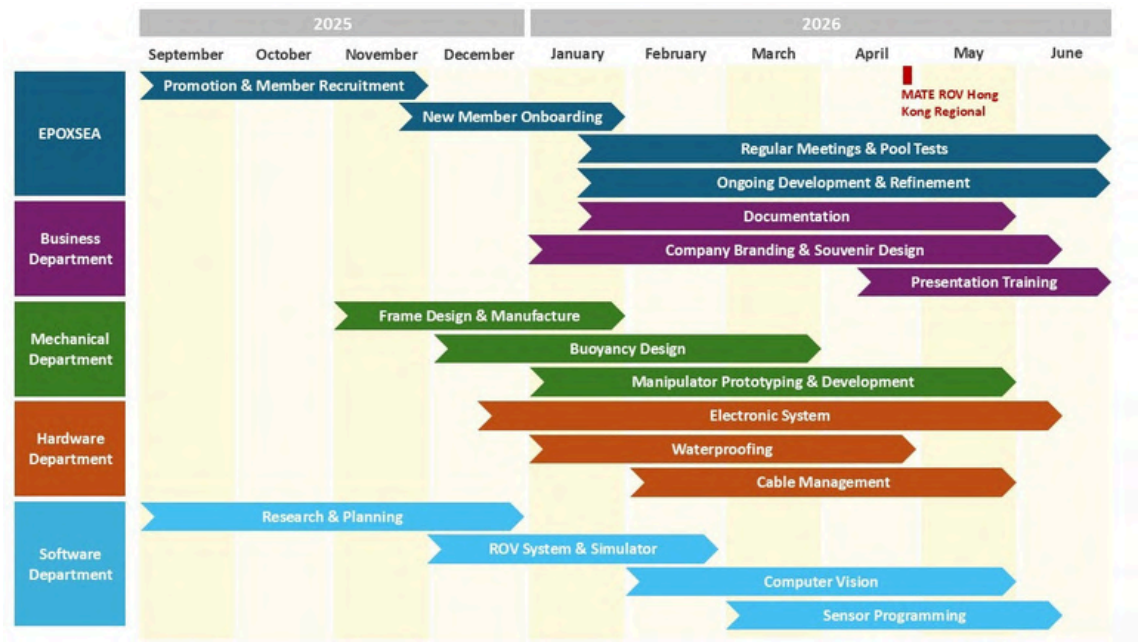


Figure 3: EPOXSEA project schedule

Resources, Procedures, and Protocols

To maintain strong communication and efficient operation, EPOXSEA holds team meetings every Monday and Thursday. During these meetings, department leaders share progress updates, report technical milestones, and the team discusses any challenges faced during the week. This routine helps us stay accountable, coordinate across departments, and solve problems in a timely manner.

We also use digital collaboration tools to improve transparency and knowledge sharing. EPOXSEA has transitioned from Lark to Microsoft Teams as

our main platform for communication, coordination, and document sharing. Within Teams, a centralized Knowledge Base stores project documentation, technical references, safety procedures, and onboarding materials, allowing all members to access important information across all departments.

Building on last year’s streamlined workflow, the Mechanical department continues to use Autodesk Fusion 360 for design collaboration and version control, while the Software department uses GitHub for code management, issue tracking, and synchronization. These tools help us work more efficiently, reduce errors, and maintain continuity across the project.

Design Rationale

Design Overview

NIXUS is built with reference to previous open-frame structures, such as INKAY (2025) and MANTA (2019), and is modified into a single-deck form, an improvement from INKAY's double-decker layout for less weight and improved portability. To optimize mission task completion, NIXUS has been significantly improved in its adaptability to diverse oceanic conditions while maintaining high modularity through six mission-specific manipulators and an advanced stabilization system.

Modularity

This year, we continue to adopt multiple printed circuit boards (PCBs), each with dedicated functions. The specialised PCBs ease the troubleshooting and debugging processes, further streamlining the ROV manufacturing process. Apart from the electronics, payload and tools are also attached to the ROV frame by quick release mounts. This 3D-printed, toolless mechanism speeds up attachment and detachment of the six manipulators, reducing downtime and speeding up transportation.

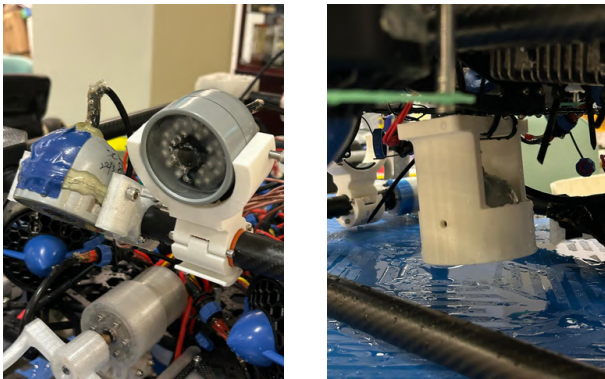


Figure 4, 5: Modular camera mounts

Adaptability

NIXUS is newly embedded with an IMU sensor and several PID controllers for maintaining maneuverable stability. The sensor-fusion system prevents ROV from being washed away from the target area, enabling it to counter the water current under windy conditions.

Open Structure

The open-frame structure exposes key components, allowing quick repairs and modifications. Compared with MANTA's bulkier foam-integrated frame and INKAY's double-decker layout, NIXUS' open structure reduces complexity to a single deck. The lighter frame weight compromises the heavier mass of external components, facilitating integration of buoyancy, electronics, thrusters, and payload and tools.

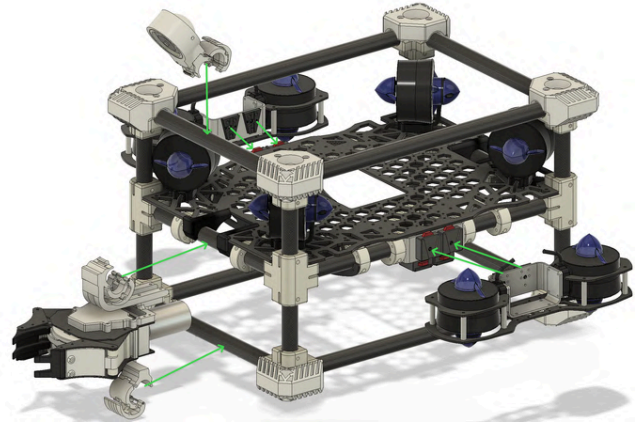


Figure 6: NIXUS structure

Planning and Design Process

EPOXSEA's design process is structured and iterative, with teamwork and continuous improvement at its core. Each design cycle begins with group brainstorming, where the full team reviews previous vehicles to retain effective features and identify areas for improvement. To aid brainstorming, the team does comprehensive research on commercial ROVs, and references professional models in the upcoming design.

For example, after using corner TPU bumpers for impact protection last year, the team focused this year on improving maintenance efficiency by exploring quick-release mounts for thrusters, manipulators, and electronics. To eliminate time-consuming screwing, we referenced industrial designs of quick-release clamps to develop our customized mounts. This toolless mechanism enabled rapid repairs of components, reducing downtime during testing.

Once the core design features were finalized, we moved into detailed development, prototyping, and production. From developing CAD models to prototyping 3D-printed manipulators, our comprehensive design phase allows for early detection and resolution of issues.

After several iterations in late 2025, the team held meetings in January 2026 to review key factors such as cost, weight, size, and component reuse from previous ROVs. The final components were then fabricated and assembled into the NIXUS vehicle, ready for testing and further refinement.

Decision and Trade-off Process

Motor Selection

EPOXSEA carefully evaluated different motor options for NIXUS before deciding on two types of brushed DC motors: the JGB37-3530 for the gripper and the JGB37-520 for SpinEOUS. These motors were chosen based on the specific needs of each manipulator and the missions they were designed to complete.

The selection process involved comparing speed, torque, voltage, rated current, and weight to determine which option offered the best balance of performance and practicality. For the gripper, high torque was essential for secure handling, while SpinEOUS required precision and efficient operation. By matching each motor to its intended function, we improved both reliability and mission performance.

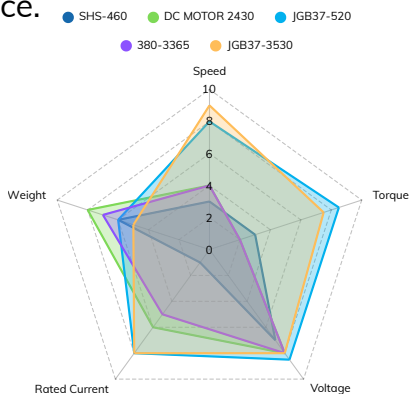


Figure 7: Comparison of motor alignment with mission needs

This comparison, as shown in Figure 7, confirmed that our two selected motors offered the most practical solution for our mission-specific applications.

Single-layer Structure

NIXUS adopted a single-layer frame this year, moving away from INKAY’s double-deck structure in order to reduce structural complexity, part count, and assembly time. While this means giving up some multi-level modularity, the trade-off results in lower weight, lower cost, and stronger structural integrity against currents. The integrated quick-release mounts installed on one accessible plane also help maintain adaptability by making tool and manipulator swaps faster and more convenient.

Vehicle Structure

NIXUS features a compact, single-deck design measuring 40 cm in width, 60 cm in length, and 40 cm in height, keeping it within class limits while allowing enough flexibility for different mission tasks. The chassis combines CFRP tubing with 3D-printed PETG components to create a structure that is both strong and lightweight, while TPU bumpers carried over from last year provide added impact protection during transport and tight manoeuvres.

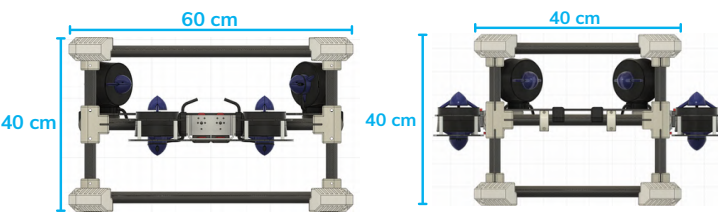


Figure 8: NIXUS front and side view

Material	Properties
Carbon Fiber-Reinforced Polymer (CFRP)	- Strong and lightweight - Corrosion resistance - Fatigue durability
Thermoplastic Polyurethane (TPU)	- Flexible shock absorption - Vibration damping
Polyethylene Terephthalate Glycol (PETG)	- High impact toughness 3D printability - Low water absorption

Table 2: Material selection rationale

Compared with last year’s dual-section frame, NIXUS uses a single-frame layout that makes the vehicle more open and accessible. This change reduces structural complexity, material usage, and overall weight, while still leaving enough internal space for efficient component placement. Although the team gave up some of the separation offered by the previous design, the simpler layout improved portability, lowered

cost, and made assembly and maintenance easier. PETG parts, including our self-designed quick mounts, further support fast, tool-free installation of thrusters and manipulators. This allows us to make changes quickly during testing, reduce downtime, and iterate at a lower cost. Overall, the vehicle structure reflects a deliberate balance between size, weight, cost, and practicality.

System Integration Design (SID) of ROV

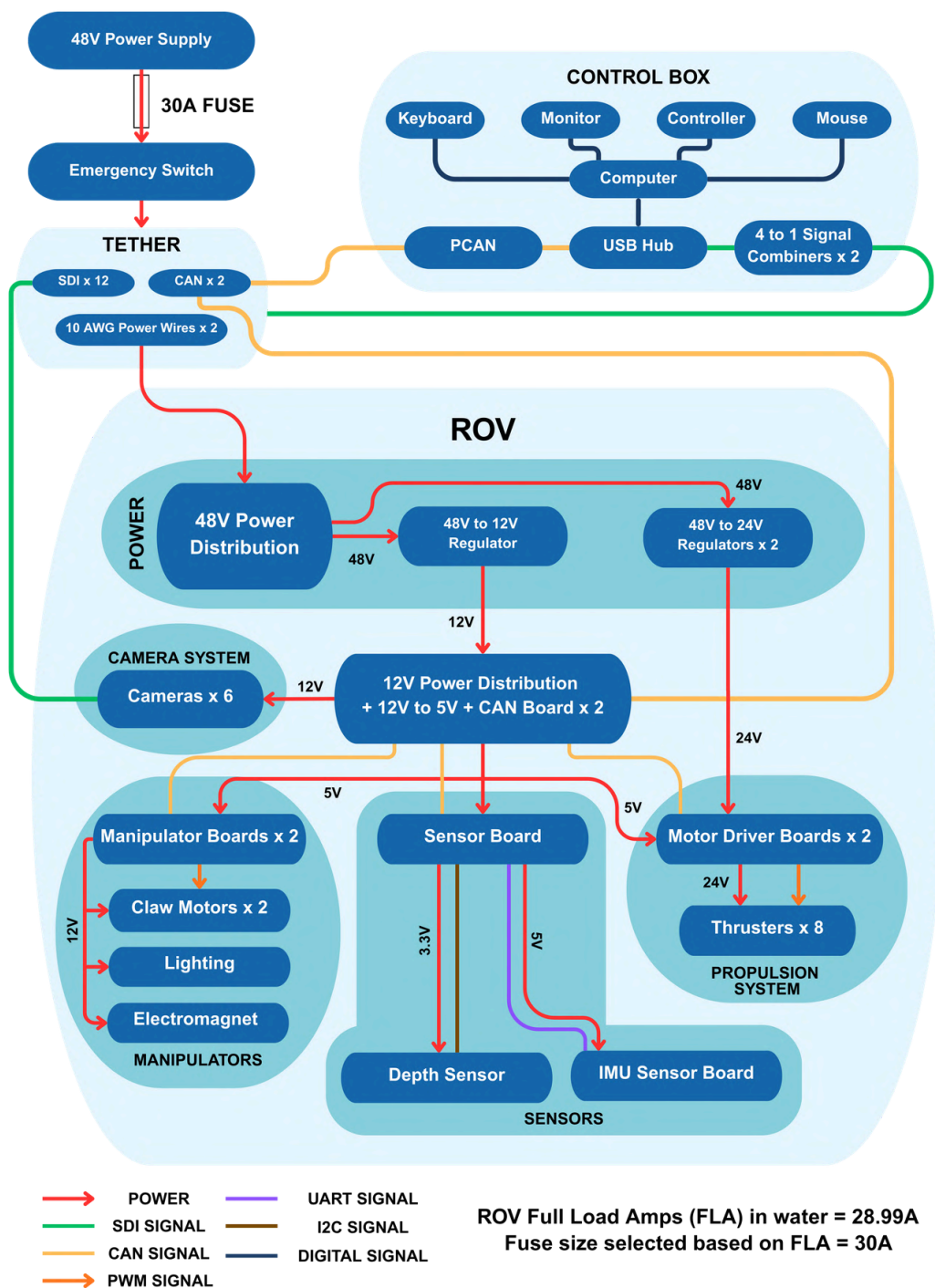


Figure 9: ROV SID

Controller Area Network

The Controller Area Network (CAN) protocol serves as the primary communication interface between the surface control box and the ROV. All boards integrate a CAN port, enabling signal transmission for system operation. Supporting a baud rate of up to 1.25 Mbps, CAN enables rapid real-time data exchange, while its robust error detection and correction mechanisms [Table 3] ensure reliable communication under demanding underwater conditions. By transmitting multiple control and feedback channels over a single differential pair, the CAN system streamlines cable management while enhancing reliability.

SOF	ID	RTR	IDE	R	DLC	DATA	CRC	DEL	ACK	DEL	EOF
1	11	1	1	1	4	8(bytes)	15	1	1	1	7

*All are in bits if not mentioned explicitly

Table 3: CAN Protocol

Power Distribution

The 48V power distribution board is connected to a 48V-to-12V regulator and two 48V-to-24V regulators, providing efficient and reliable allocation of electrical power throughout the system. The 48V-to-12V regulator distributes power to all other boards and cameras through the CAN board. Meanwhile, the two 48V-to-24V regulators are dedicated to drive the 8 thrusters for maneuvering and propulsion. This method retained from last year ensures overall performance by minimizing electromagnetic interference (EMI).

It also reduces redundancy while improving noise isolation and efficiency. Moreover, the smaller number of components implies fewer failure points, ensuring reliability during operation.

CAN Board

The board receives a 12V supply from the power distribution system and distributes this 12V bus rail to the 7 onboard cameras and two manipulators. Centralizing power distribution for these devices ensures consistent voltage delivery across all vision and manipulation channels while reducing the number of discrete power cables running through the vehicle.

An onboard voltage regulator steps down the 12V input to a regulated 5V rail, providing efficient DC-DC conversion for downstream electronics. This localized regulation minimizes voltage drop and noise that would otherwise accumulate over long cable runs, enhancing signal integrity for sensitive digital components.

In its role as a communication hub, the board receives CAN High and CAN Low differential signals from the tethered CAN bus and forwards a consolidated interface consisting of CAN signal and 5V power to the sensor, manipulator, and motor driver boards. This architecture standardizes power and CAN connectivity across all major subsystems, simplifying system-level wiring, reducing the number of unique cable assemblies, and enhancing overall reliability. The result is a cleaner electronics bay, faster troubleshooting, and improved serviceability during competition scenarios.

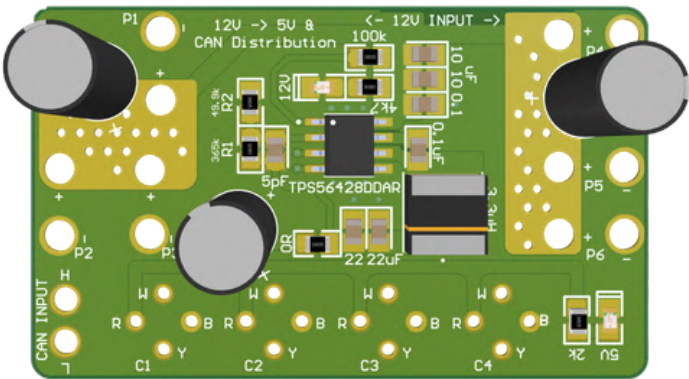


Figure 10: CAN board

Manipulator Board

The manipulator board is designed to drive up to three motors, each controlled by a dedicated PWM channel. It employs three DRV8251-based H-bridge driver stages to provide robust bidirectional motor control, enabling precise positioning for the manipulators.

Four AO3400 MOSFETs are utilized to drive auxiliary actuation devices: 2 flashlights for image recognition in task 2.1, and an electromagnet ensuring efficient and fast deployment of the recovery line to #310 U-bolt for task 2.4, while the other MOSFET serves as a backup port.

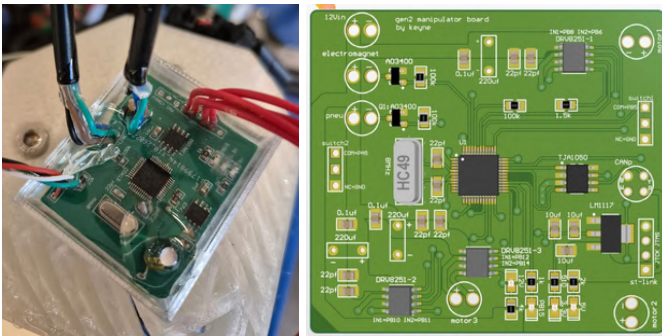


Figure 11, 12: Manipulator board

Sensor Board

The sensor board integrates the ROV's primary navigation and environmental sensing functions using a carefully selected set of components. A 10-axis Inertial Measurement Unit (IMU) provides real-time measurements of angular velocity and orientation via UART. This data is essential for accurate navigation, stabilisation and repositioning, particularly during precision tasks such as transecting. The board also incorporates an MS5837 depth sensor, which operates over the I2C protocol to deliver precise ambient pressure and depth data. This sensor enables depth-hold functionality and provides critical feedback for maintaining consistent vertical positioning throughout mission operations. Both sensors are physically integrated onto a single sensor board, which communicates with the control box via the CAN tether.

Motor Driver Board

NIXUS employs two thruster boards, each drives four thrusters via PWM, allowing the eight-thruster system to be physically separated into front and rear clusters. This distributed architecture shortens cable runs, reduces wiring complexity, and minimizes voltage drops by placing each controller near its respective thrusters. Spreading the power load across two boards lowers current density on PCB traces, reducing thermal stress and improving efficiency. The design also provides fault isolation: in case one board fails, the other can maintain partial propulsion for safer recovery. Modularity simplifies servicing, allowing individual boards to be replaced without disturbing the rest of the system.

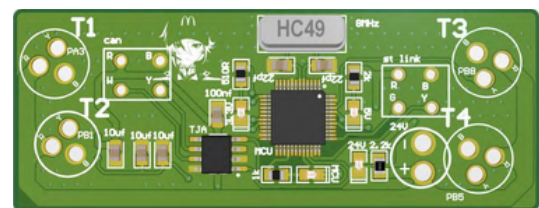


Figure 13: Thruster board

Tether

The tether is a vital component of the ROV, for establishing a secure connection to the surface. It functions not only as a power supply but also as a conduit for data exchange and signal transmission, both of which are essential for real-time operational capabilities. The tether is comprised of four primary components: two Controller Area Network (CAN) cables, twelve Serial Digital Interface (SDI) cables, two 10 American Wire Gauge (AWG) cables, and a strain relief mechanism. The 10 AWG cables, used for power supply at 48V, are characterized by their flexibility, low resistance of 0.003 ohms per meter, and ability to maintain power stability under high current loads. The SDI cables play a crucial role by transmitting real-time image signals from the camera at a rate of 12 gigabits per second,

leveraging their robust capabilities for long-distance transmission. The 2 CAN cables are dedicated to relaying control commands that govern the ROV's movement and facilitating data exchange with the offshore control unit, ensuring effective real-time communication. To enhance system reliability, 7 SDI cables and the 5 remaining backup cables, ensure continuous operation and stability of the tether system in case of failure.

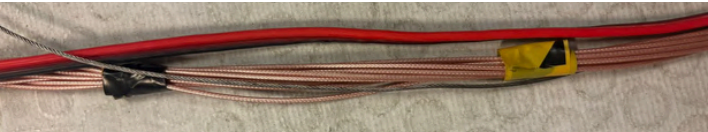


Figure 14: SDI cables, AWG cables and strain relief

To address safety considerations, the strain relief mechanism is incorporated into the tether, with one end securely connected to the control box and the other end attached to the ROV. This configuration ensures a durable and reliable connection. All cables, except for the strain relief, are secured with zip ties every 15 cm to reduce the risk of damage and maintain stable signal transmission. Additionally, all cables are encased in an expandable polyester (PET) braided sleeve, providing extra protection against potential damage during underwater operations.

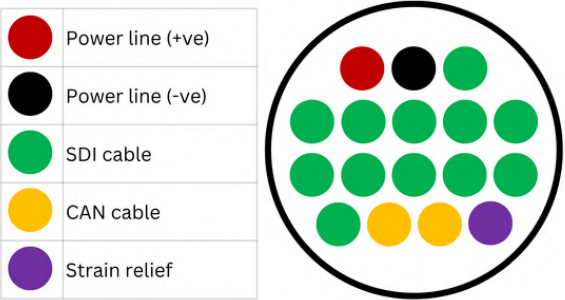


Figure 15: Tether diagram

Tether Management Protocol

Several precautions have been implemented to ensure reliable tether performance and extend operational lifespan. A systematic management protocol governs tether handling throughout all phases of deployment, prioritizing both equipment protection and personnel safety.

Pre-Deployment Inspection

Prior to each deployment, the tether is assessed for signs of wear or damage, including fraying, kinking, or compromised electrical connections. This inspection ensures that any potential failure points are identified before the ROV enters the water, mitigating the risk of in-operational failure.

Deployment and Strain Relief

During setup, strain relief mechanisms are secured at both the ROV and control box ends before connecting power and data cables. This sequence ensures that the tether jacket and strain relief—rather than the internal conductors—bear any tension loads applied during operations, reducing stress on electrical connections and signal lines.

Operational Tether Management

While the ROV is submerged, a designated tether manager monitors and adjusts the tether length as needed. Sufficient slack is maintained to minimize tension on the tether and ROV connections, while excess length is carefully coiled at the poolside to prevent entanglement with the vehicle, pool fixtures, or task elements. This approach balances freedom of movement with operational safety.

Post-Operation and Storage

Following retrieval, the disconnection procedure is executed in reverse: power and data cables are removed before strain relief is released. The tether is then coiled using proper techniques that avoid sharp bends and kinks, preserving conductor integrity and jacket flexibility. For long-term storage, the tether is placed in the cart's bottom layer, providing a dry and clean environment that protects against environmental degradation and enhances durability.

Control System Architecture

Overview

NIXUS continues to use an Event Driven Architecture (EDA) due to its scalability and flexibility. It is implemented in two main parts: the control box and the onboard CAN distribution system. The control box's system is implemented using Robot Operating System 2 (ROS2) on a Mac Mini M4, which hosts and organizes multi-thread processes while maintaining robust real-time performance. The complex inputs are then simplified by the ROS2 processes into short encoded control data. The data is further encrypted and transmitted through the tether via a CAN bus to the transceiver on NIXUS.

The architecture is meticulously divided into two systems that enable optimal performance, where heavy computations are run on the Mac Mini while mission-critical hardware control remains within the embedded systems onboard. The clean separation of the two subsystems ensures stable and quick performance and enables independent yet coordinated operation of sensor polling, thruster control, and other critical functions.

Service Layer - ROS2

The ROS2 framework, with its industry-standard Data Distribution Service (DDS), can be used to create a complex control system through the use of nodes and topics. These nodes can receive and send data to each other through topics, forming a giant information web that allows efficient transfer of data. Utilizing this, NIXUS' system is mainly composed of 5 main nodes, each with their different functions.

All of nodes enables the system to distribute the computation workload among multiple threads, greatly increasing user input responsiveness alongside data retrieval speed.

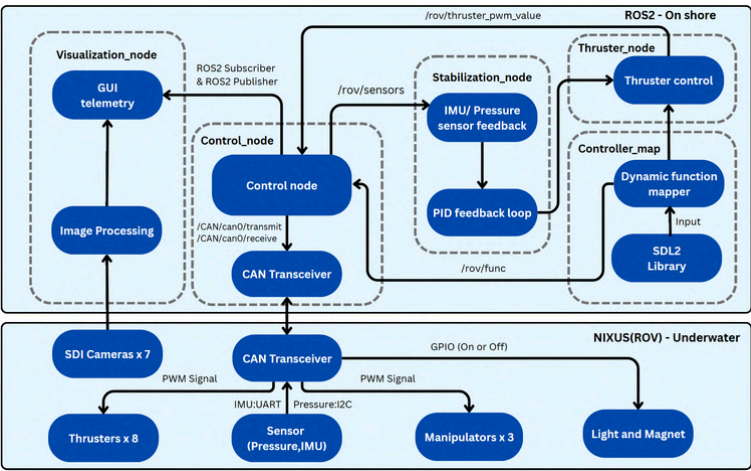


Figure 16: Directed graph of control system architecture

Node Name	Details
Controller_map	Processes controller inputs and maps them into instructions for the ROV.
Thruster_node	Controls the output of all 8 thrusters.
Stabilization_node	Receives data from sensors and adjusts thrusters properly to stabilize ROV movement.
Visualization_node	Displays all important data, such as thruster outputs, sensor data, and manipulator on-off signals, into a clear, concise graphical user interface (GUI).
Control_node	Processes all the data needed on the ROV, and hosts the conversion of topics into CAN frames to send to the ROV.

Table 4: Main nodes and their details

GUI

For convenience and ease of use, a graphical user interface (GUI) is available for the driver to be able to customize their own personalised control scheme. Live input feedback can tell them which joystick or button is moved or pressed, and name aliasing can allow the driver to give each input a name. Individual, simple commands can be assigned to each button press through the use of a dropdown menu. Combining all the features, the GUI provides the driver with all the information necessary to customize their own set of controls.

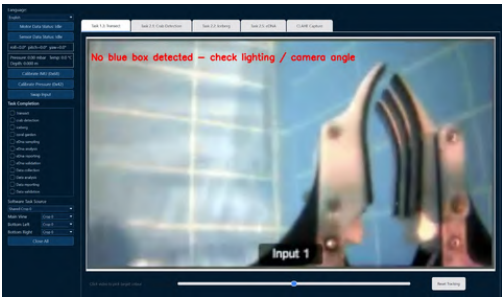


Figure 20: NIXUS GUI

3D Photogrammetry

A major software challenge in this year’s competition task involves developing a dimensions-accurate autonomous 3D model of a coral garden with some lengths given and others unknown. To achieve this, multiple technical approaches have been explored as outlined below.

The angle of the forward-facing camera mounted on the ROV was altered to pitch down while the pilot would drive the ROV around the coral garden to capture it from a 360-degree view. A program was developed to splice the live video footage recorded from the camera into many images at a rate of 2 frames per second. It is essential to capture only the most appropriate number of frames to develop the 3D model because too little would produce an inaccurate model with many gaps, and too many would use up too much time for the model to process the images.

Frame rate (per second)	Time taken to produce model (seconds)	Number of 360° rounds taken to capture frames	Model accuracy
1	-	1	No model produced
2	25	2	High
3	45	2	High

Table 5: Photogrammetry performance by frame rate evaluation

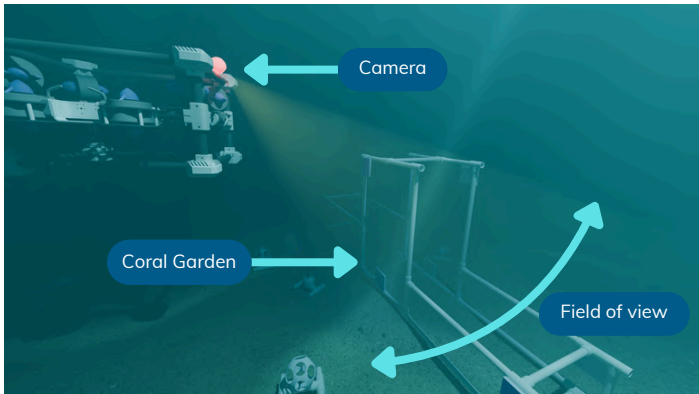


Figure 21: Render of the ROV collecting footage for 3D photogrammetry

Upon several trials, it was deduced that the most efficient and accurate 3D model could be produced using the Mac inbuilt program, Reality Composer Pro. It was crucial to capture the frames at 2 frames per second to obtain around 130 images, slowly circling the coral garden. Now, measuring the unknown dimensions of the coral garden was another crucial part of this task. The measure tool on Blender was used to measure lengths of unknown sections based on scaling from the known dimensions that were given beforehand.

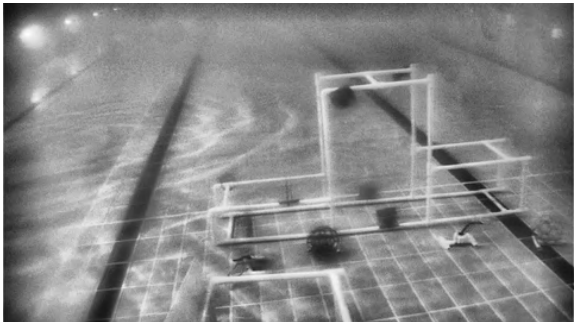


Figure 22: Test footage of coral garden

Propulsion

NIXUS utilizes eight P75 thrusters for propulsion, each capable of producing 5.1 kg of thrust. The thrusters are arranged in a BlueROV2 "Heavy" configuration [8], featuring four vectored horizontal thrusters for precise maneuvering and four vertical thrusters for altitude and roll-pitch control. This arrangement provides full six-degree-of-freedom (6-DOF) control while simplifying thrust vectoring calculations compared to more complex mixed-matrix configurations, prioritizing operational simplicity and reliability for the pilot.

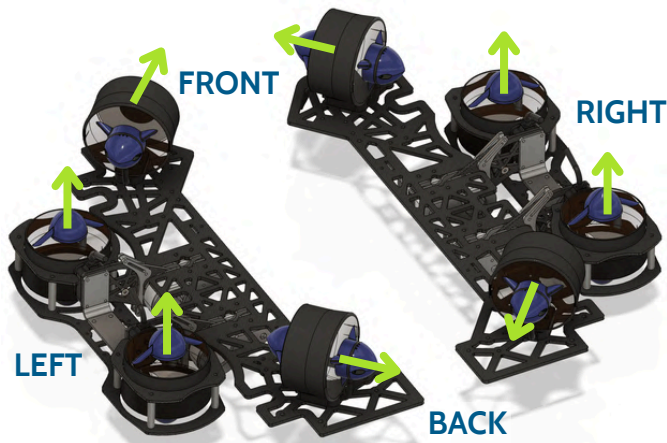


Figure 23: Thruster arrangement

Each thruster is protected by a combination of PETG shrouds and stainless steel mesh guards. The shrouds provide structural protection and hydrodynamic streamlining, while the mesh guards shield against debris without significantly obstructing flow. This dual-layer approach balances protection with performance, ensuring thrusters remain operational in debris-prone environments.

Thrusters

NIXUS retains the P75 thruster model for propulsion, building on its impressive performance in previous seasons. The P75 was selected for its proven efficiency and operational stability, having demonstrated reliable operation throughout extended in-water testing. Each thruster is connected

directly to a compact integrated electronic speed controller (ESC) positioned beneath the unit. This distributed architecture minimizes wiring length between the ESC and motor, reducing both spatial footprint and power losses compared to centralized ESC configurations. The result is improved system efficiency and a cleaner mechanical layout, enhancing serviceability and freeing space within the electronics bay for other critical subsystems.

Payload and Tools

Cameras

NIXUS employs a seven-camera configuration to provide comprehensive situational awareness. For a wider angle of view, we changed all RHSDI1600DK cameras from a focal length of 3.6 mm to 2.8 mm this year, improving pilot visibility around the vehicle during navigation and task execution. Each unit supplies high-resolution 1080p imagery over its own dedicated SDI cable, ensuring low-latency video feeds without bandwidth contention.

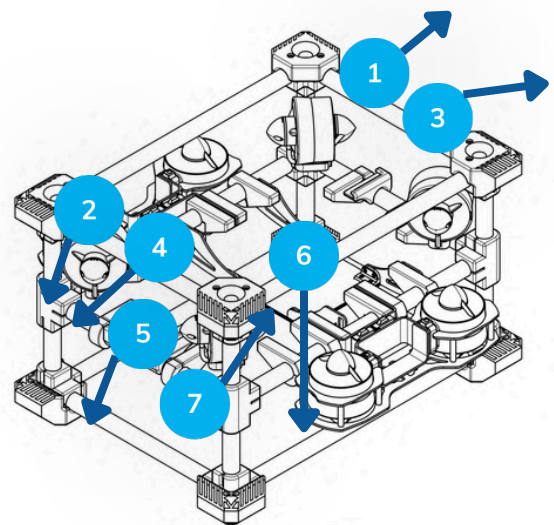


Figure 24: Positions of cameras

The cameras are positioned strategically to serve different purposes. Two primary cameras are positioned at the front and back of the frame to support general navigation and control. To ensure manipulator performance,

three additional cameras directly face the manipulators at the front, side and back. These dedicated manipulator cameras allow the pilot to position tools accurately during delicate operations such as thermistor replacement and epoxy patch application. The remaining two cameras are used specifically for task execution. One is placed at the front to capture the coral garden for Task 1.2, and the other camera is located at the bottom to transect in Task 1.3 and detect crabs in Task 2.1. With this camera arrangement, the pilot can control ROV movement with precision, facilitating operational effectiveness.

Image Processing

Crab Species Detection

When detecting the invasive species of crabs, it is crucial to use a time effective and easily accessible way to process and analyze the data. This is produced using the Ultralytics You Only Look Once (YOLO) v26 model.

Upon training the YOLO model with the provided images of the crabs, followed by data augmentation of the training data by flipping, resizing, recolouring, and distorting the images, the model is now capable of adapting to the data and can attempt to find the targets. Next, YOLO obtains the actual detection data, and compares it to the features through the training. It gives all targets a confidence score, with a higher score meaning that the model is more confident with its classification. Image processing is employed before and after running the YOLO model. Before detection, the program uses OpenCV to record the perspective of the bottom-facing camera on the ROV. This is followed by resizing of each frame and conversion into the correct color format for the model. After detection, the model draws the bounding boxes, labels, and confidence scores on the frame and displays them on the GUI screen, all of which allow easier indication of where different types of crabs are detected.

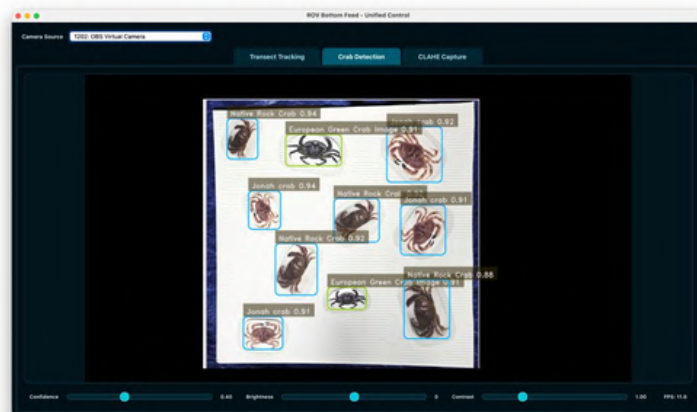


Figure 25: Image detection GUI

Dynamic Blue Box Detection for Transect Task

The transect task includes dynamic blue box detection and adaptive cropping for the ROV transect task. The image processing system uses HSV color space along with a dual color threshold in the HSV space to find the dark blue target box in the light blue background. The edges of the target box are then enhanced by applying the Canny operator and morphological operations in order to reduce the noise in the image. The target box is then scored using multiple criteria, including area, square aspect ratio, edge strength and colour purity. A weighted scoring system is applied to ensure that the target box is detected with stability. A jitter filter with a position smoothing scheme is used in order to reduce false detections. Then, the image is cropped around the blue box with a variable margin. This allows for the blue square to be constantly visible to the judge with any background distractions removed.

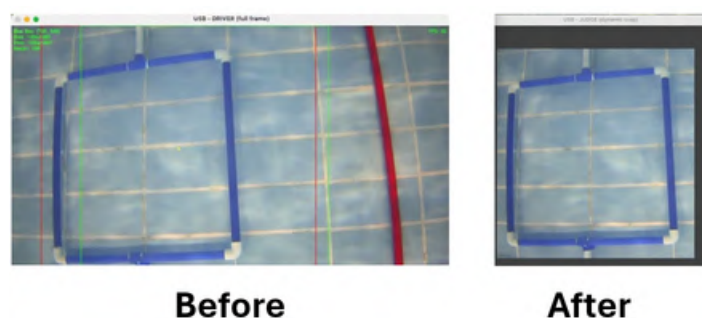


Figure 26: Before/ after cropping comparison

Sensors and Data Processing

To ensure the ROV remains in place with underwater currents, a strong stabilization is needed. Therefore, a new inertial measurement unit (IMU) was chosen to accomplish this goal. The Yahboom 10-axis IMU module has an inbuilt gyroscope, magnetometer, and magnetometer, allowing for the 3D orientation to be calculated via the Madgwick filter. Its higher performance and versatility made it the better choice between the IMUs used in previous years, as indicated in Table 6.

Alongside the IMU, an MS5837 pressure sensor is used to calculate the depth of the ROV. The MS5837 is a waterproof pressure sensor made for underwater measurements, and can detect even the slightest change in pressure.

The pressure reading can be converted into depth by using the hydrostatic pressure formula $P = h\rho g$, to estimate the depth of the ROV.

After receiving data from both sensors, the stabilization node first puts the data through a low-pass filter, to smoothen the noise. Then, the roll, pitch, and yaw of the ROV can be calculated via the Madgwick filter. By first integrating the gyroscope angular velocity over time to obtain the orientation, and obtaining the correction vector through the accelerometer and magnetometer data, a high accuracy orientation of the ROV can be obtained. Then through the use of a proportional-integral-derivative (PID) controller, the orientation and depth of the ROV can be actively maintained, allowing the operator to hold in place even under strong waves.

	Yahboom 10-axis IMU module	MPU9250	MPU6050
Used by	NIXUS (2026)	INKAY (2025)	WAHOO (2024)
Axes	3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer, 1-axis barometer (10 axis)	3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer (9 axis)	3-axis gyroscope, 3-axis accelerometer (6 axis)
Angular drift	<0.1 degrees per second*	0.2 degrees per second*	1.3 degrees per second
Communication	I2C, SPI	I2C, SPI	I2C
Limitations	The barometer is not made for underwater use.	High drift	High drift, no magnetometer leads to a high drift.
Additional Notes	Tailor made for navigation.	Small size.	Small size

* with sensor fusion

Table 6: Decision matrix for comparing IMUs

Multi-Purpose Gripper

The multi-purpose gripper utilizes a JGB37-3530 motor to drive a leadscrew-slider mechanism, which actuates a parallelogram linkage. This design ensures that jaw surfaces remain parallel throughout their motion, providing consistent engagement up to a

maximum opening width of 125 mm. To balance structural rigidity with precision, the 135 mm links are constructed from 2 mm fiberglass panels sandwiching a 3D-printed core, with the entire assembly secured by 15 through-screws to eliminate mechanical play.

By employing a leadscrew, the mechanism functions similarly to a worm gear, providing inherent self-locking through unidirectional force transmission. This allows the system to maintain a constant 150 N gripping force without power consumption during idle states. Driven by a 320 rpm rated motor, the mechanism achieves full actuation within two seconds under load, ensuring rapid and energy-efficient transitions.

The system incorporates two distinct finger configurations to manage varied mission requirements. The main forward-facing fingers are optimized for cylindrical objects and PVC pipes, utilizing a 3600 mm² contact area (80 mm × 45 mm) reinforced with high-friction tape. Complementing these is an extension with fingers offset at a 45° angle to the horizontal plane. This specialized geometry facilitates the alignment and secure handling of T-shaped components, specifically the eDNA Sensor Connector and Bubble Curtain assemblies.

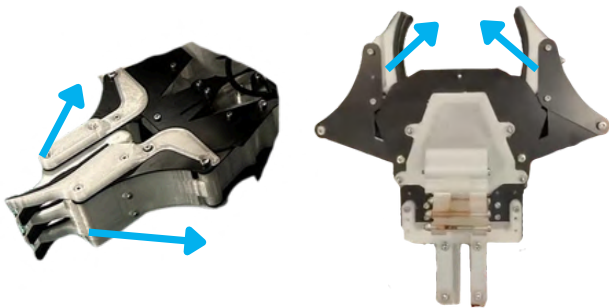


Figure 27: Multi-Purpose Gripper

SpinEOUS (Spinning Engagement for Operational Underwater Servicing)

To perform the removal of biofouling from the observatory camera in Task 2.5, we implemented a turning manipulator. The low-speed DC motor driving the rotation does not require any gears for speed reduction, allowing us to mount the 3D printed piece that engages the turning handle directly.

Printed with PETG filament, it is composed of two C-shaped arms with an opening angle of slightly less than 150°. Through testing, this angle has been proven to provide a good balance of engaging the handle securely while rotating and an ease of removal after finishing the task. The arm design provides a reliable mechanical lock during forward rotation but allows the handle to clear the mechanism passively when the ROV reverses.

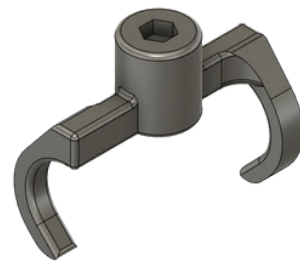


Figure 28: SpinEOUS

PHERB (Passive Hook Enclosure with Retaining Barrier)

PHERB is implemented in two different versions on the ROV, both operating under a mechanism similar to carabiner yet each designed to adapt to handle a specific task. In both versions, a 3D printed spring is able to bend inside, but its rigid part blocks it from opening again. It allows objects to slide in and traps them, profiting from being passive, hence having fewer potential failure points.

To carry the heavy lobster pot, the first version has a thicker PETG base with a spring printed in PETG-CF, balancing flexibility with sufficient strength.

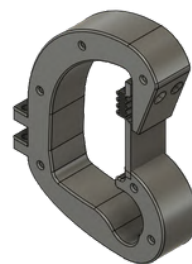


Figure 29: PHERB v1

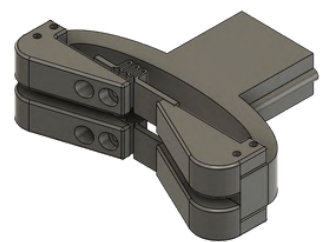


Figure 30: PHERB v2

The second version of PHERB is for securing a rope to the U-bolt in task 2.4. It is consisted of three parts: a rope spool, a hook body, and a hook base. Prior to deployment, the spool is prevented from unwinding by a retention pin. This pin is released only when the hook lock leaves the ROV, ensuring controlled rope deployment. The hook body acts as the main element that will attach to the U-bolt through the previously described mechanism. It is retained on the vehicle by a sliding mount that is terminated in a magnetic latch. This latch is designed to release only under axial tension, specifically when the hook is anchored and the ROV initiates a retreat maneuver. To prevent U-bolt slippage, the mechanism incorporates dual parallel springs. The springs can be actuated by a low-force compression to mitigate the risk of bucket falling.

Coral Catch

To improve efficiency in collecting corals and reduce mission cycle time in Task 1.1, NIXUS utilizes two passive Coral Catch manipulators to simultaneously collect both basket stars. The mechanism is similar to burdock hooks that also inspired the invention of velcro, consisting of multiple arms arranged in a circular pattern with hooks at their ends. The two manipulators are mounted at the bottom plate facing downwards, and so when the ROV “sits” on the basket stars, the hooks trap them.



Figure 31: Coral Catch

E-Pull

Task 3.1 requires a small pin to release the micropile. However, the multipurpose gripper is too bulky to handle this precision. To address this challenge, we designed E-Pull which can stick the micropile to the electromagnet once it is in close proximity. This allows for localized actuation within tight clearances, significantly increasing the success rate of the micropile deployment while maintaining the ROV's overall versatility.

Non-ROV Device (Float)

To comply with the MATE 2026 dimensional constraints, the float is enclosed in a cylindrical housing less than 1 m in height and under 18 cm in diameter. A 5 cm wide U-bolt is securely mounted on the top cap to serve as the mandatory ROV recovery interface. Vertical motion of the untethered float is driven entirely by a custom buoyancy engine, which adjusts the piston position to vary the volume of a sealed compartment, thereby changing buoyant force according to $F(B) = (\text{gravitational constant}) \times (\text{density of water}) \times (\text{volume of container})$. Autonomous vertical profiling is managed by an onboard STM32F103CBT6 microcontroller using an MS5837 pressure sensor via the I²C protocol to measure depth continuously. This allows precise descent, ascent, and station-keeping at target depths of 2.5 m and 0.4 m for 30 seconds each. Limit switches prevent piston over-travel. As the float operates without a tether, wireless communication is handled by a LoRa module via UART, transmitting pre-dive pings and post-recovery data to a surface GUI. During submersion, time and pressure data are logged to an SD card via SPI. Power is supplied by two parallel 12V battery packs consisting of ten

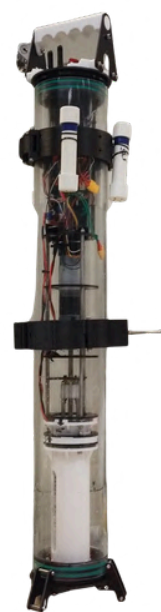


Figure 32: Float

NiMH cells, from which the 12V rail is stepped down to regulated 5V and 3.3V rails for electronics.

Build vs. Buy, New vs. Used

EPOXSEA focused on making smart choices that balance performance, budget, and sustainability. Our goal was to reuse components when they continue to meet mission requirements, and invest in new components only when they would clearly improve the ROV's capability. This helps us keep development costs in check and build on systems that have already been tested and proven reliable, allowing us to focus our efforts

on the parts of the ROV that need the most improvement.

This year, we developed specialized manipulators tailored to each task's requirements and limitations, allowing for maximum efficiency. We also reused selected reliable components such as the cameras, thrusters, Mac mini, and buoyancy materials, while buying new parts such as DC motors and pressure sensors according to specific mission needs.

For the full list of reused and newly developed components, along with justifications and rationale, please refer to Appendix C.

Mission Systems Approach

	Task	Camera	Gripper	SpinEOUS	PHERB	Coral Catch	E-Pull	Non-ROV Device
1.1	Collect basket stars	✓	✓		✓	✓		
	Collect coral species	✓	✓		✓			
1.2	Create 3D model of coral garden	✓						
	Measure length of garden	✓						
	Scale 3D model							
	Estimate height of coral garden							
1.3	Create video of coral garden	✓						
2.1	Count number of crabs	✓						
	Upload data to form							
2.2	Survey iceberg around perimeter	✓						
	Measure keep depth of iceberg	✓						
	Determine threat level to platform	✓						
	Determine threat level to assets	✓						
2.3	Release buoy	✓						
	Recover lobster pot	✓	✓					
	Return lobster pot	✓	✓					
2.4	Attach recovery line to anchor	✓	✓		✓			
	Return line to surface							
2.5	Recover old sensor	✓	✓					
	Determine organism percentage							
	Place sensor in area	✓	✓					
	Connect sensor to observatory	✓	✓					
	Remove biofouling	✓		✓				
3.1	Place bubble curtain device	✓	✓					
	Guide micropile to location	✓	✓					
	Pull pin to release micropile	✓	✓				✓	
3.2	Remove cover from port	✓	✓					
	Retrieve power connector from platform	✓	✓					
	Lay power connector through waypoint	✓	✓					
	Install connector	✓	✓					
4.1	Design and construct vertical profiling float							✓

Table 7: EPOXSEA Mission Systems Approach

Safety

At EPOXSEA, safety is a core value and shared responsibility. We are committed to proactively identifying and mitigating risks to protect both personnel and equipment. To uphold these standards, all members are ensured to receive

proper guidance, training, and oversight. They must also follow the established internal safety protocols as well as applicable local regulations.

Personnel Safety

Personal Protective Equipment (PPE) is essential when working with hazardous materials like carbon fiber and epoxy. We provide all team members with the necessary PPE to ensure their safety.

All engineers must complete mandatory safety training and review laboratory safety guidelines before entering the lab and pool. This ensures they understand the proper use of equipment (i.e. hand tools: handsaw; power tools: drill). They must also be aware of the required laboratory attire, the locations of PPE and safety equipment, and emergency contacts.

The laboratory is equipped with ventilation systems and fume extractors to safely remove harmful substances generated during activities such as soldering, 3D printing, and epoxy handling.



Figure 33: Mechanical Lead mixing epoxy

Equipment Safety

Monthly inspections of tools and equipment are conducted to ensure that any rusted, dull, or damaged items are swiftly repaired or replaced. It is crucial for team members to report any unsafe tools to a supervisor or safety officer without delay to avoid accidents.

New recruit members are required to receive tool-use training from senior engineers to reinforce safe practices in equipment handling. These safety protocols help create a safe laboratory environment and support a strong culture of safety within the workplace.

Vehicle Safety

Safety was a primary consideration throughout the development of NIXUS, with specific design measures implemented to reduce the risk of injury. The ROV's rounded and blunt exterior minimizes the risk of accidental contact, protecting both the environment and nearby personnel while supporting smooth operation. Electrical components are protected from water-induced short circuits using epoxy-filled, 3D-printed enclosures, while the control box maintains a clean internal layout with no exposed wiring to ensure safety and reliability.



Figure 34: Blunt ROV corners

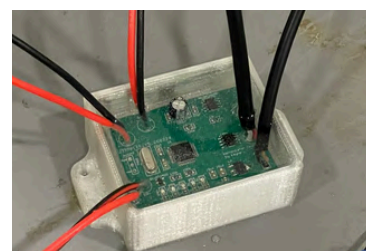


Figure 35: Epoxied PCBs

For safe ROV operation, EPOXSEA incorporates an emergency “kill-box” equipped with a stop button and inline fuse, connected via an SBS50 Anderson Powerpole connector, allowing power to be immediately cut in emergency situations. The system is operated using a Mac Mini and controller for precise control. All operations follow a structured command protocol given by driver — such as “Launch” to start the ROV and “Kill” to cut the power — with required team confirmation to prevent unintended activation and enable rapid emergency shutdown, ensuring safe and coordinated mission execution.



Figure 36: NIXUS “kill-box”

Operational Safety

Fire extinguishers and first aid kits are positioned in both the electronics and assembly areas to enable rapid response in emergencies. The workspace is maintained in a clean and orderly condition, with emergency exits and fire escape routes kept unobstructed to support accident prevention and safe evacuation. In addition, all members are required to participate in annual fire drill training to strengthen emergency preparedness. Integrated safety reminders and established operating procedures help ensure the protection of personnel, equipment, and the environment.



Figure 37: Fire rated door



Figure 38: First aid box

Construction and Operational Checklists

NIXUS' construction and operational checklists (Appendix B) ensure strict adherence to safety procedures before, during, and after operations. Team members follow these guidelines to maintain safe working conditions and protect both personnel and the environment.

Critical Analysis

Testing and Troubleshooting

Our testing process consisted of two phases: dry tests and wet tests. Throughout development, we used an iterative and data-driven approach. Starting with dry tests in the laboratory, we quickly debug individual components, then proceeding to wet tests for evaluating real underwater performance. This allowed us to assess propulsion, sensor accuracy, manipulator reliability, and image recognition under conditions that matched with the actual competition environment.

To further assess the performance of our vehicle under cold environments, we repeatedly placed components, manipulators, and cameras in an ice bath. This allowed us to verify that the materials and systems remained functional under low-temperature conditions and did not experience unexpected deformation or malfunction. Successful results from these tests gave us greater confidence in the ROV's reliability in challenging operating environments.

Troubleshooting Framework

Building on this testing foundation, we developed a structured troubleshooting process to resolve issues efficiently. When problems arose, we first isolated the fault by testing subsystems to narrow down the cause of the issue. For example, when video signal problems occurred, we swapped the SDI signal before replacing the tether, which helped us identify the root cause more quickly. To support this process, we maintained detailed logs in shared tracking sheets that recorded symptoms, causes, and fixes for each issue. We also kept redundancy measures in place, including three spare tethers, eight backup cameras, and multiple identical claw prototypes, to reduce downtime during testing.

Rapid Prototyping Cycle

A rapid prototyping cycle helps us identify mission-critical issues early, including grasping stability, image recognition accuracy, and power stability. Once a problem was identified, we developed and tested solutions within one to two weeks, allowing us to make targeted improvements without delaying the overall project timeline. This approach helped us refine the vehicle more efficiently and improve performance across all mission tasks.

Key Design Improvements

Mechanical

The gripper went through several design iterations during development. In V3, the parallelogram linkage mechanism placed the two links too close together, which caused insufficient torque and instability when closing. V4 addressed this issue by increasing the overall width and doubling the distance between the two links, resulting in much more stable grasping performance. Early versions also experienced structural failure due to excessive motor torque, so we added a limit switch to prevent over-torquing. Wet tests confirmed that the final design maintained a secure grip on task objects where earlier versions had failed.



Figure 39: Gripper V4 (left), V3 (right)

Software

Our initial image recognition model, trained using still photos, only achieved 42% accuracy for mission tasks. After pool testing, we retrained the model using video footage captured during wet tests, which better reflected the lighting and motion conditions underwater. This significantly improved accuracy to around 90%, making the system much more reliable during real task execution.

Hardware

During testing, there was camera instability while the vehicle was moving. This was traced to voltage fluctuations caused by insufficient capacitance on the power board. In response, we redesigned the board and added more capacitors to stabilize the power supply. This change improved camera performance under dynamic conditions and reduced interruptions during operation.

Accounting

This year, we strategically applied a combination of new and reused components on our ROV to balance performance with cost efficiency. To enhance functionality, we purchased new connectors, manipulators, and electronics, while retaining other reliable parts, namely the thrusters, TCU, and cameras. This approach enabled us to upgrade our ROV without incurring unnecessary expenses, resulting in lower overall project costs compared to last year.

Our primary funding comes from sponsorships provided by HKUST and external corporations. All expenses are carefully recorded in our team's KB to ensure financial transparency. Travel expenses, including flight tickets, accommodation, transport and other miscellaneous costs, totalling approximately 110,000 USD, are covered by employees. For further details, the full budget and costing data sheets are provided in Appendix A.

Appendices

Appendix A: Budgeting and Project Costing

Available Funds				
Source			Amount (in USD)	
HKUST School of Engineering			\$	2,000.00
The Milwaukee Electric Tool Corporation			\$	800.00
RS Components LTD.			\$	800.00
Carryforward balance from 2025			\$	1,800.00
			Total	\$ 5,400.00
Re-used components				
Category			Amount (in USD)	
Mechanical	Underwater thruster P75 with ESC		\$	151.90
	DC motor (JGB37-3530)		\$	54.30
Hardware	TCU (Control box)		\$	645.20
Software	Mac Mini		\$	999.00
			Total	\$ 1,850.40
Budgeting & Expenses				
Category	Type	Item(s)	Est. Cost	Expenditure
Mechanical	Purchased	PVC pipe, buoyancy equipment	\$ 50.00	\$ 63.41
	Purchased	Nuts, bolts, 3D printing filament	\$ 300.00	\$ 278.93
Hardware	Purchased	PCB, MCU, transistors, wiring, connectors	\$ 200.00	\$ 168.35
	Purchased	Tether, connectors, cable sleeve	\$ 20.00	\$ 23.93
	Purchased	Servos, pneumatics, encoder	\$ 800.00	\$ 804.76
	Purchased	Multimeters, soldering irons	\$ 400.00	\$ 348.30
	Purchased	Pressure sensor (MS5837)	\$ 15.00	\$ 15.60
	Purchased	Power supply	\$ 200.00	\$ 184.50
	Purchased	Epoxy and epoxy equipment	\$ 100.00	\$ 104.56
	Purchased	Cameras	\$ 1,200.00	\$ 1,044.60
Software	Purchased	IMU	\$ 110.00	\$ 116.85
	Purchased	HDMI cables	\$ 90.00	\$ 85.41
	Purchased	SDI cables	\$ 100.00	\$ 99.42
General	Purchased	Props for mission preparation	\$ 400.00	\$ 379.70
	Purchased	Research & Development	\$ 250.00	\$ 209.80
	Purchased	Souvenir & Marketing Display	\$ 350.00	\$ 301.90
			Total	\$ 4,585.00 \$ 4,230.02
Note: Travel expenses, including flight, lodging, transport and other miscellaneous costs (totalling approx. 110k USD), are covered by employees, and need not be included into the company's accounting records				

Appendix B: Construction and Operational Checklists

Initial Systems Check	Yes	No	Action Required
SID Documentation			
Team Spec Sheet			
Float Documentation			

Pre-deployment	Yes	No	Action Required
All electronics connections are secured and correctly connected and non-exposed			
Screw caps on all cameras are secured			
Cables and tethers are properly tightened			
Manipulators are all properly mounted and secured onto ROV			
No damage in ROV frame			
Tether is laid out neatly without knots or tangles			
Surface station tether strain relief is connected, tether ethernet and power are connected			
Surface station is stable and on a level surface			
Deck area is clear of clutter and tripping hazards			
Thrusters free from obstruction			
All members wearing appropriate and safe attires			
Verify no microplastics/debris are shed into the pool			
Confirm post-operation cleanup plan			

Power-up	Yes	No	Action Required
Control Box is receiving 48V nominal			
Verify camera connection to the Control Box is stable			
Perform thruster test, joystick movements correspond with thruster activity			
Test any electrical manipulators that require pilot control			

Deployment	Yes	No	Action Required
Verify no excess bubbles are coming out			
Clear signal communication: • "Kill" when power needs to be cut off • "Contact" before touching NIXUS • "Launch" when NIXUS is ready to be operated underwater • "Power on" before turning on NIXUS			
Appropriate length of the tether is released into water to prevent pull on ROV or entanglement			

Loss of communication / Camera feed	Yes	No	Action Required
Pilot calls out "Kill" and powers down ROV			
Crew members retrieve ROV via tether to shore			
Begin troubleshooting process until communication is restored			
Document the cause of failure and implemented repair method			

Appendices

Appendix C: Build vs. Buy, New vs. Used

System		Justification
Build		
15m tether	New	Ensure reliable performance of camera feed and power supply
PETG 3D printed manipulators	New	Customized for mission alignment and quick-swap compatibility
Frame	New	To meet new mission requirements
Universal mount	New	Payload optimization and weight reduction
PCBs	New	Innovative standardization across manipulators for easy swapping
	New	Self-designed and customized, for mission requirement alignment
Buy		
RH-SDI1600DK Camera	Reused	Excellent low-light performance and high reliability
	Reused	Shorter focal length (from 3.6mm to 2.8mm) for a wider view
Thruster guard	Reused	Durable protection
	Reused	Transport portability
Mac mini	Reused	High computational performance
	Reused	Compact size allows for higher portability
Underwater thruster P75 with ESC	Reused	High thrust-to-weight
	Reused	Reliable ESC integration
DC motor (JGB37-3530)	Reused	Cost-effective and durable
DC motor (JGB37-520)	New	Higher torque for demanding loads
Pressure sensor (MS5837)	New	Precise depth/ pressure readings
	New	Compact for single-frame fit
Manipulator light	Reused	Adequate and reliable illumination
R-3318 polyurethane foam block	Reused	Reliable for buoyancy
DC-DC Step-down Transformer	Reused	Proven reliability
IMU	New	Higher accuracy, lower drift
Flip Monitor	Reused	Enhance driver display visibility

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