BUMBLEBEE

Engineering Autonomous Systems of the Future

NUS
National University
of Singapore

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Our Story

Team Bumblebee comprises NUS students from various disciplines of Mechanical, Electrical, Computer Engineering and the School of Computing.

The project started out in 2012 with an Autonomous Underwater Vehicle (AUV). We have evolved through the years, developing our 4th Generation AUV and 3rd Generation Autonomous Surface Vessel (ASV) to participate in multiple international competitions – the Maritime RobotX Challenge, RoboSub Competition and Singapore AUV Challenge (SAUVC).

Core Vision & Key Objectives

Engineering Autonomous Systems of the Future

Inspire & Inculcate Passion in Robotics and Engineering	Explore Research & Development in Real-World Scenarios	Provide Opportunities to Learn & Lead

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Our Achievements

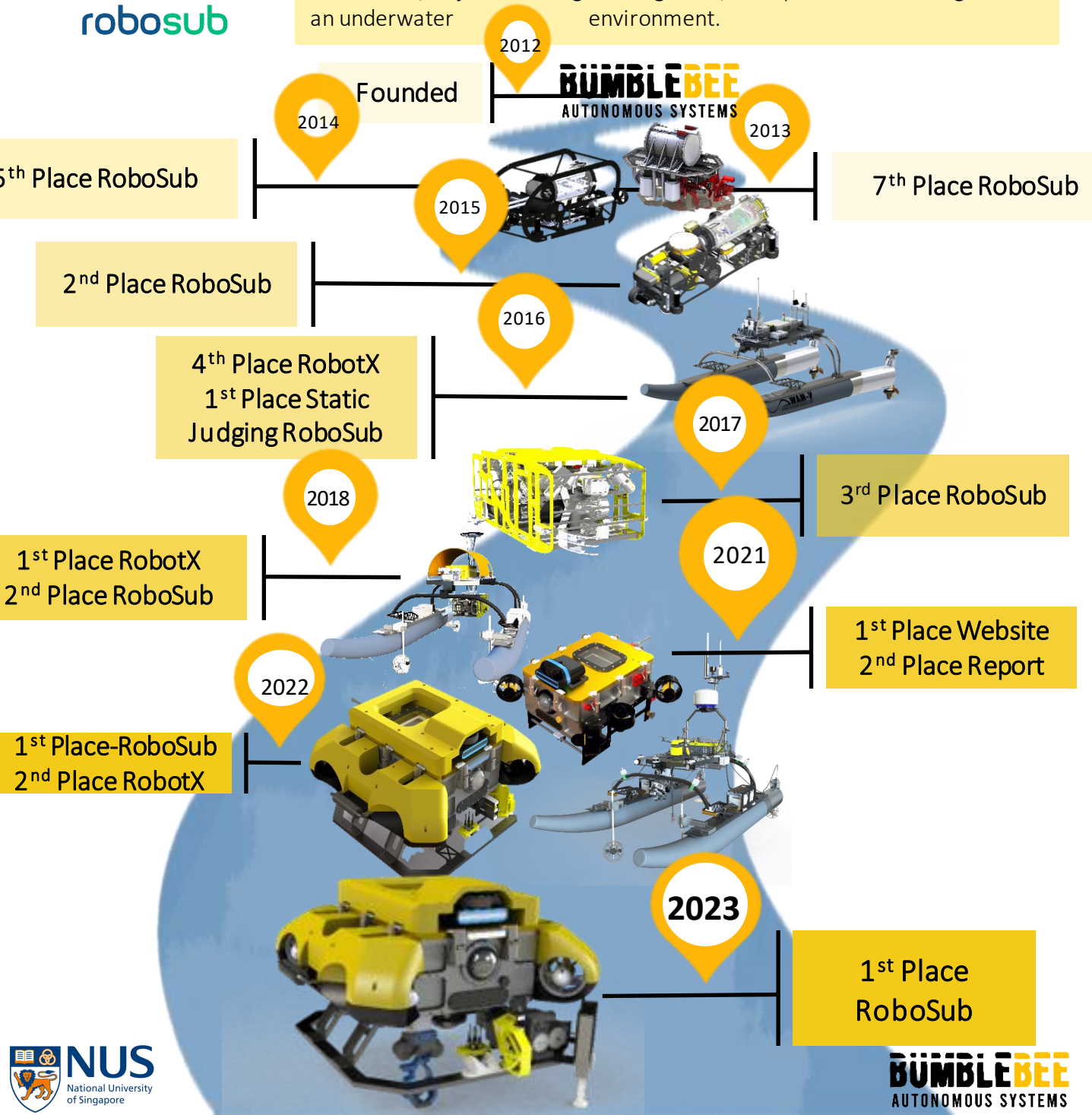**robotx**

The **Maritime RobotX Challenge** serves to foster student interest in maritime autonomous robotic systems. Participants will build upon an Unmanned Surface Vehicle (USV) platform using sensors, control systems and integration of ASV/AUVs to complete a series of multivehicle collaborative autonomous tasks.

robosub

The **International RoboSub Competition** is an international AUV competition held in the US Naval Warfare System's Transdec pool, San Diego. It challenges engineers to perform realistic missions such as acoustic localization, object and target recognition, manipulation and navigation in an underwater environment.

2012

Founded

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2014

5th Place RoboSub

2013

7th Place RoboSub

2015

2nd Place RoboSub

2016

4th Place RobotX
1st Place Static
Judging RoboSub

2017

3rd Place RoboSub

2018

2021

1st Place RobotX
2nd Place RoboSub

1st Place Website
2nd Place Report

2022

1st Place-RoboSub
2nd Place RobotX

2023

1st Place
RoboSub

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Our Masterplan

Autonomous Surface Vessel (ASV) 3.5

- Test bed for sensor suite and power architecture towards ASV 4.0
- Ground up development targeting problem areas from the previous generation

Autonomous Aerial Vehicle (Jellyfish) 2.0

- Custom drone platform with all new frame, motors and autonomy stack
- Aimed to complete autonomy challenge at RobotX 2024 in Sarasota, Florida

Autonomous Surface Vessel (ASV) 4.0

- Improved power architecture for longer runtimes and improved maneuverability
- Inter-vehicle collaborative behaviour with Jellyfish through DTLS and communication

Autonomous Underwater Vehicle (AUV) 5.0

- Next-generation AUV with state-of-the-art sensor and compute suite
- Inter-vehicle collaborative behaviour with AUV 4.0

Key Technological Developments

- Drone Take off and Landing System (DTLS) 2.0
- AUV – AUV collaborative behaviour through underwater acoustic communication

Aug '23 – Jan'24

Aug '23
ASV Integration

Jan '24
ASV 3.5 Trial

Feb'24 – Aug '24

Apr'24
SAUVC 2024

Aug '24
AUV 5.0 Launch

Sept '24 – Dec '24

Sept '24
Launch ASV 4.0

Nov '24
RobotX 2024

Jan'25 – Aug '25

May'25
AUV 4 & 5 Trials

Aug '25
RoboSub 2025

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Vehicle Design

6 degrees of freedom with forward speed of 1.5m/s

Dynamic positioning for the AUV to station-keep

Target tracking and object recognition with imaging sonar, industrial grade cameras, and computer vision algorithms

Modular electronics design for seamless plug-and-play replacement of parts
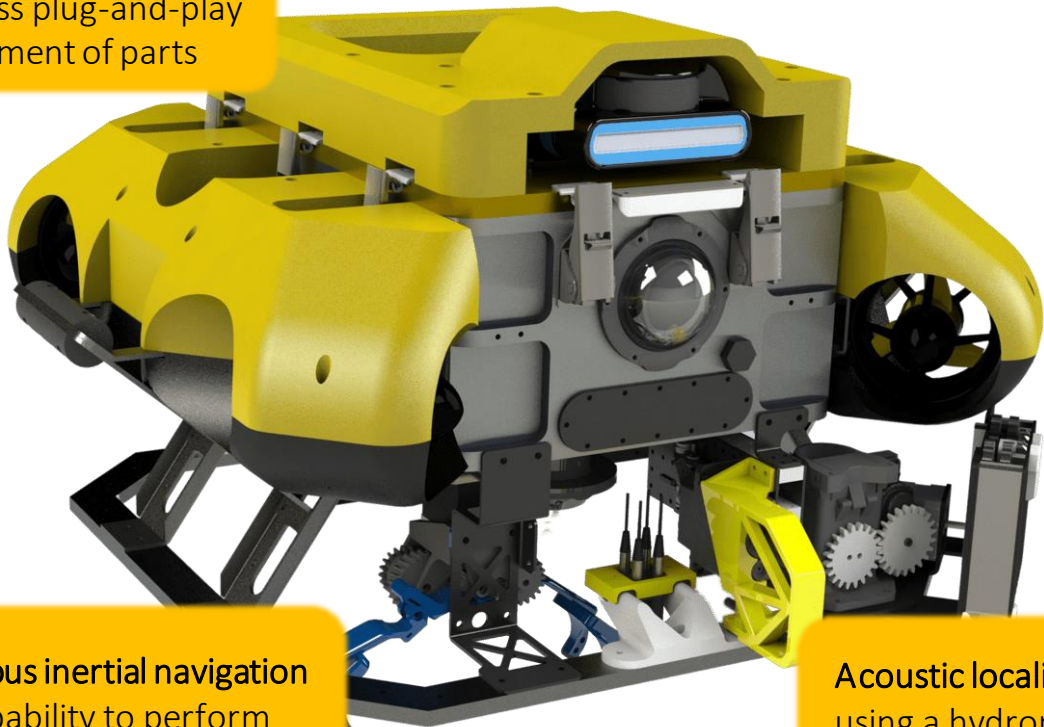
Autonomous inertial navigation with capability to perform waypoint navigation
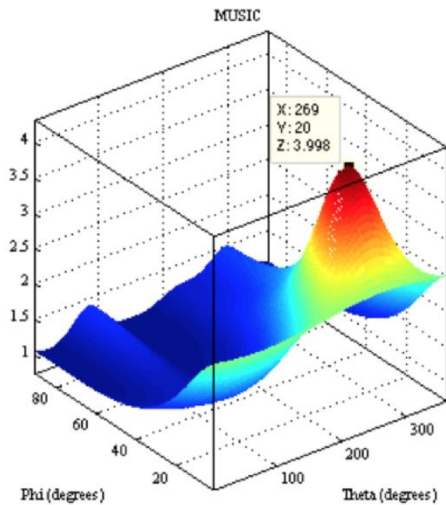
Acoustic localization using a hydrophone array

Advanced battery sub-hulls manufactured using SLM 3D printing technology

Current Capabilities

Acoustic Localization:
Bumblebee 4.0 has the capability to detect and localize to an underwater locator beacon (ULB) from far. This is accomplished by a hydrophone array and custom-made analog filters and amplifiers. We have also integrated a Field Programmable Gate Array (FPGA) into our hardware to decrease signal latency in our digital signal processing pipeline. The raw data is then used in the MUSIC (MUltiple SIgnal Classification) algorithm and provides the localization capabilities for the AUV to locate the ULB.

Underwater Perception and Tracking:
Bumblebee 4.0 is equipped with two machine vision cameras and an imaging sonar for forward and downward perception. Leveraging upon the benefits of both sonar and camera, the AUV is capable of highly robust perception and tracking objects underwater.
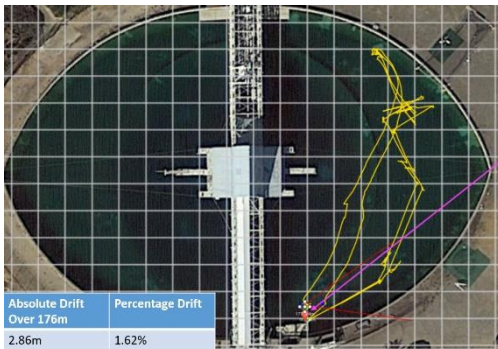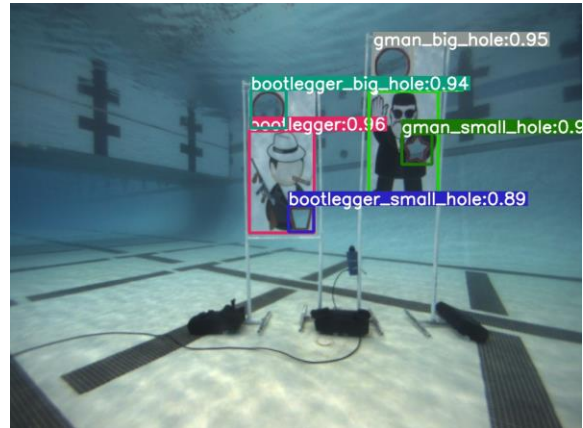
Navigation Suite:
The navigation sensor suite consists of a 9-axis Vectornav NV-100 IMU, a DVL, a barometric pressure depth sensor and a 1-axis fibre optic gyroscope. An Error-State Kalman Filter is used to obtain much higher accuracy than each sensor can provide independently. The AUV navigation system can perform accurate local and global navigation.

Autonomous Manipulation:
With a highly accurate navigation suite and robust object perception and tracking, the AUV is capable of fully autonomous object manipulation. We have tested on various types of manipulators ranging from grabbing arms, to marker droppers, to mini projectiles. The software on the Bumblebee AUV is capable of different types of manipulation.

Vehicle Design

Software Capabilities:
- Vector-based control
- Target tracking and identification
- Waypoint navigation

Datalink:
- Up to 500Mbps 5GHz radio for high bandwidth data transmission
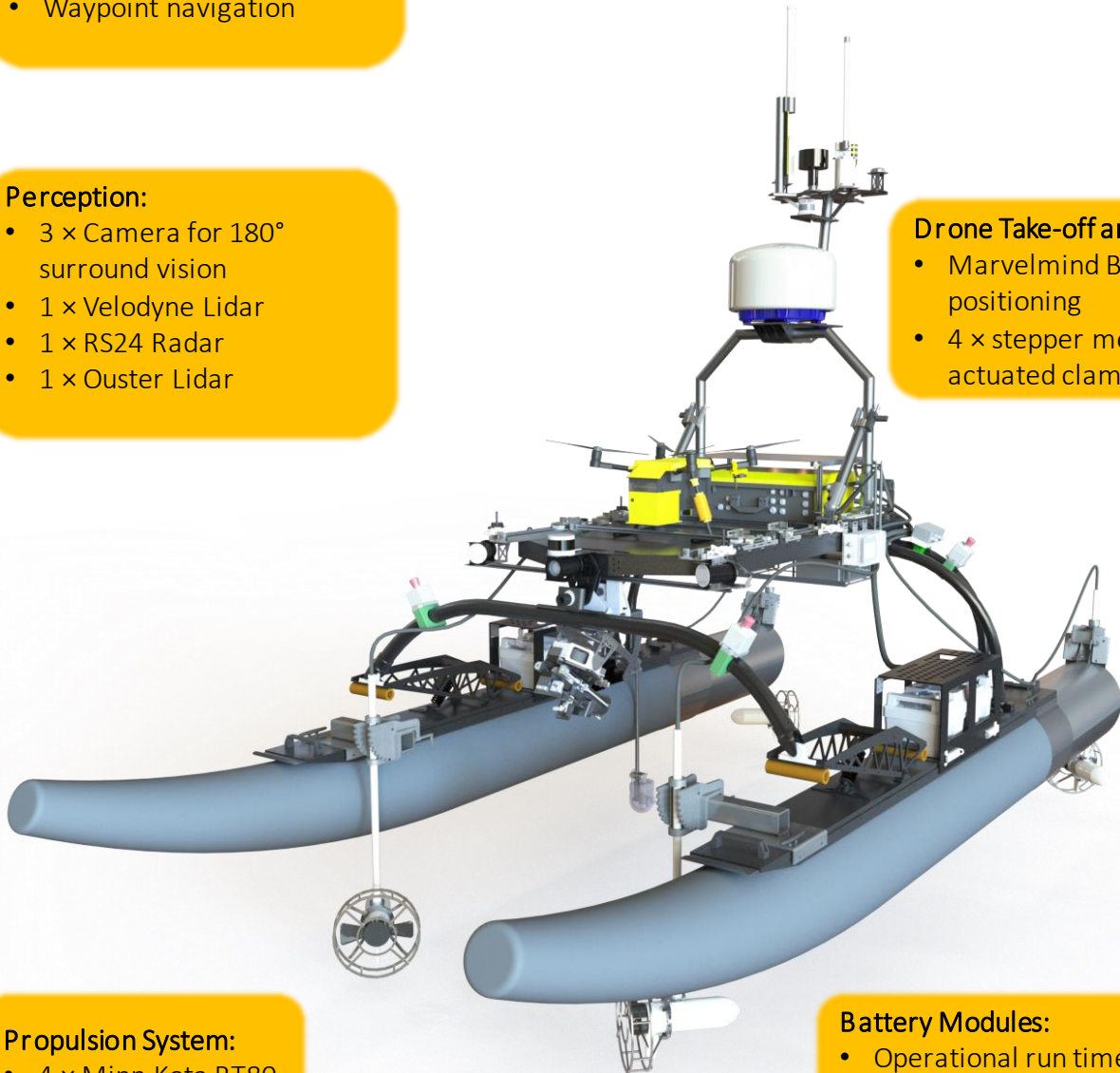
Autonomous Navigation:
- Eclipse-D: Miniature INS/GPS
- Sparton AHRS8 IMU

Perception:
- 3 × Camera for 180° surround vision
- 1 × Velodyne Lidar
- 1 × RS24 Radar
- 1 × Ouster Lidar

Drone Take-off and Landing:
- Marvelmind Beacons for positioning
- 4 × stepper motors for actuated clamps

Propulsion System:
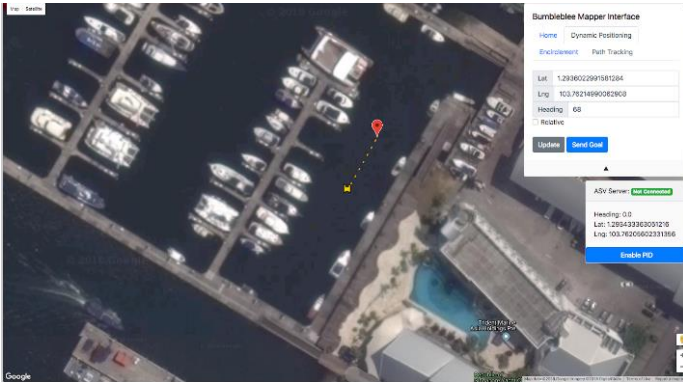- 4 × Minn Kota RT80 Trolling Motor

Battery Modules:
- Operational run time of 8 hours
- 2 × 104AH 25.9V Lithium-ion batteries

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Current Capabilities

Controls and Navigation:

ASV 3.0 has a vectored thruster configuration which allows for many precise maneuvers such as dynamic positioning, path tracking, encirclement and side movement. ASV 3.0 has achieved dynamic positioning capabilities of less than 0.5m accuracy for Sea State 3 conditions.

Perception and Collision Avoidance:

ASV 3.0 performs target recognition with the deployment of 3 cameras for 180° surround vision, 2 LiDARs for immediate collision avoidance and crowded environment mapping, as well as a radar for long-range collision avoidance and sea navigation. The software uses sensor fusion to combine the input from the camera, LiDAR and radar.
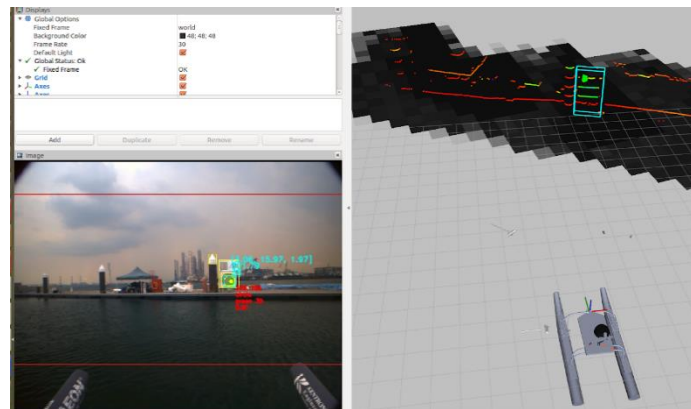
Drone Take off and Landing System

This latest upgrade allows ASV 3.0 to operate as a system of systems with the capability to launch and receive a UAV on the WAM-V's platform.

Training & Learning Programs

Team Bumblebee

Over the past few years, our members have been exposed to a wide range of hands-on work that includes 3D printing, turning/milling manufacturing processes, designing of circuit boards, developing of algorithms and systems integration. In addition, they also receive industry-level advice from our sponsors, giving the team great insights into the technologies they are working with.

Team Hornet

All new freshmen embark on a 6-month Training Programme under Team Hornet which will see them design a low-budget AUV. The goal of Team Hornet is a developmental one, allowing the freshmen to hone their technical skills in an environment not bounded by the requirements of the main vehicle.
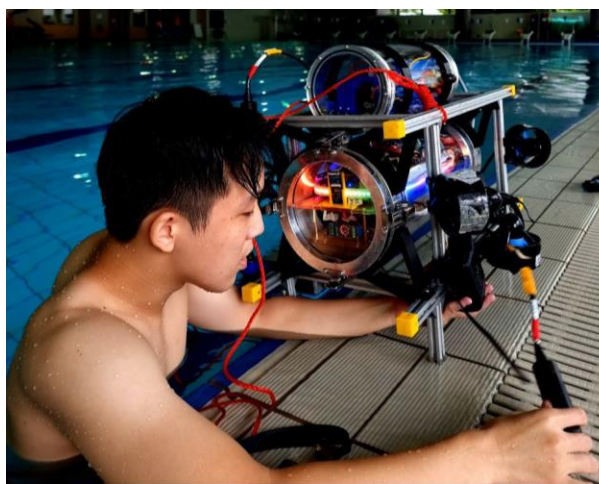
The program aims to balance learning and mentorship, offering Bumblebee prospectives a glimpse into the working and technical expectations of the main team. Their newly developed capabilities and expertise will allow them to be welcomed into the main team and given greater challenges and responsibilities.

Industry Visits

Team Bumblebee also actively takes part in industry visits to expand our knowledge. We visited private companies such as Fugro to learn about their operations as well as the systems used in their line of work. Similarly, we visited Bossard to gain a deeper insight into fasteners.

Not only does participation in outreach events help hone the soft skills of the team members, but it also gives our members insight into current developments occurring in the industry directly.

Outreach Programs

Lab Visits

Team Bumblebee also regularly conducts lab visits for fellow robotics teams and marine robotics enthusiasts. These are done in the collaborative spirit of learning.

School Sharing

Team members visit their alma maters to share their experiences in developing autonomous vehicles and participating in international competitions. We hope to inspire future batches of engineers to develop their passion in maritime robotics.

Sponsor's Appreciation

At the launch of a new vehicle, Team Bumblebee organizes a Sponsor's Appreciation Event to recognize the support that our sponsors provide. During this event, our members also take the opportunity to interact with our industry partners to not only network but exchange technical expertise.

Exhibitions

Every so often, Team Bumblebee is given the opportunity to present about marine robotics and the research that we do.

Previous exhibitions that we have attended include: RoboSoft 2023, SAUVC guest lecture and NUS IDP Exhibitions.

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Sponsorship

Platinum S$20000*

- **Extra Large Logo** displayed on vehicles
- Equipment Review on our blog
- **Priority** for test-bedding technologies
- **Access** to members' resume database
- Company logo on Journal Paper, Website, Apparels, Facebook

Gold S$10000*

- **Large Logo** displayed on vehicles
- Equipment Review on our blog
- **Access** to members' resume database
- Company logo on Journal Paper, Website, Apparels, Facebook

Silver S$6000*

- **Medium logo** displayed on vehicle
- Equipment Review
- Company logo on Journal Paper, Apparels, Website, Facebook

Bronze S$6000 & less*

- **Small logo** displayed on vehicle
- Company logo on Website and Apparels

*Inclusive of cash, equipment or software equivalent to the amount stated

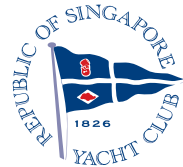**NUS** National University of Singapore

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Thank you to all our Sponsors for your continuous support!

Team Bumblebee is immensely thankful and grateful to all our wonderful sponsors. Our achievements and successes today would not have been possible without their support.

Title

Platinum

Gold

Silver

Bronze

Contact Us

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