BUMBLEBEE

Engineering Autonomous Systems of the Future

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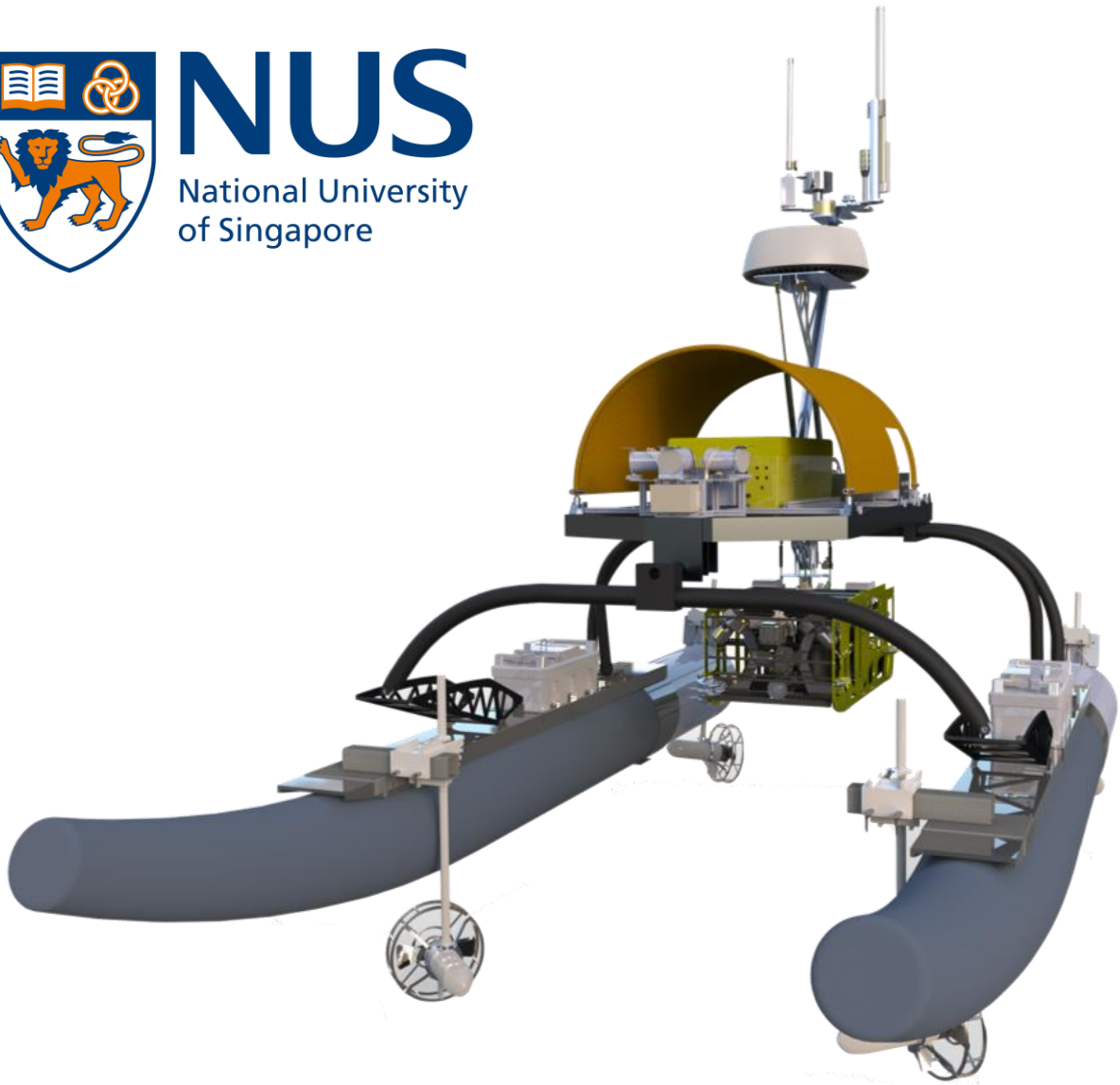
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2020 - 2021

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 2nd 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

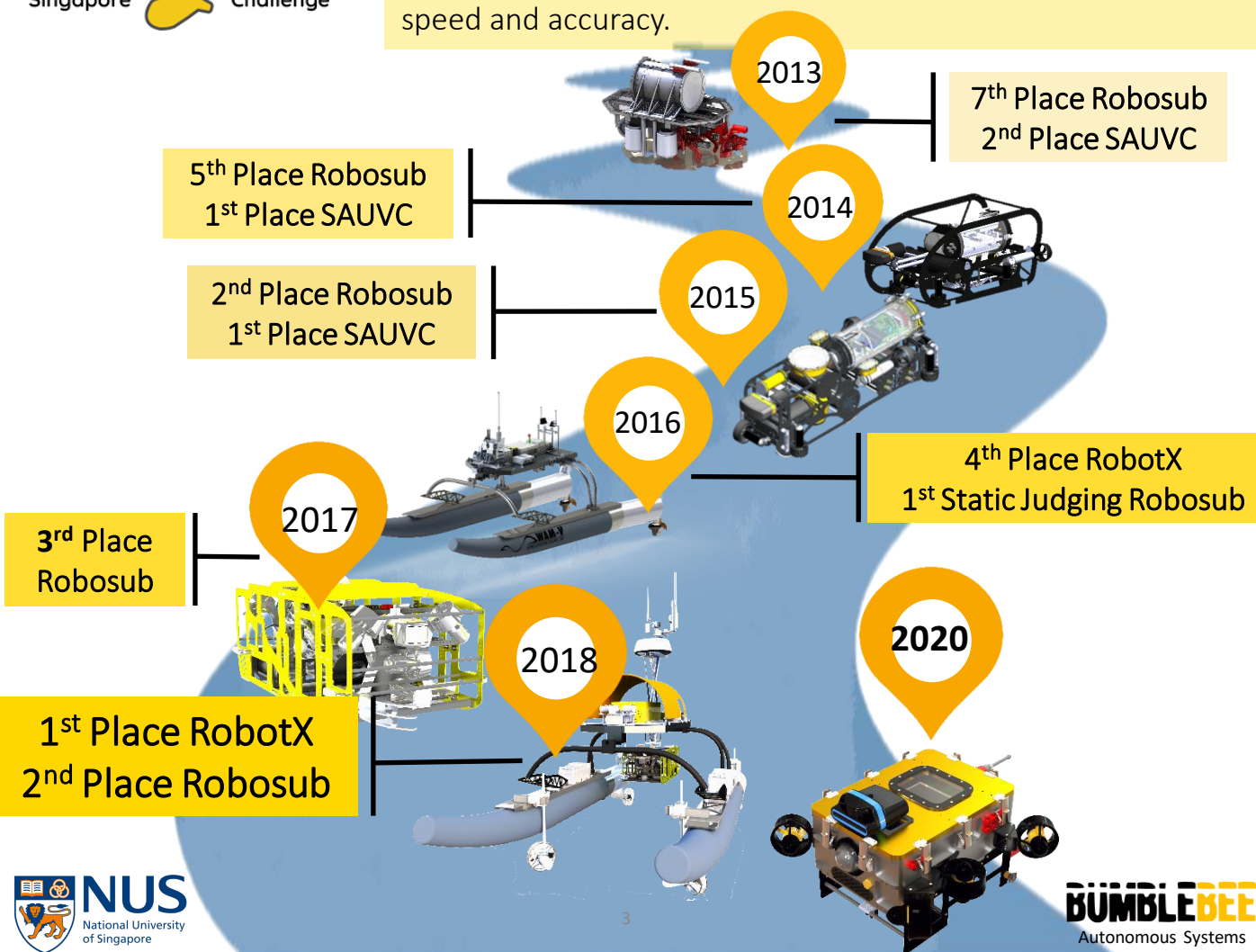| Inspire & Inculcate passion in Robotics and Engineering	Explore Research & Development in real-world scenarios	Provide opportunities to Learn & Lead

Our Achievements

Maritime RobotX Challenge serves to foster student interest in maritime autonomous robotic systems. Participants will build upon a Unmanned Surface Vehicle (USV) platform using sensors, control systems and integration of ASV/AUVs to complete a series of autonomous tasks including Launch and Recovery System (LARS).

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.

Singapore AUV Challenge (SAUVC) is an international AUV competition held in Singapore. It promotes the development of AUVs to solve real-world challenges, testing both vehicle speed and accuracy.

2013

7th Place Robosub
2nd Place SAUVC

5th Place Robosub
1st Place SAUVC

2014

2nd Place Robosub
1st Place SAUVC

2015

2016

4th Place RobotX
1st Static Judging Robosub

2017

3rd Place Robosub

2020

2018

1st Place RobotX
2nd Place Robosub

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Our Masterplan

BBAUV 3.5

- Modification for RoboSub 2021
- Last Competition for 3rd Generation AUV
- Re-designated as **BBAUV X**
  - R&D AUV Platform
  - Operational Ready for deployment

AUV 4.0

- Competition focused vehicle
  - Lighter and Smaller footprint
  - Higher Manoeuvrability
  - Multi DOF Underwater Manipulation

ASV 2.5 & LARS 2.0

- Improve Aerodynamics
- Sensors and Hardware Upgrade
- Industrial Collaboration

R&D

- Virtual Environment for Software Testbed
- Acoustic Localisation and Tracking
- Multi DOF Underwater Manipulator

Future Plans (New Competitions)

- RoboSub (Controlled Environment)
- Virtual RobotX'21

Jan'20 – Jul'20

Aug'20
Virtual
RoboSub'20

Sept'20 – Mar '21

Dec '20
Trial ASV 2.5

Dec'20
Trial LARS 2.0

Apr'21
Launch 4.0

Apr '21
SAUVC '21

Apr'21 – Jul'21

Aug '21
Robosub '21

Aug '21 – Dec '21

Dec '21
Virtual RobotX'21

Jan '22 – Dec '22

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Vehicle Design

BUMBLEBEE AUV 4.0

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

6 Degrees of Freedom with forward speed of 1m/s

Dynamic positioning for the AUV to station-keep at a single spot with no operator intervention

Autonomous inertial navigation with capability to perform waypoint navigation in open waters

Competition-focused design of AUV, that is compact, rectangular and low-weight

Acoustic localization with a hydrophone array to localize to an underwater pinger
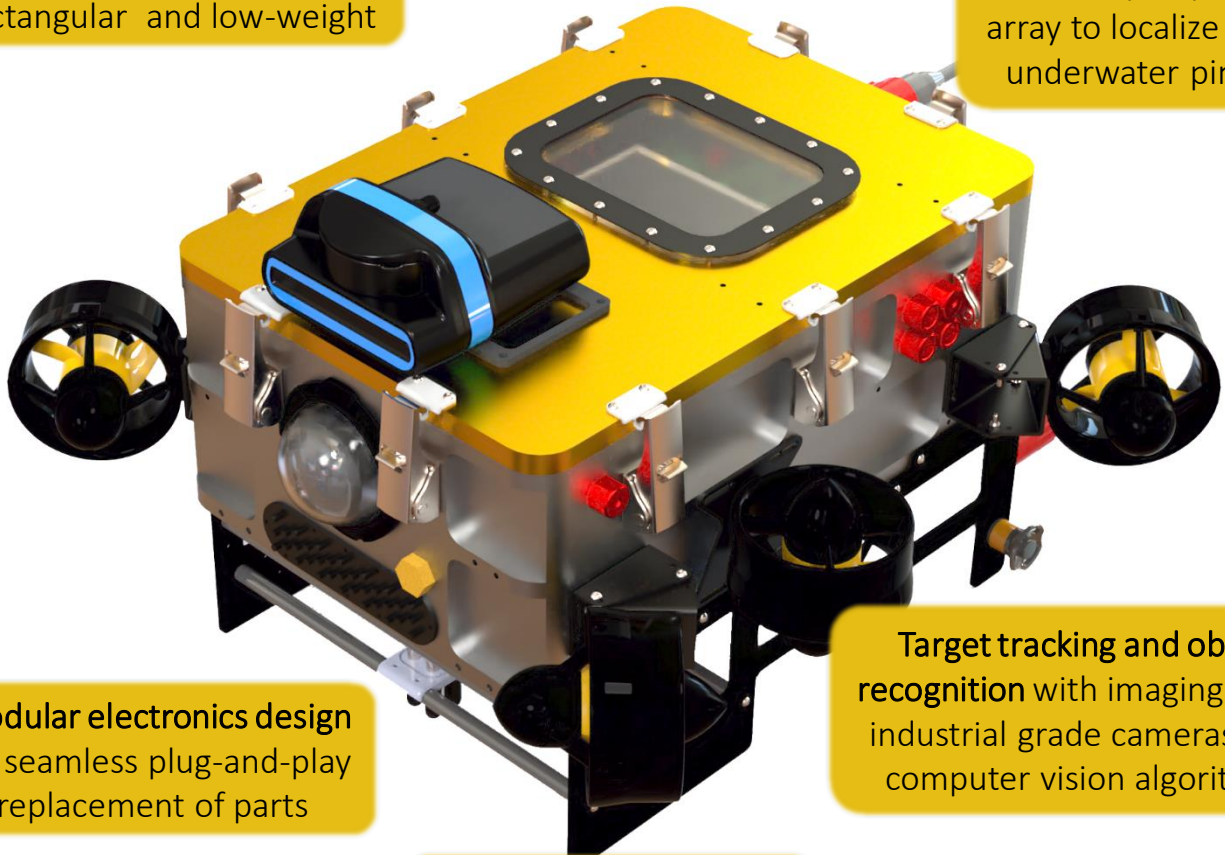
Modular electronics design for seamless plug-and-play replacement of parts

Target tracking and object recognition with imaging sonar, industrial grade cameras, and computer vision algorithms
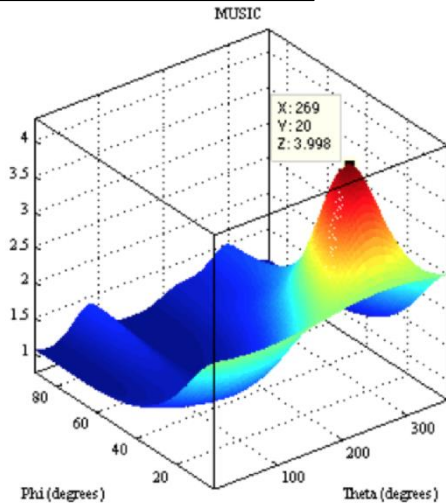
30m depth rated system

Robotic manipulation capabilities including grabber, dropper and torpedo launchers

2.5 hours operational lifetime in strong currents

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Current Capabilities

Acoustic Localisation:
Bumblebee 4.0 has the capability to detect and localise to an underwater locator beacon (ULB) from far. This ULB is similar to the beacons placed in an aircraft black box. Using a hydrophone array and a digital processing chain, the on-board hardware and software processes the acoustic signals received from the beacon with the MUSIC (MUltiple SIgnal Classification) algorithm and provides the localisation capabilities for the AUV to locate to the ULB.

Underwater Perception and Tracking:
Bumblebee 3.5 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 for highly robust perception and tracking of objects underwater.
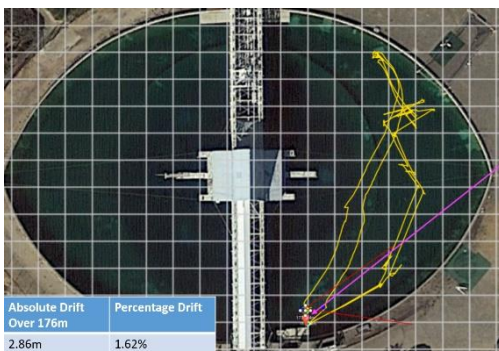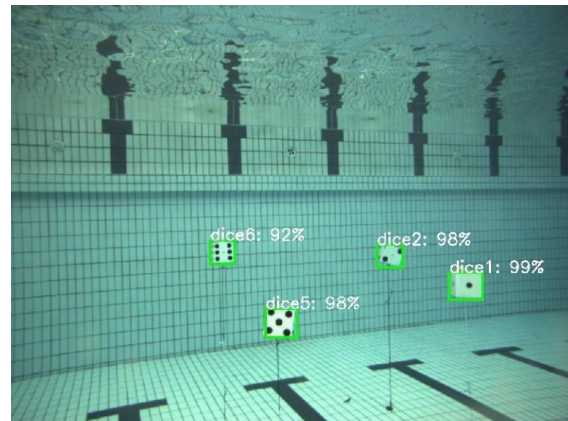
Navigation Suite:
The navigation sensor suite consists of a 9 axis Sparton IMU, 6 axis STIM300 IMU, a DVL and a barometric pressure depth sensor. An Error state Kalman Filter is used to obtain much higher accuracy than each sensor can provide independently. The AUV navigation system is capable of performing accurate local navigation and global navigation.

Autonomous Manipulation:
With a highly accurate navigation suite and robust object perception and tracking, the AUV is capable of fully autonomous manipulation of objects. 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

Datalink: Up to 500Mbps 5GHz radio for high bandwidth data transmission
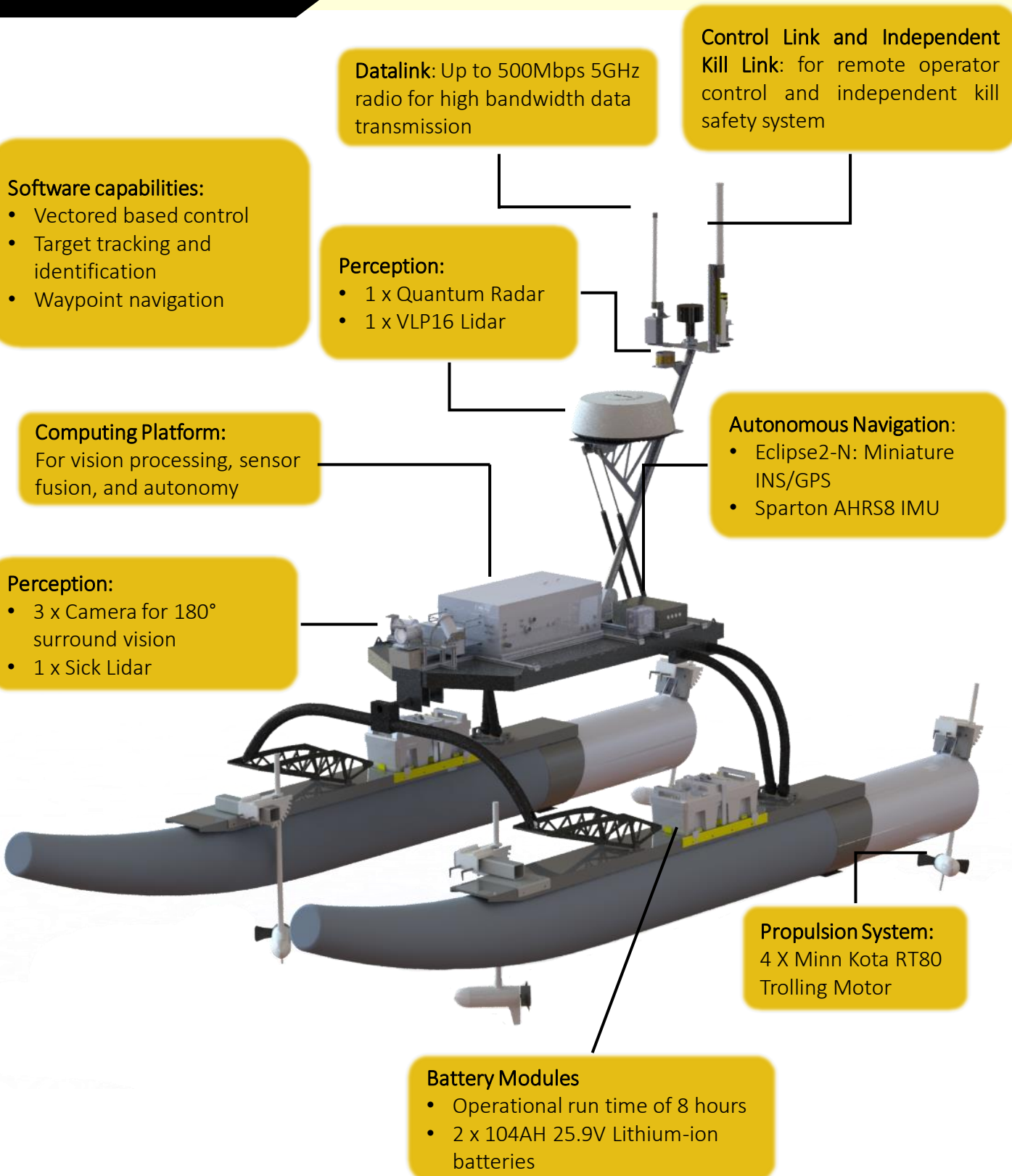
Control Link and Independent Kill Link: for remote operator control and independent kill safety system

Software capabilities:
- Vectored based control
- Target tracking and identification
- Waypoint navigation

Perception:
- 1 x Quantum Radar
- 1 x VLP16 Lidar

Computing Platform:
For vision processing, sensor fusion, and autonomy

Autonomous Navigation:
- Eclipse2-N: Miniature INS/GPS
- Sparton AHRS8 IMU

Perception:
- 3 x Camera for 180° surround vision
- 1 x Sick Lidar

Propulsion System:
4 X Minn Kota RT80 Trolling Motor

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

Current Capabilities

BUMBLEBEE ASV 2.0

Controls and Navigation:
ASV 2.0 has a vectored thruster configuration which allows for many precise manoeuvres such as dynamic positioning, path tracking, encirclement and side movement. ASV 2.0 has achieved dynamic positioning capabilities of less than 0.5m accuracy for Sea State 3 conditions.

Perception and Collision Avoidance:
ASV 2.0 performs target recognition with the deployment of 3 cameras for 180° surround vision, 2 LiDAR for immediate collision avoidance and crowded environment mapping, and radar for long range collision avoidance and sea navigation. The software uses sensor fusion to combine the input from the camera, LiDAR and radar.
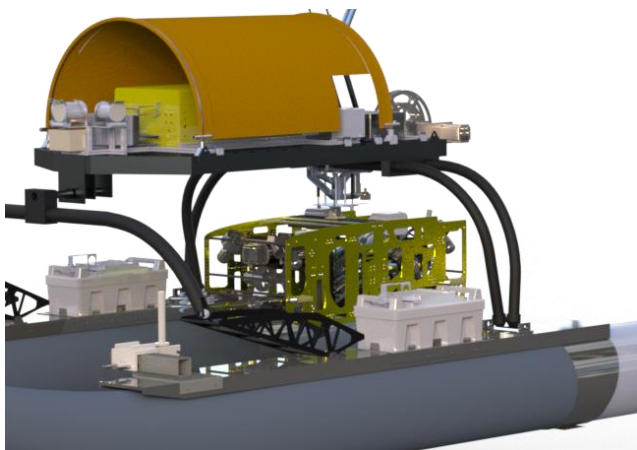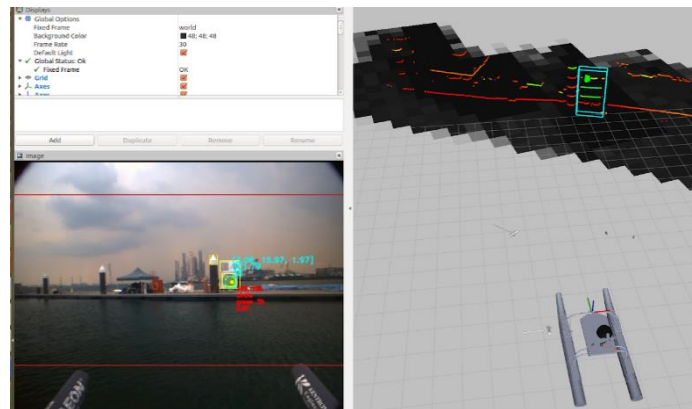
Launch and Recovery System:
This latest upgrade allows ASV 2.0 to operate as a system of systems with the capability to launch and recover an AUV without the need to deploy a manned ship for the operation.

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Training and Learning Programs

Team BumbleBee

Over the past few years, our students 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, our members also receive industry level advice from our sponsors, giving the team great insights of 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 designing a low-budget AUV. The goal of Team Hornet is a developmental one, allowing the freshmen to hone their technical skill 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.

Outreach

Team Bumblebee also actively takes part in outreach events to educate the public about autonomous systems. Some of the showcase events we attended are Singapore Week of Innovation and Technology (SWITCH), and Innovfest Unbound, as well as Media Features.

Not only does participation in outreach events help hone the soft skills of the team members, it also continually enhances Team Bumblebee's brand name.

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Sponsorship

Platinum $20000*

- **Huge 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 $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 $6000*

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

Bronze $3000*

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

Supporting Organizations <$3000*

- **Mini Logo** displayed on vehicle
- Company logo on Website and Apparels

*Inclusive of cash or equipment equivalent of the amount stated

Overall Budget Breakdown

Item	FY 20/21	FY 21/22 (projected)	FY 22/23 (projected)
Competition Expenses	0	0	178 000
AUV 4.0	15 000	35 500	12 500
ASV 2.5 + LARS 2.0	6 000 + 2000	70 000 + 31 000	16 500 + 9 000
Operations	5 000	38 000	58 000
Total (SGD)	**28 000**	**174 500**	**274 000**

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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 be possible without their support.
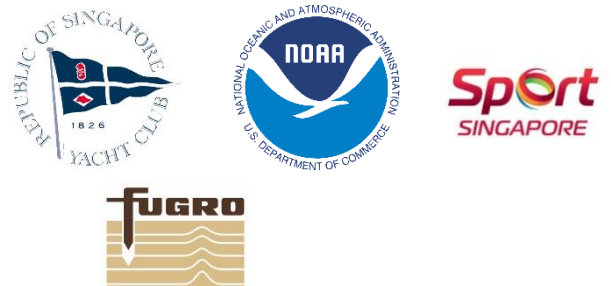
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