robotx
CHALLENGE

2022

TEAM HANDBOOK

v1.0 (December 2021)

Introduction

Welcome to the frontlines of innovation at the 2022 Maritime RobotX Challenge!

This Team Handbook contains information that teams will need to compete at the 2022 Maritime RobotX Challenge. It includes task descriptions, rules, and requirements, and other guidance and specifications. Teams are encouraged to read this document for a thorough understanding of what will be necessary to compete effectively.

What is RobotX? The Maritime RobotX Challenge is a biennial international competition hosted by RoboNation and established to foster students' interest in robotic systems operating in the maritime environment. Within the RobotX competition framework, teams are challenged to transform the Wave Adaptive Modular-Vessel (WAM-V) into an Autonomous Maritime System (AMS), developing and integrating all subsystems needed to accomplish a series of tasks on the Autonomy Challenge course. Teams must also document their designs as described in this Team Handbook.

Why RobotX? The goal of the Maritime RobotX Challenge is to expand the community of researchers and innovators capable of substantive contributions to the emerging field of autonomous, unmanned, multi-domain vehicles.

Why compete in RobotX? Participants of the Maritime RobotX Challenge may expect to:

- Increase technical proficiency;
- Establish valuable professional connections; and
- Enjoy the satisfaction of learning and collaborating while competing at a world-class level.

The Maritime RobotX Challenge builds upon the successful implementation of other student robotics competitions such as RoboBoat and RoboSub. Teams are encouraged to learn from their participation in competitions such as these and apply their skills to the advanced challenges presented in RobotX.

Maritime autonomous technology is critical to monitoring and healing our oceans. Developing the human resource to expand this effort is even more essential.

2022 ROBOTX ORGANIZERS

The 2022 Maritime RobotX Challenge is hosted by RoboNation, in collaboration with the United States Office of Naval Research (ONR), the Australian Defence Science and Technology Group (DSTG), and the Next Generation Technologies Fund (NGTF).

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Version Updates

Version	Changes	Date
v1.0	First release of Maritime RobotX Challenge 2022 Team Handbook, based on “Rules & Requirements” and “Task Descriptions & Specifications” documents from 15 June 2021.	07 December 2021

Table 1. Document Version Log

SECTION 1: RobotX Overview

Maritime RobotX Challenge 2022 *www.robotx.org*

1.1 Dates & Venue

The 2022 Maritime RobotX Challenge (RobotX 2022) will be conducted 11-17 November 2022 at the Sydney International Regatta Centre Island, Penrith in New South Wales, Australia. Multiple courses will be used for the competition (Figure 1).

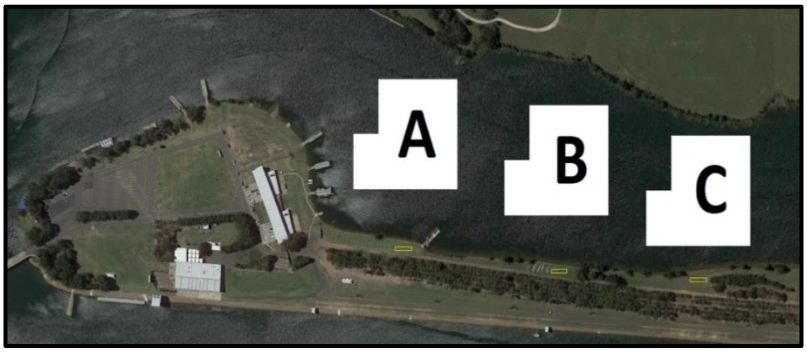

Figure 1: Preliminary Course Layout

Health and Safety

Due to the evolving nature of COVID-19 related travel and tourism guidance, teams are encouraged to stay apprised of updated rules and regulations for entering Australia and New South Wales (NSW). For more information, see Section 5: How to Compete.

1.2 Competition Structure

The competition includes:

- Autonomy Challenge demonstrate safety and performance; and
- Design Documentation presents each team's work and system design

1.3 Eligibility

Student teams from anywhere in the world are eligible to participate. All teams must use a WAM-V to compete.

1.3.1 Eligibility Details & Team Composition

- Teams must include a combination of students, faculty, industry partners, and/or government partners.
- The majority of the team members must be college-level students. Teams may also include high school students. Interdisciplinary teams are encouraged.
- All teams must include a member from industry.
    - Industry team members may provide any combination of technical support, financial support, facility support, or other resources.
    - Former students and team members who have graduated and joined industry are encouraged to continue as team members and would fulfill the industry member requirement.

SECTION 2: Competition

Maritime RobotX Challenge 2022 *www.robotx.org*

This section includes general competition information for the 2022 Maritime RobotX Challenge (RobotX 2022) including competition schedule, Design Documentation, and Autonomy Challenge.

2.1 Competition Schedule

RobotX 2022 includes:

- **Design Documentation:** Teams provide a variety of design documentation prior to and on-site at competition.
- **Autonomy Challenge:**
    - **Qualifying Round:** Teams assemble and test their AMS, participate in initial safety inspections, practice, and qualify for Semi-Finals in the water on the Qualifying and Practice Courses.
    - **Semi-Finals Round:** Teams complete runs on the Semi-Finals Courses to qualify for the Finals Round.
        - The Semi-Finals Course will be available for use after at least one team has qualified for the Semi-Finals Round.
        - All Semi-Final Rounds will be completed by 16 November.
    - **Finals Round:** Teams complete runs on the Finals Course.

Date	Event	Location
September-November	Design Documentation (prior to on-site competition)	Online
11 November	Team Orientation Vehicle Assembly Licensed Pilot Flight Tests	Sydney International Regatta Centre
12 November	Qualifying and Practice Course Open Licensed Pilot Flight Tests	
13 - 15 November	Qualifying and Practice Course Open Semi-Finals Course Open (after at least one team has qualified) Design Documentation Presentations System Assessment	
16 November	Qualifying and Practice Course Open Semi-Finals Course Open Semi-Finals Round Completed	
17 November	Finals Round Awards	

Table 2. RobotX 2022 Schedule

2.1.1 Daily Events

Each day starts and ends with a mandatory team meeting conducted by the Technical Directors. Team Leads are required to attend. All participants are strongly encouraged to attend.

- **Morning Meetings:** Technical Directors present the Plan-of-the-Day. Teams have an opportunity to provide feedback and ask questions.
- **Evening Meetings:** Technical Directors summarize the day's events, describe any course changes for the following day, and teams are encouraged to provide feedback.

2.3 Design Documentation

Prior to the on-site competition, teams provide a variety of design documentation. During the competition, teams provide an oral presentation and their AMS will be assessed by subject matter expert judges.

2.3.1 Delivered Prior to On-Site Competition

The following design documentation is delivered prior to the on-site competition. Submission details can be found in Section 5.2 Pre-Competition Requirements.

Team Website

Teams are required to submit a website in English that documents their team, system design, and competition approach, addressing the following areas:

1) Website Content: Layout and detailed contents of the website are left for the teams to develop; however, the team website should include:

- Team name and contact information
- Team name, picture and contact information for each contributing member
- System diagrams
- Instructional/Informative videos
- Procedures (text, images)
- Design decision documentation (text, images, videos)
- Blogs for historical records of build progress
- List of sponsors with logos

2) Website Quality: Websites are often the first impression of a project. Potential supporters such as supervisors, sponsors, or advisors must find the website visually appealing and easy to navigate. Development of the website should include careful consideration of user experience, including:

- Written in English, or English translation provided
- Clear prioritization of key content
- Site search functionality
- Basic design elements: contrast, repetition, alignment and grouping to organize/highlight content
- User accessibility, as defined by the W3C Web Accessibility Initiative: www.w3.org/WAI
- Cross browser compatibility for modern web browsers (Chrome, Firefox, Safari, MS Edge)
- A mobile friendly display

Technical Design Paper
Teams are required to submit a technical design paper in English that describes the design of their USV and UAV autonomy systems, propulsion system, and control systems, as well as strategies for their approach to the tasks. This paper should include the rationale for their design choices. An editable template will be available on the RobotX website at a later date: robotx.org/2022.

Team Introduction Video
Teams are required to submit a video introducing their team members and highlighting their team personality.

Format Requirements:
1. Teams must abide by all applicable social distancing protocols.
2. Video must be conducted in English or include subtitles in English.
3. Video must be no more than three (3) minutes in length.
4. Video may include graphics, vehicle performance and/or simulation. These elements will not affect scoring but may be utilized as tools within the video.
5. Videos must be hosted by team:

    OPTION 1: Hosted on the team's YouTube Channel.
    - Videos consolidated in a RoboNation YouTube Playlist.
    - Must follow all YouTube Rules & Policies, including appropriate music copyright management.

    OPTION 2: Embedded on Team Website.
    - If teams do not have access to YouTube, the option to host/embed video on the Team Website is available.

2.3.2 Delivered During On-Site Competition

Design Documentation Presentation
Teams give a design documentation presentation to a panel of judges. Each team must present what they plan to do on the course and how that plan impacted their design and selections. This oral presentation must be conducted in English and may include visual aids. This presentation includes:
- Team Intro Video (3 minutes)
- Team presentation (25 minutes)
- Judge question & answer (10 minutes)
- Team & judge dialogue (7 minutes)

Teams receive an assigned 45-minute presentation time on 13, 14, or 15 November.

System Assessment
Judges inspect the team's AMS and assess technical design, craftsmanship, technical innovation, and visual impact of the design. Team members should be present to answer technical questions posed by the judges during this inspection. The System Assessment schedule will be provided at the competition site.

Teams receive an assigned 30-minute assessment time on 13, 14, or 15 November.

2.2 Autonomy Challenge

These challenges showcase AMS performance through autonomous completion of a range of tasks designed to represent research and real-world applications.

The task elements on the Autonomy Challenge differ from the equipment used in previous RobotX, RoboBoat, and RoboSub competitions. Under each task description is a table that includes the specifications that will be used for the RobotX 2022.

2.2.1 Mandatory Activities

Prior to entering any of the Autonomy Challenge courses, teams are required to demonstrate their ability to safely operate their autonomous systems (USV and UAV).

2.2.2 Qualifying Round

Qualifying and Practice Courses are available for teams to practice, demonstrate proficiency, and qualify for the Semi-Finals Round. During this round, multiple courses are available, and each course includes all tasks. Teams may schedule times to practice or qualify on individual tasks on these courses.

Multiple teams may be on a Qualifying and Practice Course at the same time. Once a team demonstrates proficiency on individual tasks, they qualify for the Semi-Finals Round. Teams that qualify for the Semi-Finals Round may continue to use the Qualifying and Practice Courses for practice on individual tasks. (Section 2.6 Qualifying Round)

2.2.3 Semi-Finals Round

Teams that qualify for the Semi-Finals will have access to the Semi-Finals Courses. Teams operating on the Semi-Finals Courses may earn points towards entry into the Finals Round. Only one team may be on a Semi-Finals Course at a time. During the Semi-Finals Round, teams may attempt tasks in any order and must operate autonomously for the entire run. (Section 2.7 Semi-Finals Round)

2.2.4 Finals Round

During the Finals Round, successful completion of the full Finals Course requires the AMS to use information from multiple task elements. The AMS must demonstrate the ability to collect and use information from individual tasks to complete other tasks. The AMS must operate autonomously for the entire run. (Section 2.8 Finals Round)

2.4 Mandatory Activities

Prior to entering any of the Autonomy Challenge courses, teams must demonstrate their ability to safely control their autonomous systems (USV and UAV).

2.4.1 USV Demonstration

Static Safety Inspection

Prior to deploying in the water, the USV must meet all safety requirements. At a minimum, the following areas will be checked:

- Buoyancy Pods
- Emergency Stop System (location of switches, on-board and remote functionality)
- Tow points and tow line are clearly marked (forward and aft)
- Lift points are clearly marked
- Safety issues related to propellors or hazards
- All systems are properly secured

More details on system requirements are available in Section 4.3.1 USV Requirements.

Dynamic Navigation Demonstration

After the USV Static Safety Inspection, teams must demonstrate that the USV can autonomously maintain positive control and effectively detect and navigate the channel markers. The USV must successfully navigate through two pairs of red and green buoys in a fully autonomous manner. This demonstration is a mandatory requirement to enter the Autonomy Challenge course for Qualifying and Practice, Semi-Finals and Finals Rounds. The Dynamic Navigation Demonstration may be completed with or without the UAV on-board the USV.

Teams may be required to repeat this demonstration each time the USV is re-deployed in the water.

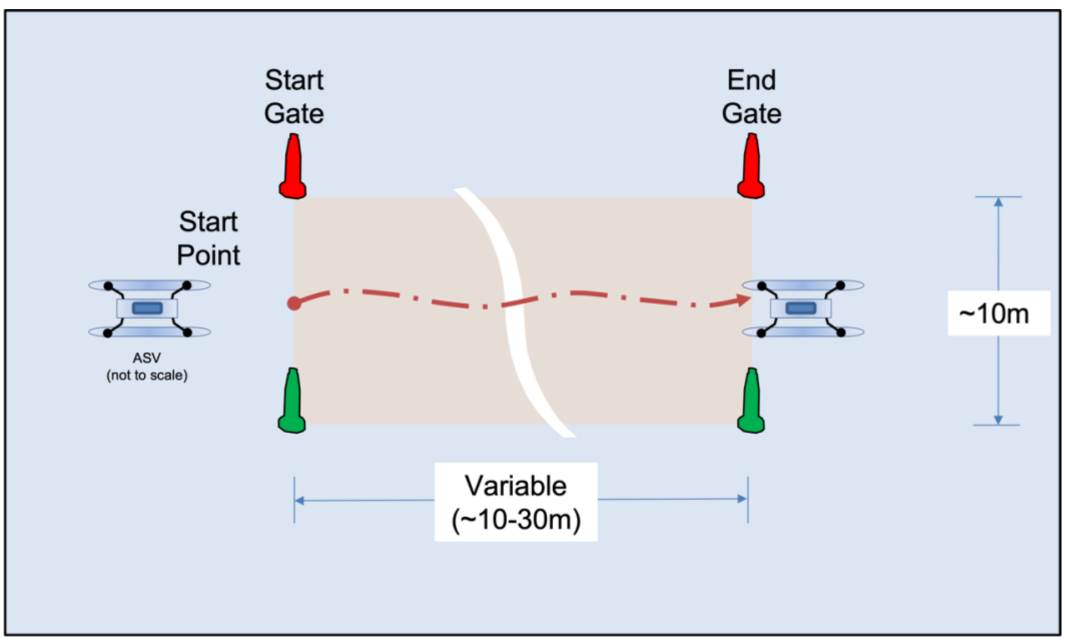

Figure 2. Dynamic Navigation Demonstration

Task elements for Dynamic Navigation Demonstration are detailed in Table 3 below.

Task Element	Description	Color	Ht. Above Waterline	Base Diam.
Start Gate Port Marker	650mm Dia. Marker Buoy	Stock Red	850mm	650mm
Start Gate Starboard Marker	650mm Dia. Marker Buoy	Stock Green	850mm	650mm
End Gate Port Marker	650mm Dia. Marker Buoy	Stock Red	850mm	650mm
End Gate Starboard Marker	650mm Dia. Marker Buoy	Stock Green	850mm	650mm
Buoys are supplied from Marine Buoys Australia: www.marinebuoysaustralia.com				

Table 3. Task Elements for Dynamic Navigation Demonstration

2.4.2 UAV Demonstration

Pilot Certification and Flight Test

Teams must meet all requirements as outlined by the Australian Civil Aviation Safety Authority (CASA) with respect to pilot licensing for this class of UAVs. The CASA refers to Unmanned Aircraft as Remotely Piloted Aircraft (RPA) (commercial use) or model aircraft (recreation use). It is recommended for teams to have 2-3 Licensed Pilots.

Prior to competition, teams must submit a logbook of flight hours and pilot license issued by their respective country for each Licensed Pilot, as outlined in Section 5.2 Pre-Competition Requirements.

During the first competition days, 11-12 November, each team's Licensed Pilot is required to conduct and pass a flight test. The flight test requirements will be provided at a later date.

Static Safety Inspection

Prior to being cleared for flight, the UAV must pass a static safety inspection. At a minimum, the following areas will be checked:

- Meets the requirements for size and weight;
- Safety issues related to propellors or hazards; and
- All subsystems are properly secured.

More details on system requirements are available in Section 4.3.2 UAV Requirements.

Dynamic Governor Demonstration

The demonstration will be conducted in remote-control mode. The UAV will be operated by the team's Licensed Pilot. The UAV must demonstrate:

- Flying within the limits of a pre-defined area;
- Flying below a flight ceiling limit; and
- A 'return to home' override.

Teams that meet all the above requirements may proceed to the tasks in the Qualifying and Practice Round which utilize a UAV.

2.5 Task Descriptions

This section provides details of the RobotX 2022 Autonomy Challenge tasks. During the Qualifying and Practice Round, teams attempt individual tasks to earn the opportunity to advance to the Semi-Finals Round. Teams are encouraged to develop a strategy approaching these tasks that best suits their AMS.

2.5.1 Task 1 – Situational Awareness & Reporting

The Communications Protocol provides a standardized protocol through which heartbeat and task information are communicated to judges and the Technical Director team (see Appendix C).

- While operating within any Autonomy Challenge course, the AMS transmits a 'heartbeat' message.
- While attempting Autonomy Challenge tasks, the AMS transmits task specific messages, including a specific report as appropriate.

Task Description

At each Autonomy Challenge course operation tent, teams are provided with a wired RJ45 connection. Information from the team's Operator Control Station (OCS) is transmitted to the Technical Director network, using this wired connection. Teams are expected to provide their own wireless link for information exchange between the AMS and their OCS. Details regarding communications protocols can be found in Appendix C: Communications Protocol.

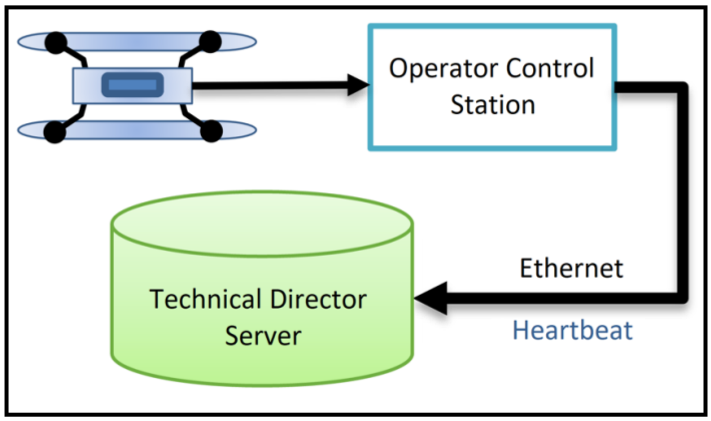

Figure 3: AMS Heartbeat

2.5.2 Task 2 – Entrance and Exit Gates

The Entrance and Exit Gates task consists of three gates with an underwater beacon within each gate. The AMS detects the active underwater beacon, transits through the gate with the active beacon, then circles the black buoy located beyond the gate, and returns through the gate with the active underwater beacon.

Task Description

There are four marker buoys designating the three gates:

- Gate 1 is bounded by a red buoy and a white buoy;
- Gate 2 is bounded by two white buoys; and
- Gate 3 is bounded by a white buoy and a green buoy (see Figure 4).

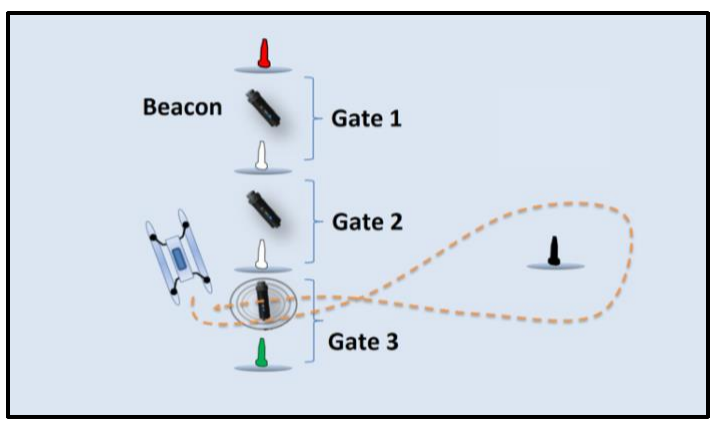

Figure 4: Example Entrance and Exit Gate Task

In the middle of each gate, there is a submersed beacon. Beacon specifications are available in Appendix B: Beacon Specifications. The space between each gate is approximately 10m. The black buoy is located within 20m of the gates.

Task Elements
Task elements for the Entrance and Exit Gates task are detailed in
.

Task Element	Description	Color	Ht. Above Waterline	Base Diam.
Port Marker	650mm Dia. Marker Buoy	Stock Red	850mm	650mm
Middle Marker (Quantity: 2)	650mm Dia. Marker Buoy	Stock White	850mm	650mm
Starboard Marker	650mm Dia. Marker Buoy	Stock Green	850mm	650mm
Buoy to Circle	650mm Dia. Marker Buoy	Black	850mm	650mm
Buoys are supplied from Marine Buoys Australia: www.marinebuoysaustralia.com				

Table 4: Task Elements for Entrance and Exit Gates

2.5.3 Task 3 – Follow the Path

The Follow the Path task consists of a set of white marker buoys, followed by four pairs of red and green marker buoys, followed by a set of white marker buoys. The AMS detects the pathway designated by the marker buoys and navigates through the winding pathway without contacting any of the marker buoys or any obstacles which may be placed in the vicinity. Teams may use a UAV to accomplish this task.

Teams that wish to experience a virtual version similar to this task may visit https://github.com/osrf/vrx.

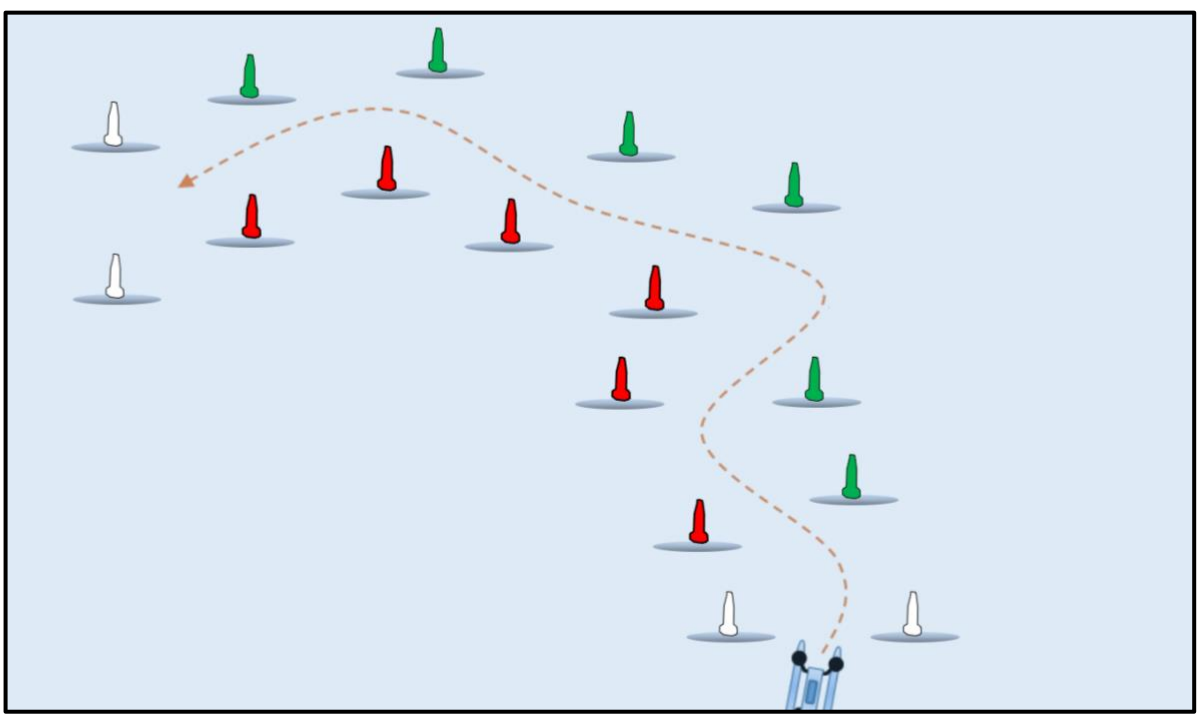

Figure 5: Example Follow the Path Task

Task Description

The white marker buoys designate the start line and end line of the Follow the Path task. The red and green pairs of marker buoys are located in between the start and end lines. Black, round obstacle buoys are placed within the task boundary at random, which may be within the pathway. The AMS may start this task at either end of the pathway and continue along the pathway until passing through all six pairs of red and green marker buoys and then exiting the pathway through the remaining set of white marker buoys.

Task Elements

Task elements for the Follow the Path task are detailed in Table 5.

Task Element	Description	Color	Ht. Above Waterline	Base Diam.
Field Boundary Marker	470mm Dia. Round Foam Filled Barrier Buoy	Stock Orange	470mm	470mm
Path Start/End (Quantity: 4)	650mm Dia. Marker Buoy	Stock White	850mm	650mm
Path Marker (Quantity: 6)	650mm Dia. Marker Buoy	Stock Red	850mm	650mm
Path Marker (Quantity: 6)	650mm Dia. Marker Buoy	Stock Green	850mm	650mm
Obstacle	470mm Dia. Round Buoy	Black	470mm	470mm
Buoys are supplied from Marine Buoys Australia: www.marinebuoysaustralia.com				

Table 5: Task Elements for Follow the Path

2.5.4 Task 4 – Wildlife Encounter – React and Report

The Wildlife Encounter – React and Report task consists of three marine life markers floating at the surface of the water. Each marine life marker consists of a flat piece of plywood containing an image painted with a unique spectral signature. The images represent Australian marine life and include a platypus, a turtle, and a crocodile. Each image may be identified and classified using Hyperspectral Imaging Spectroscopy (HSI).

An UAV may be used to accomplish this task; and may be the only way to successfully do so.

After the AMS detects and classifies the Hyperspectral Images painted on the face of the marine life markers, the USV will use the information to maneuver as follows:

- Circle the platypus in a clockwise direction
- Circle the turtle in an anticlockwise direction

In addition, the AMS will report the location of the platypus, turtle, and crocodile. Data and imagery collected during this task is submitted to the judges for review.

Task Description

Three marine life markers are affixed on top of floating docks, parallel to the water surface. The marine life markers are placed at random locations within the task area. The marine life markers are made from a 1.5m x 1.5m flat piece of plywood on which a distinct coating with a unique spectral signature has been applied. Each marine life marker will have a unique coating to represent a different marine animal (platypus, turtle, or crocodile). To an RGB camera, these coatings may be indistinguishable.

For the reporting component of this task, there are specific data reporting requirements; the format and submission timeline will be provided at a later date.

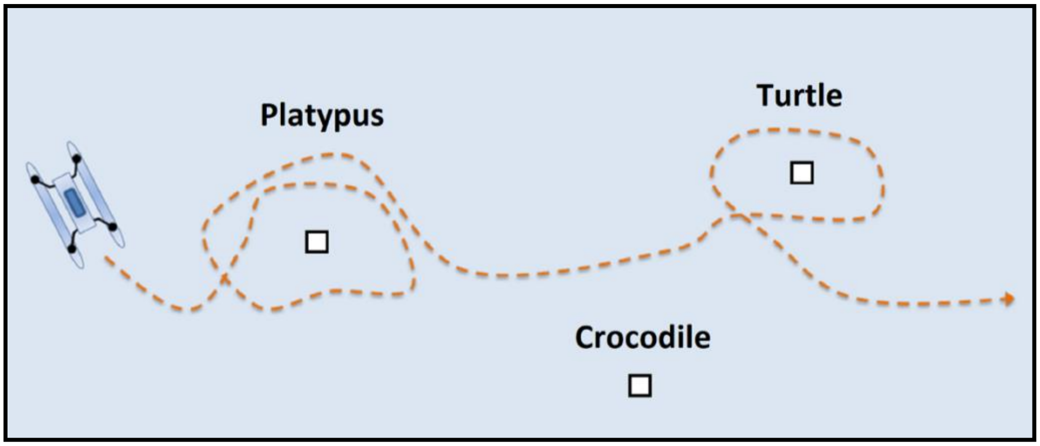

Figure 6: Example Wildlife Encounter – React and Report Task

Task Elements

Task elements for the Wildlife Encounter – React and Report task are detailed in Table 6.

Task Element	Description	Color	Ht. Above Waterline	Base Dimensions
Marine Life Markers	Horizontal plywood painted with paints with different spectral signatures. The plywood sits on top of a platform of floating dock bricks of similar dimensions.	N/A	N/A	1.5m x 1.5m
Field Boundary	470mm Dia. Round Buoy	Stock Orange	470mm	470mm
Floating Dock	Floating platform that holds Marine Life Markers	N/A	N/A	1.5m x 1.5m
HSI Camera	An hyperspectral camera will be provided at no cost to registered teams that wish to use the RoboNation-furnished camera to undertake this challenge. (Appendix E: Hyperspectral (HSI) Cameras)			

Table 6: Task Elements for Wildlife Encounter – React and Report

2.5.5 Task 5 – Scan the Code

The Scan the Code task consists of a floating platform with a light bar which displays a sequence of RGB lights. The AMS observes the three-light sequence displayed, and reports the colors observed and the sequence of their occurrence. The AMS may use information about the light sequence to complete other tasks as described in Section 2.7 and Section 2.8.

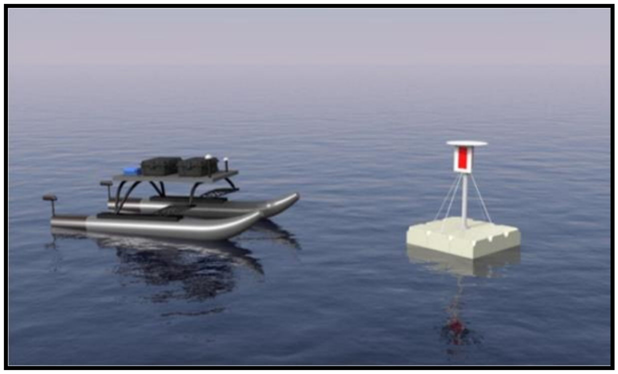

Figure 7: Example Scan the Code Task

Task Description

A light bar is affixed to a vertical pole rising above a floating platform. The light bar is within 3m above the water surface. The floating platform is located within an unmarked search area of approximately 40m x 40m. The light bar appears black when it is inactive. When activated the light bar displays colors one at a time to randomly generate a three-color sequence (e.g. red-green-blue). A single color appears for 1 second, followed by a second color displayed for 1 second, followed by a third color displayed for 1 second. After which the lights remain off (black) for 2 seconds. This same pattern is repeated continuously. A color may be repeated in the three-color pattern, but the same color will not appear twice in a row.

1st Color	2nd Color	3rd Color
RED	GREEN	BLUE
RED	BLUE	GREEN
BLUE	RED	GREEN
BLUE	GREEN	RED
GREEN	BLUE	RED
GREEN	RED	BLUE
RED	GREEN	RED
RED	BLUE	RED
GREEN	RED	GREEN
GREEN	BLUE	GREEN
BLUE	GREEN	BLUE
BLUE	RED	BLUE

Figure 8. Possible color combinations for the Scan the Code Task

Task Elements

Task elements for the Scan the Code task are detailed in Table 7 and in Appendix A: Light Buoy Specifications.

Task Element	Description	Ht. Above Waterline	Base Dimensions
Floating Dock	Floating platform that holds tower structure	N/A	1.5m x 1.5m
Light Buoy	Specifications are detailed in Appendix A: Light Buoy Specifications	1-3m	N/A
Dock units are supplied from DOCKPRO: dockpro.com.au			

Table 7 : Task Elements for Scan the Code Task

2.5.6 Task 6 – Detect and Dock

The Detect and Dock task consists of a floating platform with three docking bays as shown in Figure 9. At each bay is a different colored vinyl panel (red, green, or blue). The AMS detects the designated color and docks within that bay.

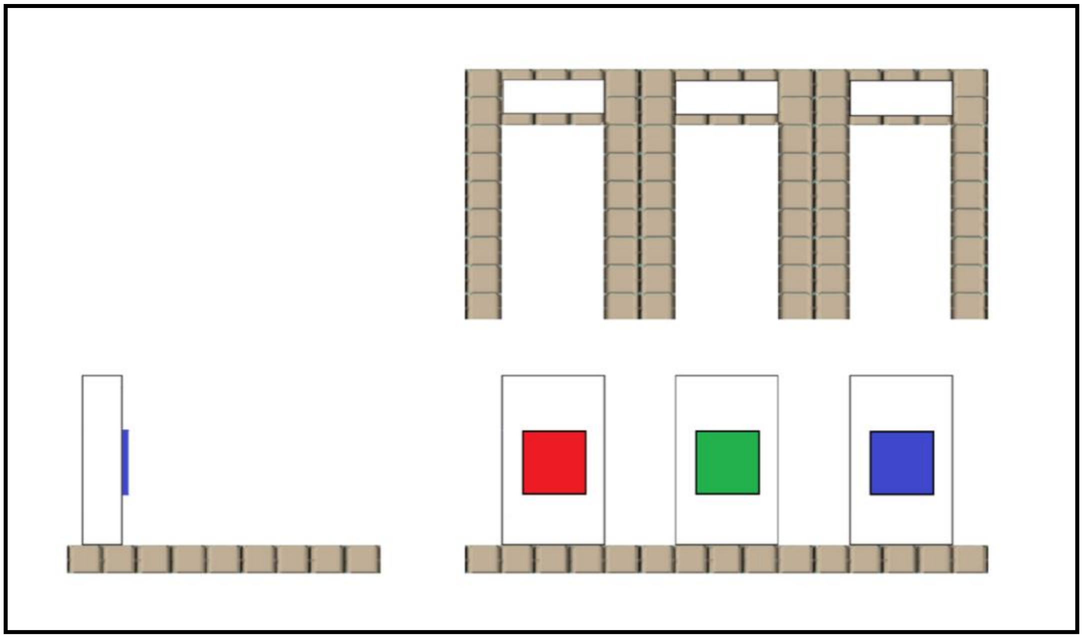

Figure 9: Example Detect and Dock Bays

Task Description

For this task, three identical interconnected docking bays arranged as shown in Figure 9 float at the water surface. A 1m square vinyl panel with a 0.6m color square is positioned at each docking bay. The color square is centered on the white background and displays one of three colors: red, green, or blue. The color square is placed about 0.5m above the waterline.

Task Elements

Task elements for the Detect and Dock task are detailed in Table 8.

Task Element	Description	Ht. Above Waterline	Base Dimensions
Floating Dock	Floating platform that holds panels	N/A	Overall width: 20m x 8m Tines: 2m x 6m Docking bay: 4m width
Flat-Panel Structure	Panels with color display	0.5m	1m x 1m Color display: 0.6m square (red, green, and blue)
Dock units are supplied from DOCKPRO: dockpro.com.au			

Table 8: Task Elements for Detect and Dock

2.5.7 Task 7 – Find and Fling

The Find and Fling task consists of a floating platform with three flat panel structures. Each structure has a color square affixed to it and has two square holes cut into the face of the structure. The AMS finds a designated color displayed by the color square and flings racquetballs into either of the two holes located on this designated structure.

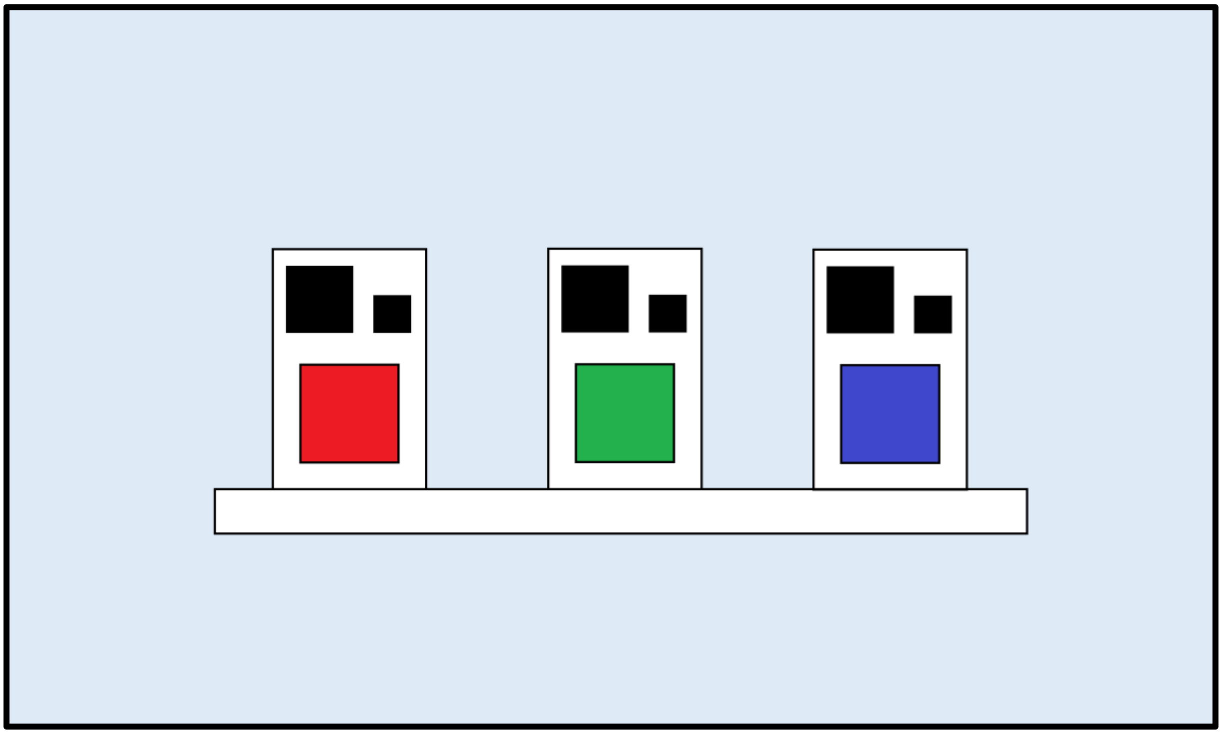

Figure 10. Find and Fling Task floating platform and panel structures

Task Description

For this task, three white flat panel structures are supported on a floating dock. Each panel has a color square affixed to it and two square openings (holes) cut out of the panel. One of the holes is 0.5m on a side, and the other is 0.25m on a side. The holes are located next to one another above the color square. Each hole is outlined in black. The color square is 0.6m square and displays one of three colors: red, green, or blue. The color square is affixed about 0.5m above the waterline. The white, flat panel structures are spaced evenly across the floating platform as shown in Figure 10.

Task Elements

Task elements for the Find and Fling task are detailed in Table 9.

Task Element	Description	Base Dimensions
Floating Dock	Floating platform that holds panels	Overall width: 20m x 4m
Flat-Panel Structure	Panels with color display	1.5-3m x 2-3m Color display: 0.6m square (red, green, and blue)
Projectile	Penn Ultra-Blue Racquetball	N/A
Dock units are supplied from DOCKPRO: dockpro.com.au		

Table 9: Task Elements for Find and Fling

2.5.8 Task 8 – UAV Replenishment

The UAV Replenishment task is designed to be accomplished using a UAV. For this task, the UAV launches from the USV, then locates and picks up a colored disk from a floating helipad. The UAV then delivers it to another floating helipad, placing the disk within a circular target area.

Task Description

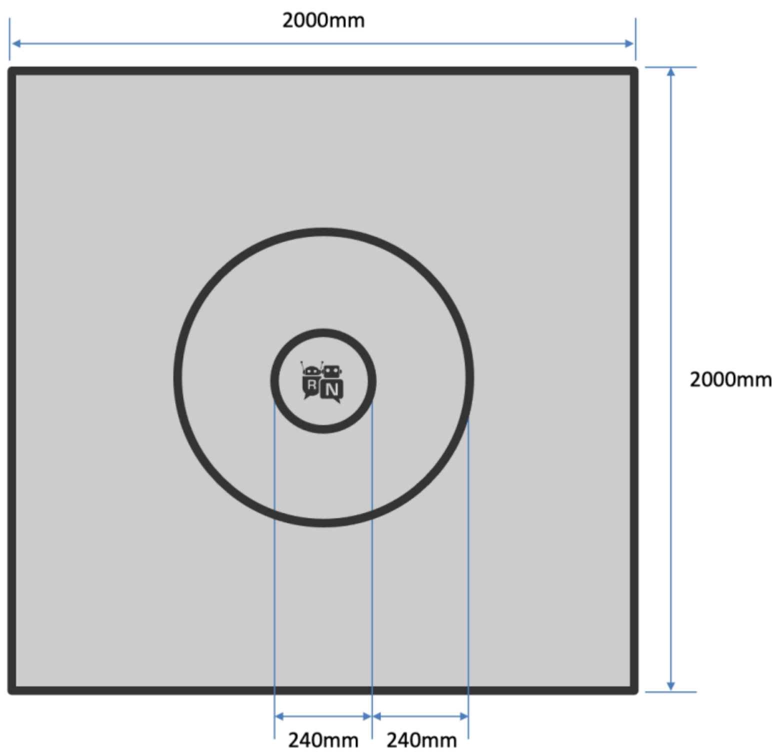

Figure 11: Preliminary Helipad

Two floating helipads are located randomly within the task area. Each helipad is positioned on a raised platform approximately 200-400mm above the surface of the water. The helipad is approximately 2m x 2m and is marked with concentric rings. The center ring is 240mm in diameter, and the outer ring is 720mm in diameter. (Figure 11)

The composition of the colored disks is described in Table 10. There may be multiple-colored discs on a helipad, (red, green, or blue). (Figure 12)

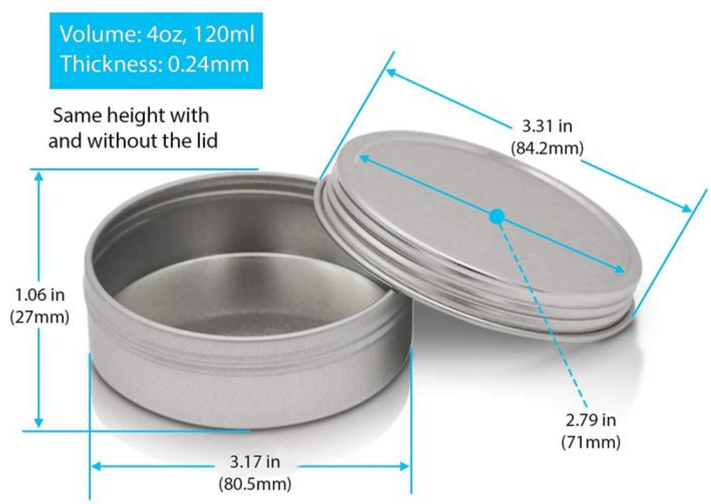

Figure 12: Colored Disk
(Top covered by a round adhesive sticker colored red, green, or blue)

Task Elements
Task elements for the UAV Replenishment task are detailed in Table 10.

Task Element	Description	Base Dimensions
Floating Dock	Floating platform that holds helipad	Overall width: 2m x 2m
Helipad	See Figure 11. Helipad will be secured on a hard, flat, raised surface floating on the water.	2m x 2m
Colored Disks	SimbaLux Screw Top Round Steel Tin Cans 4 oz (120 ml) with Self Adhesive Round Stickers. See Figure 12. Available for purchase: www.amazon.com	N/A
Dock units are supplied from DOCKPRO: dockpro.com.au		

Table 10: Task Elements for UAV Replenishment

2.5.9 Task 9 – UAV Search and Report

Once teams have demonstrated their UAV can autonomously launch and land safely (Section 2.4 Mandatory Activities), they are cleared to operate their UAV on the Autonomy Challenge courses. The UAV Search and Report task is, however, conducted over land.

For this task, the UAV launches from a designated start point, conducts a search of a field marked by four orange buoys, detects and determines the location of 2 distinct objects in the field, and lands at the designated end point. Teams may implement any search pattern; however, the UAV must stay within the boundary of the task. Teams report the object and its geographic location.

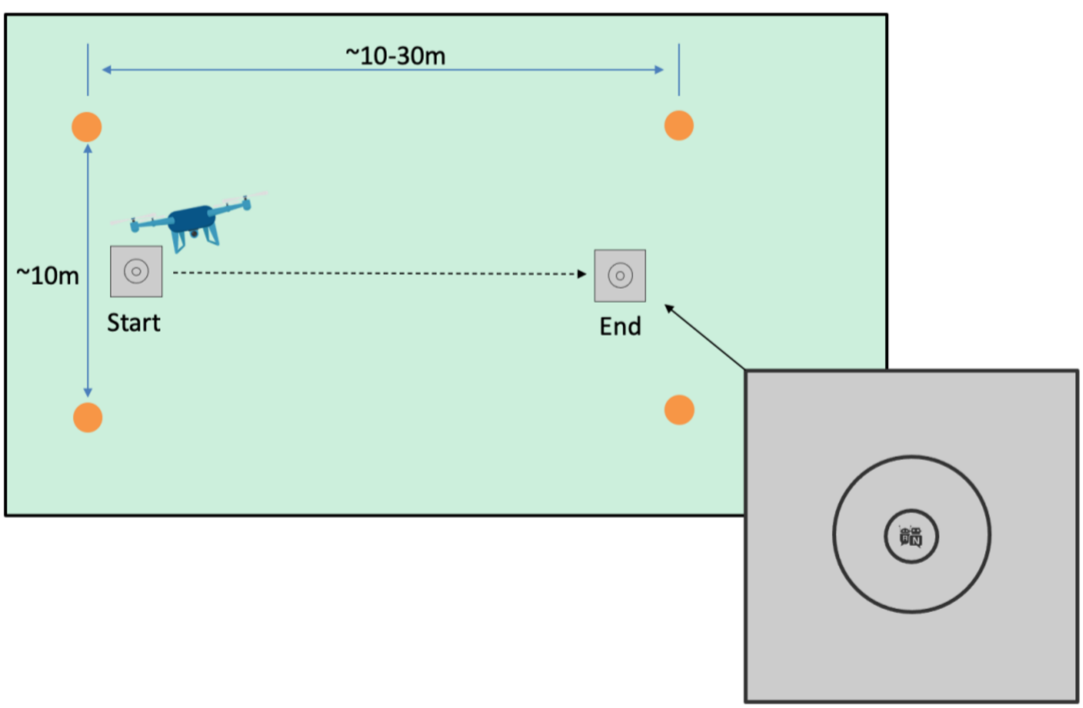

Figure 13. UAV Search and Report

Task Description
The start and end points for this task are called the helipads. A helipad is approximately 1.5m x 1.5m and is marked with concentric rings. The center ring is 240mm in diameter, and the outer ring is 720mm in diameter. The start and end helipads are positioned at the long ends of a field approximately 10-30m long x 10m wide.

There are two objects placed randomly within the field. The objects are approximately 1.5m x 1.5m and are marked with a RoboNation 'R' and an 'N' (80% grey color logos on 20% grey color background). The field is marked by 4 round orange buoys affixed to the ground.

Task Elements
Task elements for the UAV Search and Report task are detailed in Table 11.

Task Element	Description	Color	Ht. Above Waterline	Base Diam.
Field Boundary	470mm Dia. Round Buoy	Stock Orange	470mm	470mm
Objects	Flat white panel with 'R' or 'N' RoboNation symbol	White	N/A	1.5m x 1.5m
Helipad	See Figure 11. Helipad is secured on a hard, flat, raised surface.	N/A	N/A	2m x 2m
Buoys are supplied from Marine Buoys Australia: www.marinebuoysaustralia.com				

Table 11: Task Elements for UAV Search and Report

2.6 Qualifying Round
Autonomy Challenge courses are available for teams to practice or qualify for the Semi-finals Round. The preliminary layout for the Qualifying and Practice Courses will be provided at a later date.

2.7 Semi-Finals Round
Once teams have demonstrated proficiency on certain tasks, they qualify for the Semi-Finals Round. More details on the Semi-Finals Round and a preliminary layout for the Semi-Finals Course will be provided at a later date.

2.8 Finals Round
More details on the Finals Round will be provided at a later date.

SECTION 3: Scoring & Awards

3.1 Scoring

Details of task scoring, including partial scoring for select sub-elements of each task, are in development. These will be provided at a later date. Scores are calculated by the judges; all decisions of the judges are final.

All teams that meet the minimum Qualifying Round requirements will be eligible to compete in the Semi-Finals Round. Upon completion of the Semi-Finals Round, the judges will announce the top-scoring teams who will progress to the Finals Round. The judges have the discretion to select the number of teams advancing to the Finals Round.

After the competition, the judges will issue overall standings. Any team accepted into the Finals Round will be ranked ahead of all teams that did not participate in the Finals Round.

3.2 Awards

Awards are provided in two categories: Final Standings and Judges' Special Awards.

3.2.1 Final Standings

Teams are awarded prize money reflective of their overall ranking after scores are calculated. The first-place team receives a trophy and a RoboNation champion banner.

3.2.2 Judges' Special Awards

Throughout the competition, judges and staff are always on the lookout for exemplary behavior from teams to acknowledge with special awards.

SECTION 4: Rules & Requirements

4.1 Rules

1. Teams must use a WAM-V to compete. (Section 4.3: Platform & System Requirements)
2. No combustion engines of any type may be used on the AMS.
3. Teams must include a combination of students, faculty, industry partners, and/or government partners. (Section 1.3: Eligibility)
4. One student member of the team must be designated as the "team lead". The team lead must be conversationally fluent in English. The team lead, and only the team lead, will speak for the team during the competition runs.
5. Team leads are required to attend daily team meetings conducted by the Technical Directors. (Section 2.1: Schedule)
6. Teams must remain on site at the competition venue during the competition hours to be eligible for prizes.
7. Prior to entering the Autonomy Challenge courses, teams must demonstrate the ability to operate their USV and UAV safely. (Section 2.4: Mandatory Activities)
8. At any point, the Technical Director Team may require a team to repeat the USV Demonstration and UAV Demonstration to re-deploy. (Section 2.4: Mandatory Activities)
9. Course boundaries will be clearly identified. The AMS must stay within the course or task boundaries while attempting any tasks.
10. During the execution of any task, it is acceptable to use a UAV, for instance to assist mapping the Autonomy Challenge task.
11. All decisions of the judges are final.
12. RobotX organizers are not responsible for any damage to a team's AMS as the consequences of participating in the competition.

4.2 Safety

Safe operations are a priority for the RobotX staff. All considerations to maintain safety for operators and the surrounding environment must be made. These guidelines are the minimum requirements for all teams and their systems during the competition.

1. All Radio Frequency (RF) equipment must be operated within the rules and regulations of the host country. This includes, but is not limited to, frequency, transmitting power, antenna height, etc. This is detailed on the Australian Communications and Media Authority (ACMA) website and summarized in Appendix D: Radio Communications Restrictions.
2. AMS power systems must follow the safety rules and regulations of the host country as well as the team's home country.
3. RobotX staff may suspend team operations at any time for safety considerations. The staff is not required to advise the team prior to the decision to terminate the run attempt. In all matters of safety, the decisions of the RobotX staff are final.

4.2.1 Safety Inspections

Before operating in the water, all systems must pass a safety inspection. This includes, but is not limited to:

1. A Safety Inspector will complete a safety checklist, verifying successful operation of all safety features at each unmanned system launch.
2. Teams will demonstrate compliance with all the requirements, to include identifying all actuators, and moving parts and their associated protection mechanisms (shrouds, etc.).
3. Verification of both kill switches' operation (remote and physical) will be repeated each time a team enters the water.

4.2.2 Battery Safety Requirements

Teams are required to understand and follow battery safety best practices on the battery chemistry selected by the team. Lithium-ion chemistry batteries may become damaged and create a hazard if misused/abused, representing the greatest risk to people, facilities, and the environment. The following safety rules and requirements must be followed:

1. Teams must submit battery specifications, Material Safety Data Sheets (MSDS), and proper disposal procedures, sourced from the battery manufacturer for all batteries.
2. Teams must keep a hard copy of the battery safety documentation for all batteries in Team Village (on-site) at all times, for reference.
3. Li-Po (Lithium Polymer) battery packs need cell level safety and balancing circuits and must be labeled HAZMAT when shipped.
   - Each team must understand and follow their own country's regulations as well as those of the host nation. Australia's battery safety regulations: batterysafetyguide.com.au.
4. All batteries must be stored, used, and maintained in accordance with manufacturer guidelines.
5. Students are required to inspect their batteries daily for signs of swelling, heat, leaking, venting, burning or any other irregularities.
6. Lithium batteries that become too warm during use or have become swollen or malformed must be removed from use and reported to the Technical Director.
7. Lithium batteries that do not hold a charge must be removed from use and reported to the Technical Director.
8. A team member must be present at all times to monitor charging batteries.
9. At the competition site, if any of the above battery conditions are observed students must immediately notify the Technical Director or RobotX staff and provide the battery specifications and safety information.
10. Failed or failing Lithium-ion batteries must be handled in accordance with manufacturer's safety and disposal guidelines. In the absence of specific guidelines, batteries must be placed in a LiPo safe bag, which must then be placed in a bucket, covered with sand, and placed in a designated safety zone.
11. Teams are only permitted to change or replace AMS batteries in Team Village.

4.2.3 Kill Switch (Emergency Stop) Requirements

The AMS must comply with the kill switch requirements detailed below. Each competing USV must have two emergency stop systems, also known as 'kill switches' or 'E-Stops':

- On-Board: A hard-wired, on-board, emergency stop system,; and
- Off-Board: A wireless remote emergency stop, located off-board and on or near the operator control station.

Upon activation of either emergency stop system, the switch must instantaneously (less than 1 second) disconnect power from the vehicle's thruster units. Emergency stop systems must operate in a fail-safe fashion. If any part of the Emergency stop system or any sub system it relies on (communication, power, etc.) fails or loses connection, the switch must instantaneously (less than 1 second) disconnect power from the vehicle's thruster units. An example of how to implement this is shown in Figure 14. Systems should be designed such that power, to the thrusters, cannot be restored until the emergency switch is reset.

The Technical Director team will conduct a detailed engineering and safety inspection including a team demonstration of the proper operation of all emergency systems. Teams must be prepared to discuss the design and implementation of their fail-safe systems in detail, if requested.

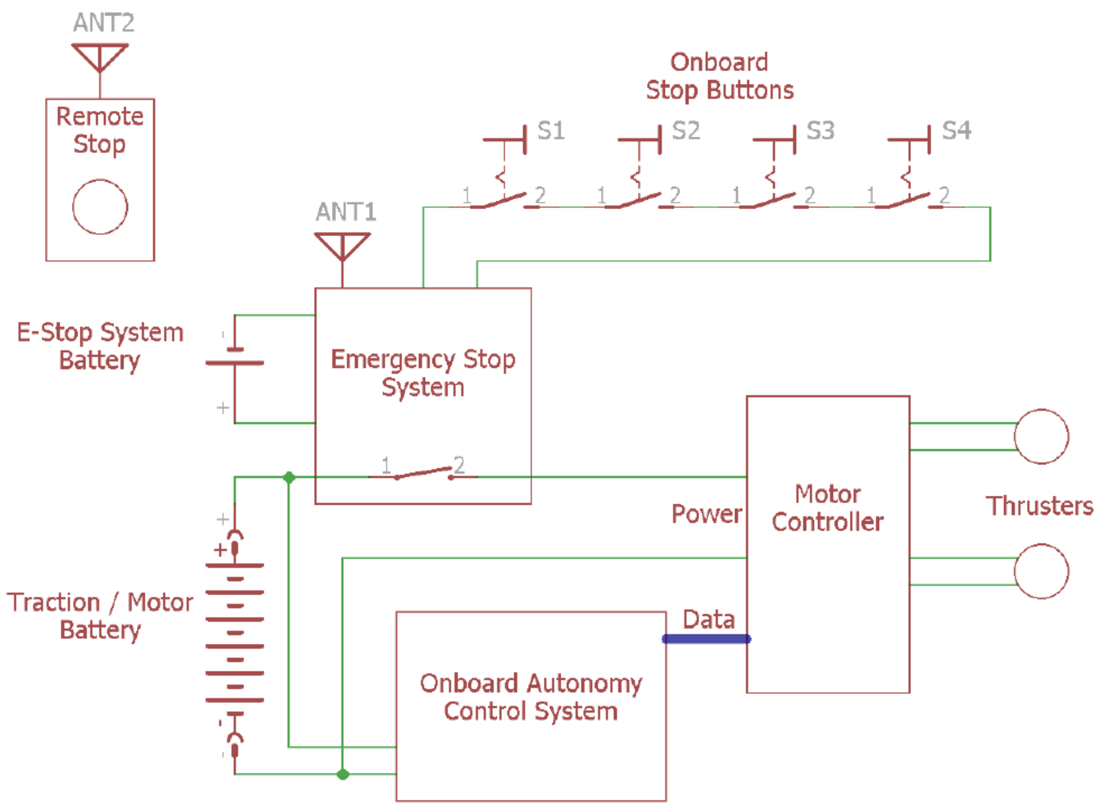

Figure 14: Example Emergency Stop Circuit

Onboard Emergency Stop System (USV)

All USVs must have an onboard emergency stop capable of being actuated by personnel from a support craft. For personnel safety, the switch may be triggered from a distance by a wooden or plastic pole/paddle for surface craft. Keeping this in mind, teams should select rugged and reliable components for their safety system.

Teams must place activation switches for the emergency stop system on each of the four arms leading from the payload deck to the skid plate, or suspension bracket on the pontoons. Examples of acceptable kill switch placement are shown in Figure 15. This switch must be demonstrated to disable AMS thrusters within 1 second of activation in all AMS operating modes.

Figure 15: Examples of Kill Switch Placement

Emergency Stop Button (USV)

A large, red button should be installed so that safety personnel, from the support craft can easily actuate the button. The engage/disengage button should be red in color and have a press to activate and twist or pull to reset feature. On actuation, this button, momentary contact switch or not, on actuation, should cut power to the thrusters immediately on actuation. The thrusters must remain in a powered-down state until the judge gives permission for the team to reinitialize the system. An example of a suitable button is shown in Figure 16 and can be found at www.mcmaster.com.

Figure 16: Example Kill Switch

Wireless Emergency Stop (USV)

All USVs must be equipped with a portable, handheld, Wireless Emergency Stop controller. This controller must immediately (less than 1 second) disconnect power to the vehicle's thruster units when activated. This system must also meet the host country RF guidelines for frequency and transmit power.

Emergency Return-to-Home Function (UAV)

All UAVs must have an emergency return-to-home function which can be operated remotely off-board, operating on its unique frequency and link. Upon activation of the return-to-home function, the UAV must instantaneously stop all other tasks, ascend to 25m above ground level, return to 'home' GPS coordinates and land.

4.2.4 Visual Feedback System Requirements

Teams are required to implement a visual feedback system to clearly indicate the operational status of the USV to improve the safety of RoboNation support operations. This lighting system will serve as a visual status indicator to anyone in the vicinity of each team's USV. It is strongly recommended the UAV also has a clearly visible indicator showing operational status. Resources and general guidelines outlined here may be used by teams to acquire, integrate and test a system that meets the RobotX safety requirements.

Basic Requirements

The lighting system shall consist of a minimum of three lights: red, amber and green or blue. Lights must be in a vertically arranged configuration and mounted such that they provide a 360-degree daylight visibility, when viewed from shore or nearby vessel (approximately 150 meters).

Lighting system colors shall correspond with the applicable mode of the team's autonomous system as indicated in Table 12. The lights may be flashing or steady on/off according to the state of the system.

Color	Mode
Amber or Yellow	Tele-Operation / Manual Operation
Blue or Green	Autonomous operation
Red	E-Stop active (propulsion disabled)

Table 12: Light Color and Correlating Modes

Several visual indicator examples are shown in Figure 17, including off-the-shelf and custom LED array approaches; however, design and selection of the final system is the team's decision.

Figure 17: Example Visual Indicators

Detailed Specification

- The minimum height of the lighting systems must be 12.5cm.
- The maximum height and diameter of the lighting system are at the team's discretion and may be dependent on the number of additional lights included.
- Teams must procure lighting systems that are visible in sunlight and can be observable from the shore and the on-water support craft (approximately 150m). Teams should use lighting systems that have clear enclosures rather than colored enclosures with standard light bulbs. Generic versions of these lighting systems are used indoors on machines and equipment for status indication across several industries and are available globally.

4.3 Platform & System Requirements

4.3.1 USV Requirements

1. All teams are required to use the WAM-V-16 USV manufactured by Marine Advanced Robotics (www.wam-v.com) as their primary competition USV.
2. WAM-Vs must be equipped with buoyancy pods. Examples of previously used pod designs are presented on the RobotX website in the RobotX Guide "WAM-V Propulsion Examples" paper and student technical papers from previous events. Pods are also available directly from the WAM-V manufacturer.
3. Each USV must have at least two (2) orange tow points, one set forward and one set aft. The tow points may need to be used to tow the WAM-V between the boat ramp and the course area, and in the event it suffers a failure during course operations.
    a. Towing points must be marked with bright orange lettering, spelling out "TOW" to indicate the locations of the tow points.
    b. Lettering must be at least 7cm tall.
4. The USV should be capable of operating in sunny, rain (light or heavy) and varying wind conditions. Although the competition location is normally sunny at this time of year, the competition will continue through these weather conditions.
5. Teams are required to ensure that their design does not exceed the payload capacity of the WAM-V surface platform. Basic WAM-V specifications are available on the RobotX.org website. Teams are advised to address basic principles of naval architecture to include considerations of centers of buoyancy, centers of mass, and metacentric height when locating sensors and other equipment on the WAM-V.
6. Propellers must be shrouded for safety.
7. Each team's WAM-V and trailers must fit under the competition tents (maximum allowable height: 3028mm). Additional masts are acceptable but must be removeable or capable of being folded down to ensure tent height clearance.

4.3.2 UAV Requirements

Note: The Australian Civil Aviation Safety Authority (CASA) refers to Unmanned Aircraft as Remotely Piloted Aircraft (RPA) (commercial use) or model aircraft (recreation use). For the purposes of this document, the terms Drone, Unmanned Aerial Vehicle (UAV) and model aircraft are used synonymously.

1. The maximum allowable model aircraft category (size) for this competition is small. This category allows model aircraft no more than 7kg. Model aircraft that weigh more than this will not be allowed to fly at the competition.
2. Current CASA model aircraft registration and operating requirements will change in 2022 and are yet to be confirmed. Further updates will be provided to teams when these new requirements are confirmed.
3. When flying it is important to ensure CASA Drone safety rules are adhered to: https://www.casa.gov.au/drones/rules/drone-safety-rules
4. As UAVs will be operating above water, they must be able to float in freshwater. This will enable recovery in the case of an emergency and will minimize damage to onboard systems.
5. The UAV should be capable of operating in sunny, rain (light or heavy) and varying wind conditions. Although the competition location is normally sunny at this time of year, the competition will continue through these weather conditions.

4.3.3 System Management & Monitoring Requirements

1. Each team's AMS must include an Operator Control Station (OCS) capable of controlling and monitoring the system.
   a. The OCS must have the ability to start and stop autonomous operations.
   b. The OCS must have the ability to remotely kill the platform as described in Kill Switch Requirements.
   c. The AMS must stop operating if it goes out of range from the OCS.
   d. Teams are required to connect to the Technical Director's Network via the hard-wired Ethernet link, to be provided in the team operations tent. Protocols for this communication are outlined in Appendix C: Communications Protocols.
   e. Teams are responsible for providing robust and reliable communications between the OCS and AMS to attempt the competition tasks.
   f. Teams must provide a display for judges showing the results for the tasks that require reporting. This display must comply with the display requirements documented in the sections: Qualifying Round, Semi-Finals Round, Finals Round.
   g. All shore-based equipment used by the team during in-water runs must be contained to the team's designated operating tent and table.
2. Teams are required to implement a clearly visible indicator on the USV showing operational status. It is strongly recommended the UAV has a clearly visible indicator showing operational status. Specifications for a sample indicator are provided in the Visual Feedback System Requirements. *Note*: These are minimum requirements.
3. Teams are required to implement and provide a graphical display for use by judges as described in the sections: Qualifying Round, Semi-Finals Round, Finals Round.

4.4 Obstacle Avoidance

The ability to avoid obstacles is a core capability for unmanned systems. Each buoy on the course represents an object to be avoided or approached in some way. In addition, obstacle buoys may be placed throughout the operating areas in an effort to provide a more representative real-world challenge.

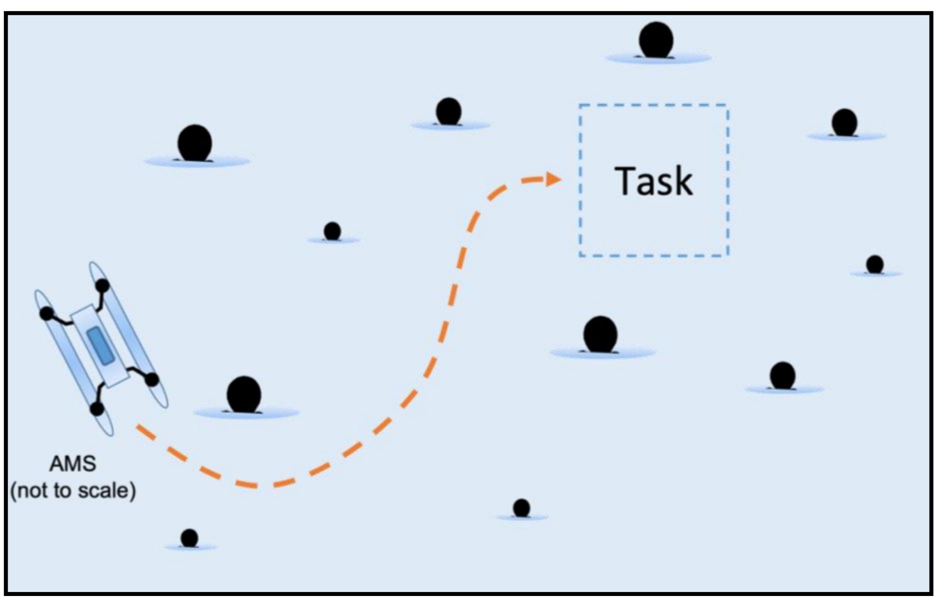

Figure 18: Obstacle Avoidance

SECTION 5: How to Compete

5.1 Register and Intent to Compete

5.1.1 Intent to Compete

During the registration process, teams must Before the RobotX 2022 Registration opens, teams are invited to complete an Intent to Compete form expressing intent to compete in the 2022 Maritime RobotX Challenge. The Intent to Compete form is available on the RobotX website, RobotX.org/2022.

RoboNation will provide a hyperspectral camera at no cost to teams. Teams who complete an Intent to Compete form will receive the HSI cameras as soon as they are available. The cameras may be used to accomplish the Wildlife Encounter – React & Report task (Section 2.5.4). Camera specifications and details are available in Appendix E: Hyperspectral (HSI) Camera.

5.1.2 Data Sharing Access Requirements

During the registration process, teams must All teams are required to register to compete using the Registration form found on the RobotX website, RobotX.org/2022. This registration collects each team's point of contact information, demographics, and the Pre-Competition Requirements outlined in Section 5.2. There is no registration fee required to compete.

Teams that complete the Registration form before January 31 are eligible to receive a shipping stipend, up to $5,000 USD. Eligible teams are required to meet all shipping deadlines to remain eligible for receiving the stipend.

5.1.3 Data Sharing Access Requirements

During the registration process, teams must provide a generic email account and a team acronym that will be used in the Data Sharing project (Section 5.6). The generic email can be associated with any email provider. An example of the Generic Email is: robotx-team@outlook.com. The team acronym must be within 2-10 characters, abbreviating the team's school or organization. Examples of the team acronym are: RN or ROBOTEAM.

Access will be given to teams that complete the Intent to Compete form and/or Registration form. Only official registered teams will maintain access to the Data Sharing project for the RobotX 2022 season.

5.2 Pre-Competition Requirements

These requirements are collected prior to participation on-site at the competition, during the registration process. In addition to the list below, mini challenges may be issued over the next year for which information will be released in future issues of this Team Handbook.

5.2.1 Team Information Package

Teams are required to submit a team roster including all participants that support the RobotX 2022 effort, liability waivers, forms, and other contact information.

5.2.2 Shipping Plan & Compliance

Teams are required to submit a shipping plan. The RobotX staff provides support to ensure that teams' equipment can be received, worked through Australian Customs, and staged for competition. A shipping plan template, shipping address, and point of contact for the RobotX freight forwarder will be provided to teams at a later date.

5.2.3 Battery Safety Documentation

Teams are required to submit battery specifications, Material Safety Data Sheets (MSDS), and proper disposal procedures, sourced from the battery manufacturer for all batteries. More information can be found in Section 4.2 Safety.

5.2.4 Pilot Certification

Teams who compete with a UAV are required to submit a logbook of flight hours and a pilot license issued by their respective country, for each Licensed Pilot. It is recommended for teams to have 2-3 Licensed Pilots.

Details are being finalized and will be provided to teams at a later date.

5.2.5 Design Documentation Package

Teams are required to submit the team website, technical design paper, and team introduction video of their Design Documentation prior to being on-site at the competition. Guidelines can be found in Section 2.3 Design Documentation.

5.3 Timeline

Date/Deadline	Event
June – December 2021	Intent to Compete
January – February 2022	Registration
September 2022	Shipping Plan Deadline Pilot Certification Deadline
October 2022	Team Information Deadline Design Documentation Package Deadline Battery Safety Deadline

5.4 Logistics

5.4.1 Shipping

Shipping guidelines and information related to the selected freight forwarder will be released in future issues of this Team Handbook.

5.4.2 Health and Safety

COVID-19 Protocols and Local Guidance
The Health and Safety of the RoboNation community is our number one priority. RoboNation follows all local and state health guidelines. We will continue to communicate with any changes to on-site protocols as we approach RobotX 2022. Please follow safety guidelines at work, at home, and in the community to help slow the spread of coronavirus.

Updated rules and restrictions for travel to and within Australia are available on the NSW Government's COVID-19 website, www.nsw.gov.au.

5.4.3 On-site Logistics

Team Village
Each team will be provided with a covered working area on the island with access to both 240VAC, 10A, 50Hz power and a wireless internet connection. The Team Village resides on a flat bitumen surface. This is where teams should conduct development, maintenance, and repair of their systems. Batteries may be charged during the day at the Team Village but may not be left charging overnight.

Team Course Operating Areas (Shoreline)
Teams will be provided with an area along the shoreline near the course areas where they will be able to set up their shore equipment. This space consists of a tent-covered area (6 tents, each 3m x 3m) with a single 1.8m long table per tent, 240VAC, 10A, 50Hz power, and a hard-wired Ethernet connection to the Technical Director network. The power provided is for Operator Control Station (OCS) use only and shall not be extended to any platforms on the beach. This space is shared between all teams utilizing the course.

Transporting the AMSs at the Competition Venue
The RobotX staff will provide trailers for the AMSs at the competition venue. These trailers shall be used to move the AMSs between locations on site using vehicles provided and operated by the staff. These trailers will be used to launch and recover the AMS using the venue boat ramp.

5.5 Communications

5.5.1 Pre-Competition Communications
RobotX teams have a variety of opportunities to interact with each other and the RobotX staff.

Team Time Meetings
Leading up to the on-site competition, there are regularly held virtual meetings where teams are asked to have a team representative join. These Team Time meetings are hosted by the RobotX organizers and technical team to provide teams with competition updates and the opportunity to ask questions.

RobotX Discussion Forum
All questions, comments, and suggestions should be posted on the RobotX Discussion Forum. Teams are encouraged to actively participate in the online community and monitor it for the latest news and updates regarding all things RobotX.

Band App
The RobotX Community in the Band App is used to keep registered RobotX teams updated on the latest announcements, resources, and special deals throughout the competition season. Each team member is encouraged to download the Band App (band.us), available on Android and iOS, and get to know the other RobotX teams. Access information is provided in the team registration process, outlined in Section 5.1 Register and Intent to Compete.

Point of Contact: university-competitions@robonation.org

5.5.2 On-site Communications

Team Lead
Each team must designate a student team member as their team lead. The team lead is the only person allowed to speak for the team. The team lead is the only person permitted to request vehicle deployment, run start, run end, or vehicle retrieval. The team lead must be conversationally fluent in English to communicate with RobotX staff. Teams who do not have members fluent in English should contact RobotX staff as soon as possible.

Technical Director Team
The RobotX Technical Director Team consists of:

- Technical Director
- Deputy Technical Director
- Safety Inspectors
- Course Managers

Other RobotX Staff
On-site at competition, the RobotX Staff can be identified with "Staff" on the back of their RobotX shirts.

5.5.3 RobotX Website
The official competition website is www.RobotX.org/2022. This website includes all official documents and a detailed list of the registered RobotX Challenge teams. Helpful resources, past competition results, and other engagement opportunities can be found on this website. Information and documents are updated regularly, and it is the team's responsibility to check the website for updates.

5.6 Data Sharing
A Data Sharing project has been established for registered teams competing in RoboNation's RoboBoat, RoboSub, and RobotX competitions. This project aims to increase collaboration between teams and to provide access to shared resources and test data to validate and debug the reliability and robustness of teams' machine vision algorithms. Access information is provided in the team registration process, outlined in Section 5.1 Register and Intent to Compete.

For more information on Data Sharing, visit the RoboNation Data Sharing website: RobotX.org/data-sharing.

SECTION 6: Glossary & Acronyms

6.1 Glossary

Phrase	Definition
Autonomous Maritime System (AMS)	The entire maritime system, including WAM-V Unmanned Surface Vessel (USV) and any off-board systems deployed from the surface platform, such as the Unmanned Aerial Vehicle (UAV).
Wave Adaptive Modular-Vessel (WAM-V)	An innovative surface craft manufactured by Marine Advanced Robotics and utilized as the primary competition vessel for RobotX teams.
Qualifying and Practice Courses	These courses are designed to provide opportunities to demonstrate proficiency in one task at a time. They contain an instance of each task.
Semi-Finals & Finals Courses	These courses are designed to allow demonstration of autonomous execution of multiple interdependent tasks. They contain an instance of each task.
Team Lead	Designated spokesperson for each team.
Technical Director Team	Technical team that runs the courses, safety inspections, set-up, and tear-down.
RobotX Staff	RobotX support personnel.
Judge	Subject Matter Experts that observe and score the Autonomy Challenge and Design Documentation.
Sponsor	Organizations that provide support to RobotX.

6.2 Acronyms

Acronym	**Definition**
ACMA	Australian Communications and Media Authority
AMS	Autonomous Maritime System
CASA	Australian Civil Aviation Safety Authority
N/A	Not available
NMEA	National Marine Electronics Association
OCS	Operator Control Station
RGB	Red, Green, Blue
RF	Radio Frequency
RPA	Remotely Piloted Aircraft
UAV	Unmanned Aerial Vehicle (the terms drone, and model aircraft are used synonymously in this document)
USV	Unmanned Surface Vessel
WAM-V	Wave Adaptive Modular Vessel

Appendix A: Light Buoy Specifications

A.1. Network Information

A.1.1 Description

The light buoy consists of three faces. Each face has an RGB matrix panel that indicates the color sequence. These RGB panels are commonly used to make the large 'Jumbotron' displays used at sports venues.

The light sequence is created by having the entire panel display one color at a time with all three faces displaying the color in unison. The panel will cycle through four colors. Each color is displayed for 1 second, then the panel goes dark (no color) for 2 seconds until the pattern repeats.

This light sequence begins once the team's AMS enters autonomous mode and starts an operational run for points.

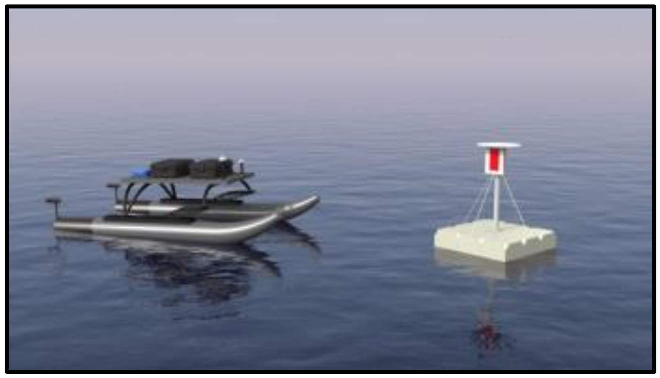

Figure 19. Light Buoy Concept

A.1.2 Specifications

The dimensions of one of the three identical faces are shown in Figure 20. The top edge of these faces is between 3m (9.8 feet) and 1m (3.2 feet) above the water. The border around the light bar is white, as illustrated. The structure supporting these faces is subject to change and is not specified here.

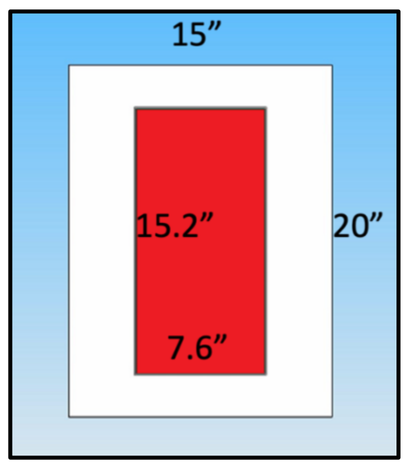

Figure 20. Light Buoy Face

A.1.3 Parts Source

The LED panels used for the competition buoy panels were purchased at the following link:
http://www.adafruit.com/products/420

Software that teams may use to program and test a representative light panel is available at GitHub:
https://github.com/madsci1016/RobotXLightBuoy

Appendix B: Beacon Specifications

Each team that plans to attempt the Entrance & Exit Gates task needs to build a localization system compatible with the competition beacon system. The beacon type and configuration are described in this appendix for reference so that teams may acquire a comparable unit for testing.

B.1. Beacon Model

The beacon selected for use during the RobotX competition is the Benthos ALP-365. This model has a selectable frequency between 25 and 40kHz with a 0.5kHz increment. It also has multiple options for repetition rate.

Beacon specifications can be found at: robotx.org/benthos-locator.

Beacons are activated as described in the applicable task descriptions. The frequency and pulse rate of the beacons in each field may change daily; this information will be made available to teams on site. The full range of frequencies (25 – 40 kHz) and pulse rate (0.5 Hz to 2 Hz) is used throughout the competition.

Figure 21: Benthos ALP-365 Beacon

During the competition there are multiple units active at any time, with at least one in each course. To mitigate interference issues, each active beacon is separated by at least 2 kHz in frequency. The beacons are also controlled such that they send out a pulse at time intervals in sequence with the other courses. Teams are advised to not rely on this to complete the challenge.

Appendix C: Communications Protocols

Maritime RobotX Challenge 2022 *www.robotx.org*

This appendix describes the communications protocols to report vehicle status and completion of Autonomy Challenge tasks. Each team's implementation of the requirements outlined below may be tested during the competition. RoboNation shall provide support to test this implementation prior to RobotX 2022.

C.1. Network Information

During operations, teams are provided with a hard-wired connection (RJ-45) to the Technical Director's network. This connection must be used to transmit the AMS heartbeat and other reports.

When connected to the Technical Director network, the team's computer must request an IP address from a Technical Director Network DHCP server. Once connected, they should establish a TCP connection to a server with an address and port number, correlating to the selected course. Address and port numbers for each course will be provided during the event. A unique NMEA sentence has been defined for each challenge requiring communication between the AMS and a judge.

Teams are responsible to provide a robust and reliable data link between the AMS and the team's Operator Control Station (OCS).

C.2. General Message Information

All communication is formatted as an NMEA-like sentence characterized by the following guidelines:

- Each message's starting character is a dollar sign.
- The next five characters identify message type.
- All data fields that follow are comma delimited.
- Where data is unavailable, the corresponding field remains blank (it contains no character before the next delimiter).
- All dates and times are to be reported in Australian Eastern Daylight Time (AEDT).
- The first character that immediately follows the last data field character is an asterisk.
- The asterisk is immediately followed by a checksum represented as a two-digit hexadecimal number. The checksum is the bitwise exclusive OR of ASCII codes of all characters between the $ and *.
- <CR><LF> ends the message.

A different NMEA sentence has been defined for each challenge requiring communication between the vehicle and a judge. The vehicle SHOULD NOT transmit any message at a rate more than once per second (1Hz). The vehicle should only transmit one task message at a time, and it should be the task the vehicles is currently on. If any task messages are used for scoring purposes, only the last message for that task transmitted by the vehicle will be considered.

C.3. Heartbeat Message

The AMS is required to transmit a heartbeat status message at exactly a frequency of 1 Hz. This heartbeat is used to verify the link has been established with the Technical Director Network and competition equipment. In addition, this channel is used to relay information specific to a challenge during its run attempt. The fields for the heartbeat message are shown in Table 13, and followed by an example heartbeat message.

Name	Example	Description	Notes
Message ID	$RXHRB	Protocol Header	
AEDT Date	111221	ddmmyy	Use Australian Eastern Daylight Time (AEDT)
AEDT Time	161229	hhmmss (24hr time format)	Use Australian Eastern Daylight Time (AEDT)
Latitude	21.31198	Decimal degrees	Provides ~1.11m accuracy
N/S indicator	N	N=north, S=South	
Longitude	157.88972	Decimal degrees	Provides ~1.04m accuracy
E/W indicator	W	E=east, W=west	
Team ID	ROBOT	Team ID	5-character code assigned by Technical Director
System Mode	2	Current mode of AMS 1=Remote Operated 2=Autonomous 3=Killed	
UAV Status	1	Current UAV Status 1=Stowed 2=Deployed 3=Faulted	The 'Stowed' state used only when the UAV is secured to the USV. The 'Deployed' state is used whenever the UAV is not on board the USV. The 'Faulted' state is used whenever the UAV is not functioning as designed.
Checksum	11	Bitwise XOR	
<CR><LF>		End of message	

Table 13. RobotX 2022 Heartbeat Message Fields

Heartbeat Example Message: $RXHRB,111221,161229,21.31198,N,157.88972,W,ROBOT,2,1*11

C.4. Entrance and Exit Gates

The Entrance and Exit Gates message provides a method for the AMS to report the gate where it detects an active beacon using the protocol specified in Table 14. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXGAT	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
Active Entrance Gate	1	Gate 1, 2, or 3
Active Exit Gate	2	Gate 1, 2, or 3
Checksum	3C	Bitwise XOR
<CR><LF>		End of message

Table 14. Entrance and Exit Gate Message Fields

Entrance and Exit Gate Example Message: $RXGAT,111221,161229,ROBOT,1,2*3C

C.5. Follow the Path

The Follow the Path task requires that the AMS navigate a path defined by pairs of buoys. The AMS may report when it has completed the path using the protocol specified in Table 15. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXPTH	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
Finished	1	1 = In Progress 2 = Completed
Checksum	3C	Bitwise XOR
<CR><LF>		End of message

Table 15. Follow the Path Message Fields

Follow the Path Example Message: $RXPTH,111221,161229,ROBOT,1*3C

C.6. Wildlife Encounter – React and Report

The Wildlife Encounter – React and Report task requires that the AMS identify and classify 'wildlife' objects with a UAV and circle the objects according to their classification. The AMS may report the number of 'wildlife' objects detected and their classification using the protocol specified in Table 16. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	RXENC	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
Num Detected	3	1, 2 or 3 'wildlife' objects detected
1st Wildlife	P	Classification of 1st Wildlife Object P=Platypus, C=Crocodile, T=Turtle
2nd Wildlife	C	Classification of 2nd Wildlife Object P=Platypus, C=Crocodile, T=Turtle
3rd Wildlife	T	Classification of 3rd Wildlife Object P=Platypus, C=Crocodile, T=Turtle
Checksum	51	Bitwise XOR
<CR><LF>		End of message

Table 16. Wildlife Encounter – React and Report Message Fields

Wildlife Encounter Example Message: $RXENC,111221,161229,ROBOT,3,P,C,T*51

C.7. Scan the Code Message

The Scan the Code task requires that the AMS locate and observe a buoy with a light bar to determine the light pattern displayed. The AMS must then transmit the detected light pattern using the protocol specified in Table 17. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXCOD	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
Light Pattern	RBG	Colors identified from first to last, over time R=red, B=blue, G=green
Checksum	5E	Bitwise XOR
<CR><LF>		End of message

Table 17. Scan the Code Message Fields

Scan the Code Message Example: $RXCOD,111221,161229,ROBOT,RBG*5E

C.8. Detect and Dock Message

The Detect and Dock task requires the AMS to identify an assigned colored vinyl panel and dock the AMS in the corresponding docking bay. The AMS may report the detected color of the face where it docks using the protocol specified in Table 18. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXDOK	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
Color	R	Color of the docking bay being attempted R=red, B=blue, G=green
AMS Status	1	Status of the AMS 1=Docking, 2=Delivering
Checksum	4E	Bitwise XOR
<CR><LF>		End of message

Table 18. Detect and Dock Message Fields

Detect and Dock Example Message: $RXDOK,111221,161229,ROBOT,R,1*4E

C.9. Find and Fling Message

The Find a Fling task requires the AMS to identify an assigned colored vinyl panel and deliver a payload into one of the holes. The AMS may report the detected color of the face where it delivers its payload using the protocol specified in Table 19. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXFLG	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
Color	R	Color of the shape on the face being targeted R=red, B=blue, G=green
AMS Status	1	Status of the AMS 1=Scanning, 2=Flinging
Checksum	40	Bitwise XOR
<CR><LF>		End of message

Table 19. Find and Fling Message Fields

Find and Fling Example Message: $RXFLG,111221,161229,ROBOT,R,2*40

C.10. UAV Replenishment

The UAV Replenishment task requires that the AMS use the UAV to pick up an item from the dock and deliver it to a floating helipad. The AMS may report when the UAV deploys, picks up the item, and delivers the item using the protocol specified in Table 20. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXUAV	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Team ID	ROBOT	5-character code assigned by Technical Director
UAV Status	Current status 1=Stowed 2=Deployed 3=Faulted	The ‘Stowed’ state is used only when the UAV is secured to the USV. The ‘Deployed’ state is used when the UAV is not on board the USV. The ‘Faulted’ state is used when the UAV is not functioning as designed.
Item Status	Current status 0=Not Picked Up 1=Picked Up 2=Delivered	The ‘Not Picked Up’ state is used when the item has not been picked up by the UAV. The ‘Picked Up’ state is used upon successful pick-up of the item by the UAV. The ‘Delivered’ state is used upon successful delivery of the item by the UAV.
Checksum	2C	Bitwise XOR
<CR><LF>		End of message

Table 20. UAV Replenishment Message Fields

UAV Replenishment Example Message: $RXUAV,111221,161229,ROBOT,2,1*2C

C.11. UAV Search and Report

The UAV Search and Report task requires the UAV to launch from a designated start point, conducts a search of a field marked by four orange buoys, detects and determines the location of 2 distinct objects in the field, and lands at the designated end point. Teams may implement any search pattern; however, the UAV must stay within the boundary of the task. using the protocol specified in Table 21. An example is provided below the table. When the AMS transmits this message the Technical Director system echoes the received message back to verify transmission.

Name	Example	Description
Message ID	$RXSAR	Protocol Header
AEDT date	111221	ddmmyy
AEDT time	161229	hhmmss
Object being reported	R	“R” or “N”
Object Latitude	21.31198	Decimal degrees
N/S indicator	N	N=north, S=South
Object Longitude	157.88972	Decimal degrees
E/W indicator	W	E=east, W=west
Object being reported	N	“R” or “N”
Object Latitude	21.31198	Decimal degrees
N/S indicator	N	N=north, S=South
Object Longitude	157.88972	Decimal degrees
E/W indicator	W	E=east, W=west
Team ID	ROBOT	5-character code assigned by Technical Director
UAV Status	Current status 1=Manual 2=Autonomous 3=Faulted	 The ‘Manual’ state is used only when the UAV is under manual control. The ‘Autonomous’ state is used when the UAV operating autonomously. The ‘Faulted’ state is used when the UAV is not functioning as designed.
Checksum	0D	Bitwise XOR
<CR><LF>		End of message

Table 22. UAV Search and Report Message Fields

UAV Replenishment Example Message:

$RXSAR,111221,161229,R,21.31198,N,157.88972,W,N, 21.32198,N,157.89972,W,ROBOT,2*0D

Appendix D: Radio Communication Restrictions

Radio communication is managed under the restrictions laid out in the Radio Communication Class Licenses controlled by the Australian Communication and Media Authority (ACMA).

In Australia, Class Licenses let you operate common radio equipment on shared frequencies without needing to get additional approval and alleviate the requirement to have specific qualifications. Each class license tells you:

- What equipment you can use under the license;
- The permissible frequency range; and
- The rules for using it.

The relevant class licenses have been summarized below. Whilst every attempt has been made to ensure the below details are correct, the authoritative sources are the class licenses located in the links.

D.1. Class Licenses

D.1.1 Intelligent Transport Systems Class License (SHF)

This class license lets you operate an intelligent transport systems (ITS) station. ITS uses wireless technology for vehicles and traffic systems to communicate from:

- Vehicle to person
- Vehicle to vehicle
- Vehicle to structure

The following restrictions apply:

- SHF: 5855MHz to 5925MHz
- Radiated power does not exceed a maximum ERIP of 23dBm/MHz
- https://www.acma.gov.au/licences/intelligent-transport-systems-class-licence

D.1.2 Radio-Controlled Models Class License (HF/VHF)

This class license lets you use radio equipment to control model planes, trains, cars, and boats. All users operate on shared frequencies. The following restrictions apply:

- HF: 29MHz band (29.72MHz to 30Mhz)
- VHF: 36 MHz band (36MHz to 36.6MHz)
- Maximum EIRP greater than 300 milliwatts and not exceeding 1 watt
- https://www.acma.gov.au/licences/radio-controlled-models-class-licence

D.1.3 Citizen-Band Radio Stations Class License (HF/UHF)

This class license lets you use citizen band (CB) radios to communicate over short distances. The following restrictions apply:

- HF: 26.965MHz to 27.405MHz (inclusive)
- UHF: 476.4125MHz to 477.4125MHz (inclusive)
- https://www.acma.gov.au/licences/citizen-band-radio-stations-class-licence
-

D.1.4 Low Interference Potential Devices (LIPD) Class License (MF/VHF/UHF/SHF)

This class license lets you use some short-range devices on shared frequencies. These include:

- Wi-Fi devices
- Telecommand for drones
- Radars including automotive
- Ultra-wideband transmitters
- Infrared equipment
- Video sender transmitters

The following restrictions apply:

- https://www.acma.gov.au/licences/low-interference-potential-devices-lipd-class-licence

D.1.5. Radio Navigation Satellite Service Class License

This class license lets you use radio navigation satellite service receivers. These are commonly called GPS (Global Positioning System) receivers.

The following restrictions apply:

- You can only receive RNSS signals on the frequencies listed in the class license:
  - 1164 to 1215MHz
  - 1215 to 1240MHz
  - 1240 to 1300MHz
  - 1559 to 1610MHz
- https://www.acma.gov.au/licences/radio-navigation-satellite-service-class-licence

Appendix E: Hyperspectral (HSI) Camera

OpenHSI is a complete camera and software hyperspectral imaging system developed by staff and students at the University of Sydney, originally funded by The Commonwealth of Australia's Defence Science and Technology Group (DSTG), Maritime Division. Ongoing work is currently funded by DSTG's StarShot program on Remote Undersea Surveillance as part of the 'More Together' Strategy.

The goal of the OpenHSI project is to proliferate deeper understanding of Hyperspectral Imaging Spectroscopy through making the system open and providing best practice tools to create (3D print and assemble), calibrate and operate an imager, that is affordable for Science and Engineering specialists in Remote Sensing. To this end, the software uses OpenSource tools as much as possible including NASA's 6S radiative transfer model through the Py6S python software.

The University of Sydney's Associate Professor Sergio Leon-Saval and Dr. Christopher Betters of the Sydney Astrophotonic Instrumentation Laboratory (SAIL) developed the first OpenHSI camera from previously published designs, adapting it to readily available materials, and thus incrementally changing the design, at the request of Dr. Bradley Evans and his team from DSTG.

The Australian Research Council funded training centre CubeSats, UAV and their applications (CUAVA) students Yiwei Mao (PhD Candidate) and Samuel Garske (PhD candidate) developed their software to support the camera as part of their PhD and have publications pending on their work. Professors Iver Cairns and Associate Professor K.C.Wong and Dr. Bradley Evans supervise Yiwei and Sam.

RoboNation, together with DSTG and funded by the Next Generation Technologies Fund, will incorporate a version of the OpenHSI system in the Australian based event.

Since the project commenced, Sydney Photonics Pty Ltd was founded by Dr. Christopher Betters to commercialize the technology and will supply competitors in the upcoming RobotX Challenge with OpenHSI cameras developed for RobotX.

Join us in making use of this technology, help us enhance the communities understanding of hyperspectral imaging spectroscopy. We encourage you to participate in the community and support the work of the OpenHSI team.

E.1. Python Library

https://github.com/openhsi/openhsi/tree/master/

PyPi https://pypi.org/project/openhsi/

E.2. Documentation and Tutorials

https://openhsi.github.io/openhsi/

Forum Support: https://robonationforum.vbulletin.net/forum/robotx/-2022-robotx-challenge