robotx CHALLENGE

2024

TEAM HANDBOOK

V3.0 (October 2024)

Introduction

Welcome to the forefront of innovation, with the 2024 Maritime RobotX Challenge!

This Team Handbook contains the information that teams will need to compete at the 2024 Maritime RobotX Challenge. It includes task descriptions, rules and requirements, specifications and other guidance. This document will provide teams with a comprehensive 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 was established to foster student interest in robotic and autonomous systems operating within the maritime environment. The RobotX competition framework challenges teams to transform the Wave Adaptive Modular-Vessel (WAM-V) into an Autonomous Maritime System (AMS), developing and integrating an Unmanned Surface Vehicle (USV) and an Unmanned Aerial Vehicle (UAV) to accomplish a series of tasks on the Autonomy Challenge course. Teams also learn the critical need to document their designs throughout the process.

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 and unmanned, multi-domain vehicles.

Why compete in RobotX? Participants of the Maritime RobotX Challenge can 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 more 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.

2024 ROBOTX ORGANIZERS

The 2024 Maritime RobotX Challenge is hosted by RoboNation, in collaboration with the United States Office of Naval Research (ONR).

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Version Updates

Version	Changes	Date
V1.0	First release of Maritime RobotX Challenge 2024 Team Handbook.	08 September 2024
V2.0	• Section 2.5.2 - 2.5.3: Added alternative buoy source/specifications for Task 2 – Entrance/Exit Gates and Task 3 – Follow the Path. • Section 2.5.3: Updated buoy sock colors for buoys positioned on either end of the path. • Section 2.5.7: Updated estimated weight of colored disk used in Task 7 - UAV Replenishment. • Section 3.1.2: Incorporated full scoring breakdown for Semi-Finals and Finals. • Section 5.3.3: Added trailer specifications.	18 September 2024
V3.0	• Section 1.1: Updated venue layout. • Section 2.5.4: Corrected the directions of the required circles with each wildlife to be consistent with scoring. • Section 2.5.8: Clarified language to: "This task can be attempted by any team once they have been cleared for safe operations of their UAV." • Section 5.3.3: Updated tent workspace to 15' x 25' per team. Added approximate tent height of 10'. • Appendix D: Heartbeat communications protocol and message formatting updated.	08 October 2024

Table 1. Document Version Log

SECTION 1: RobotX Overview

Maritime RobotX Challenge 2024 *www.robotx.org*

1.1 Dates & Venue

The 2024 Maritime RobotX Challenge (RobotX 2024) will be conducted 3-9 November 2024 at Nathan Benderson Park in Sarasota, Florida, USA. Multiple courses will be used for the competition.

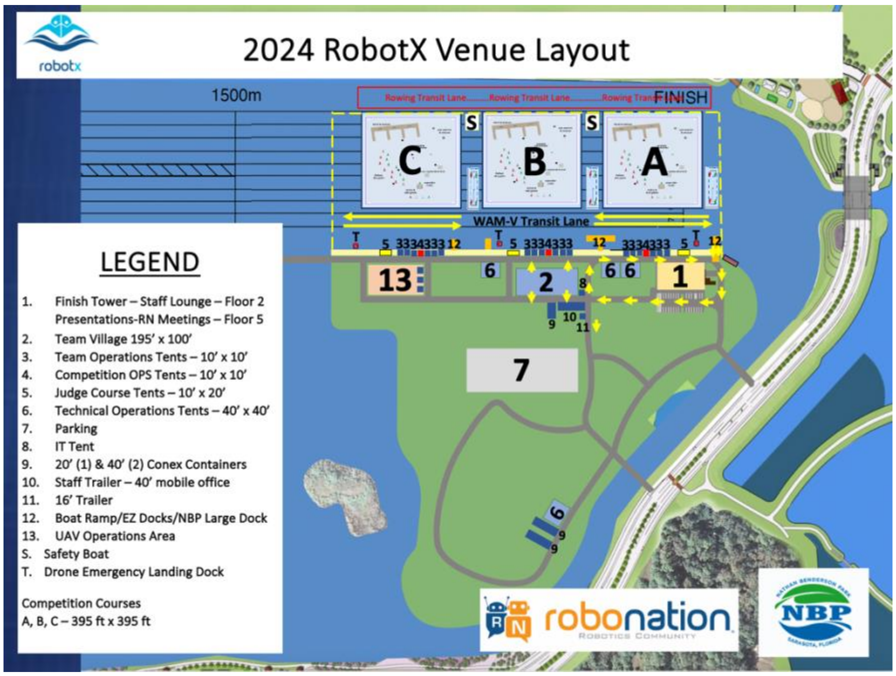


Figure 1: Preliminary Venue Layout

1.2 Competition Structure

RobotX 2024 includes the (1) Autonomy Challenge that demonstrates autonomous performance and safety; and (2) Design Documentation that presents each team's work and vehicle design.

1.3 Eligibility

Teams can be from anywhere in the world and must use a WAM-V 16 to compete. Information about the WAM-V can be found at robotx.org/about.

1.3.1 Eligibility Details & Team Composition

- Teams are composed of students, faculty, industry partners, and/or government partners.
- The majority of the team members must be undergraduate through post-grad students. Teams may also include high school students. Interdisciplinary teams are encouraged.
- Combination of students, faculty, industry partners, and/or government partners.

1.4 Point of Contacts

RobotX Questions:	Registration Questions:	Technical Questions:	On-Site Logistics/Safety:
autonomy@robonation.org	support@robonation.org	robotx.org/discord	events@robonation.org 850.642.0536 (Cheri)

SECTION 2: Competition

This section includes general information for the RobotX 2024 including competition schedule as well as requirements related to Design Documentation and the Autonomy Challenge.

2.1 Competition Schedule and Timeline

A detailed competition schedule can be found on the RobotX website.

Date	Event	Location
01 November 2023 – 18 March 2024	Registration Open	Registration Portal
23 September	Event Information Submission Deadline • Team Information • On-Site Requirements • Background Checks (required for Teams with minor students only) • Merchandise Order	
~~30 September~~ **07 October Extension**	Online Design Documentation Submission Deadline • Team Website • Technical Design Report • Team Introduction Video Event Hotel Booking Deadline (Section 5.3.1 Travel + Lodging	
03 November	Opening Ceremony / Team Orientation Vehicle Assembly Licensed Pilot Flight Tests Practice Course Opens (afternoon)	Nathan Benderson Park
04-06 November	Qualifying and Practice Course Open Design Presentations / System Assessments	
07-08 November	Qualifying and Practice Course Open Semi-Finals Round	
09 November	Finals Round & Awards Ceremony	

Table 2. RobotX 2024 Schedule

2.1.1 Daily Events

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

- **Morning Meetings (0745):** Technical Directors present the Plan-of-the-Day. Teams have an opportunity to provide feedback and ask questions.
- **Evening Meetings (1700):** Technical Directors debrief the day's events, describe any course changes for the following day, and teams are encouraged to provide feedback.

2.2 Design Documentation

Prior to the on-site competition, teams provide a portfolio of design documentation. During the competition, teams give an oral presentation; and their AMS will be assessed by judges, who are subject matter experts (SME).

2.2.1 Delivered Prior to On-Site Competition

The following design documentation is delivered prior to the on-site competition. Instructions for how to submit deliverables can be found in Section 5.2 Pre-Competition Requirements. The deliverable deadlines can be found above in Table 2.

Team Website (Total Maximum Points: 180)
Teams must submit a website in English that documents their team, vehicle 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 must include:

- Current team name and contact information
- Vehicle photos and/or videos
- Supporting media, which may include:
    - 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

Team Website Scoring Metrics *(Total Maximum Points: 180)*
The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Team Information *(20% of score)*

Outstanding	Team website includes all required team information, including the team's name and contact information, and a list of team members and sponsors. All mentions of the vehicle are relevant to the current competition year.
Strong	Team website provides a brief introduction to the team, team members and sponsors. There is supporting media on the vehicle.
Average	Team website introduces the team and/or team members.

Below Average	Team website provides little to no information on the team. There is no mention of the vehicle.
Requirements Not Met	The required team information is not included on the website.

Vehicle Design Documentation *(40% of score)*

Outstanding	Vehicle development and testing process is thoroughly documented with instructional and informative supporting media and historical recording. This could include photographs, diagrams, videos, procedures (text + images), design documentation (text + images + video), or blogs for historical records.
Strong	Good documentation on vehicle development and testing process is provided. Supporting media is accessible.
Average	Vehicle development and testing process is adequately presented with some evidence of supporting media.
Below Average	Few pictures or videos of the vehicle, but no instructional or informative documentation included.
Requirements Not Met	No visuals or documentation of the vehicle is available on the website.

Website Quality *(40% of score)*

Outstanding	Website places a heavy emphasis on human factors. Layout is visually appealing, easily maneuverable, and does an excellent job of drawing user's attention to relevant content.
Strong	Website considers user experience. Layout does a good job of drawing user's attention. Users can navigate the site easily and quickly.
Average	Website quality was adequate. Users can navigate the site to find most information.
Below Average	Layout and/or design makes it difficult to find information. Website does not have a user-friendly display.
Requirements Not Met	Website is busy and difficult to read; no guidance on maneuvering site.

Technical Design Report (TDR)

Teams must submit a technical design report in English that describes the design of their AMS 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. Requirements and scoring metrics for this report are outlined in Appendix A: Technical Design Report.

Team Introduction Video

Teams must submit a video introducing their team members and highlighting their team personality. This video is meant to be a creative showcase of what makes each team unique, such as the mission of the team or the team culture. Teams should consider this video as an "elevator pitch" or project proposal for an opportunity to earn additional funding or support.

Format Requirements:

1. Video must be conducted in English or include subtitles in English.
2. Video must be no more than three (3) minutes in length.
3. Video may include graphics, vehicle performance, and/or simulation.

4. Videos must be hosted by the team. Teams have the choice of hosting on YouTube or on their Team Website. The video must follow YouTube Rules & Policies, including appropriate music copyright management.

Team Video Scoring Metrics *(Total Maximum Points: 120)*
The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Formatting *(10% of score)*

Strong	All formatting guidelines are followed. Video is conducted in English or includes English subtitles, video is no more than 3 minutes in length, and video is hosted on the team's website or YouTube channel.
Requirements Not Met	Video does not follow formatting requirements.

Video Quality *(20% of score)*

Outstanding	Visuals immediately draws attention. Overall, the video is solid in frame (not shaky), correctly lighted, in precision focus, appropriately segmented, and visually clear in all respects. Transitions between segments are clear and smooth. The video is less than 3 minutes total runtime.
Strong	Good visual impression. Majority of video is clear, adequately lit, and places people and objects in recognizable scale and perspective. Video segments are generally of the appropriate length, transition well, and are related to each other. Use of video effects is good. Runtime is less than 3 minutes.
Average	Video quality is satisfactory.
Below Average	Frames and segments are shaky, distracting or poorly lit. Some segments are out of focus. Some heavy shadows are obscuring viewpoint. Visual effects are distracting rather than informative. Video exceeds 3 minutes in length.
Requirements Not Met	No focus on visual quality. Video exceeds 3 minutes in length.

Information Organization *(25% of score)*

Outstanding	Video is a complete introduction of the team makeup including team members, sub-teams, activities, mentors, and major sponsors. Organization of video information is logical and compelling.
Strong	The viewer is left with good understanding of the information shared in video.
Average	Video information is somewhat scattered throughout video, leaving the viewer lacking complete understanding of project.
Below Average	Video provides incomplete information regarding the team members, activities, or progress. The information presented is extraneous, confusing, or low quality.
Requirements Not Met	No organizational strategy is apparent.

Clear and Effective Communication *(25% of score)*

Outstanding	Effective and compelling use of video medium to communicate the introduction of the team. Easy for non-technical viewer to understand and support. [You're left wanting to learn more.]
Strong	Exhibits moderately compelling use of video medium to communicate the introduction of the team. Strong potential, moderately compelling, mostly understandable to non-technical viewer. [You're left strongly considering to learn more.]
Average	Adequately uses the video medium to introduce the team. Not difficult to understand, but not compelling either.
Below Average	Exhibits some ability to use video to attempt to introduce team and project overview. Difficult for viewer to understand and/or was not compelling. [You're left unenthused.]
Requirements Not Met	Poorly used video medium to convey team introduction. Information was as not clearly understood and was not compelling. [You're left with little information.]

Creativity *(20% of score)*

Outstanding	Team creativity and enthusiasm is clearly evident in the video. Appropriate use of humor is understated and well done. Video captures user's attention without diminishing or obscuring the information delivered. Effects of careful post-production editing are clear.
Strong	Some creativity has been used throughout video. The visual style and tone are consistent throughout video.
Average	Exhibits a moderate attempt at creativity.
Below Average	Little attempt made to include creative or imaginative ideas in video. Poor visual effects and enthusiasm for the project.
Requirements Not Met	Little imagination or creativity is evident in production. Information is presented lacking enthusiasm.

2.2.2 Delivered During On-Site Competition

Teams must give a design strategy presentation to a panel of subject matter expert judges. The goal of the presentation is to share the team's system design approach to the challenges presented in the Autonomy Challenge, specifically the capabilities required for each task. The presentation should include:

- a concise description of the team's strategic vision, and
- how the vehicle design compliments the team's goals.

This oral presentation must be conducted in English and may include visual aids (i.e. digital slides, poster board). If digital slides are used, teams must provide their own computer and adapters for an HDMI connecter to use the presentation display monitor. Teams receive an assigned 30-minute presentation time. Please find the latest presentation schedule here: robotx.org/2024. This presentation includes:

- Team Introduction Video – 3 minutes
- Presentation – 20 minutes
- Judge Question & Answer – 5 minutes

Design Presentation Scoring Metrics *(Total Maximum Points: 180)*
The design presentation is worth a total of 180 points. The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Competition Strategy *(30% of score)*

Outstanding	Presentation includes a concise description of the team's strategic vision and how the vehicle design compliments their goals. The team clearly explains how they developed their competition strategy.
Strong	Presentation describes their competition strategy and how their vehicle design aligns with meeting their competition goals.
Average	Presentation includes a brief overview of how the vehicle design aligns with the team's competition strategy and goals.
Below Average	Team mentions a competition strategy but no additional details on how it was developed or how it led to their strategic vision.
Requirements Not Met	Team does not mention their competition strategy, vision or how their vehicle design is aligned with vision.

Design Rationale *(30% of score)*

Outstanding	Team presents their design process and how their decisions relate to their overall competition strategy. Lessons learned from testing or previous competition experience are described, including application throughout the design process.
Strong	Presentation includes a description of the team's design process and includes narrative on how testing or previous experience influenced vehicle design.
Average	Team describes the rationale behind the vehicle design process.
Below Average	Presentation includes mention of the design process, lacking a clear rationale of design choices.
Requirements Not Met	No mention of the team's design process or the rationale behind the design process.

Effective Communication & Professionalism *(20% of score)*

Outstanding	Presentation materials and team members' knowledge are effective and support the team's message. Team members are engaging, respectful, and professional, while interacting positively with the judges and each other.
Strong	Presentation materials are presented in a professional manner and support the team's message. Presentation is well prepared and appears to be rehearsed in advance.
Average	Presentation materials are presented in a mostly professional manner and support the team's message.
Below Average	Presentation materials and styles are adequate but less than engaging.
Requirements Not Met	The message was not effective, and the presentation was not organized.

Judge Questions & Dialogue *(20% of score)*

Outstanding	The team effectively uses evidence, experience, and research from their project to inform responses to all questions and discussion posed by the judges.
Strong	The team responded professionally and knowledgeably to judges' questions.
Average	The team responded adequately to most or all of the judges' questions, mostly interacting with courtesy and professionalism.
Below Average	The team did not provide sufficient answers to the judges' questions and interacted with minimal courtesy and professionalism.
Requirements Not Met	Team members were not able to respond to many or all questions and did not take the initiative to engage in dialogue with the judges.

System Assessment

Judges inspect the team's AMS and assess technical design, technical innovation, and craftsmanship of the design. Team members should be present to answer technical questions posed by the judges during this inspection and be prepared to explain their design strategy and how decisions made impacts on the technical design, functionality, and craftsmanship.

Teams receive an assigned 30-minute slot. After the assessment, teams should make themselves available for a team photo and optional video interview. Please find the latest schedule here: robotx.org/2024.

System Assessment Scoring Metrics *(Total Maximum Points: 180)*

The system assessment is worth a total of 180 points. The scoring metrics include a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

Technical Design *(45% of score)*

Outstanding	Design and implementation of systems and subsystems are well aligned with team's strategy, design decisions, and engineering principles. Clear and thoughtful design choices are evident in the technical functions, key decisions, and testing regimen.
Strong	Good and knowledgeable rationale and execution of design selections made, aligning with team's strategy, design decisions, and engineering principles.
Average	Adequate explanation of technical design decisions, equipment selections, and testing regimen, mostly evident in the vehicle and subsystems.
Below Average	Rationale of technical design is briefly covered with minimal alignment with team's strategy, design decisions, and engineering principles.
Requirements Not Met	Design and implementation of systems and subsystems are not aligned with team's strategy, design decisions, and engineering principles.

Innovation *(30% of score)*

Outstanding	Full system demonstrates creative and innovative solutions by applying existing technology in novel ways within the system, using existing technology in a previously unintended way, or creating new technology or products incorporated into the system.
Strong	Clear evidence of innovative approaches across multiple sub-systems. Research and testing were conducted throughout the development process.
Average	There is moderate evidence that creative and innovative solutions were incorporated into system to improve performance.
Below Average	Little evidence of creativity or innovation in design choices throughout the system.
Requirements Not Met	No technical innovation noted.

Craftsmanship *(25% of score)*

Outstanding	System is assembled with exquisite care and thoughtful attention to detail and aesthetics. Construction and improvisations are neatly executed to maintain high levels of functionality, durability, and adherence to the team's design philosophy. Any vehicle adornment demonstrates creativity, originality, etc.
Strong	System is assembled with care and attention to detail and aesthetics. Construction and improvisations maintain acceptable levels of functionality, durability, and adherence to the team's design philosophy.
Average	System is assembled to execute acceptable levels of functionality, durability and adherence to team's design philosophy.
Below Average	Minimal evidence that system is assembled with care and attention to detail and aesthetics. Adherence to team's design philosophy is vague and unclear.
Requirements Not Met	Evident hazards or potential hazards throughout the system. The system was assembled with minimal care and attention to detail. Little to no attention to aesthetics.

2.3 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 are similar equipment used in the previous iterations of the RobotX Challenge, hosted in Hawai'i (2016 and 2018). Under each task description is a table that includes the specifications that will be used for RobotX 2024.

2.3.2 Qualifying Round

At the start of competition, Qualifying and Practice Courses will be available for teams to practice, demonstrate proficiency, and qualify for the Semi-Finals Round. Multiple teams may be on a Qualifying and Practice Course at the same time; but only one team can attempt to qualify on a task at any one time. The proficiency requirements for qualifying on each task can be found in Section 2.6 Qualifying Round. Teams must qualify on a pre-determined number of tasks to advance to the Semi-Finals Round.

Teams may schedule times to practice or qualify on individual tasks on these courses, with the Technical Director. During the competition, this schedule will be available at robotx.org/course-schedule.

2.3.3 Semi-Finals Round (Thursday-Friday, November 7-8)

Teams that complete the predetermined number of task qualifications will advance to Semi-Finals and have access to a full course. Only one team may be on a Semi-Finals Course at a time.

During the Semi-Finals Round, successful completion of the full Finals Course requires the AMS to demonstrate the ability to collect and use information from individual tasks to complete other tasks. Teams may attempt tasks in any order and must operate autonomously for the entire run. The proficiency requirements for Semi-Final runs can be found in Section 2.7 Semi-Finals and Finals Rounds.

2.3.4 Finals Round (Saturday, November 9)

Teams that advance to Finals will be determined based off Semi-Finals performance scores, at the judges' discretion. Finalists will be announced during Friday evening's Team Meeting. Only one team may be on a Finals Course at a time.

During the Finals Round, successful completion of the full Finals Course requires the AMS to demonstrate the ability to collect and use information from individual tasks to complete other tasks. Teams may attempt tasks in any order and must operate autonomously for the entire run. The proficiency requirements for Final runs can be found in Section 2.7 Semi-Finals and Finals Rounds.

2.4 Mandatory Activities

The mandatory USV Demonstration and UAV Demonstration must be successfully completed prior to entering an Autonomy Challenge course or attempting a task.

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 safety requirements 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 requirements for propellors, including propeller guard; and
- All systems are properly secured.

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

Dynamic Navigation Demonstration

This demonstration is a mandatory requirement to enter the Autonomy Challenge. Teams should be prepared to conduct a demonstration each day. 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 between two pairs of red and green buoys; as shown in Figure 2. 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.

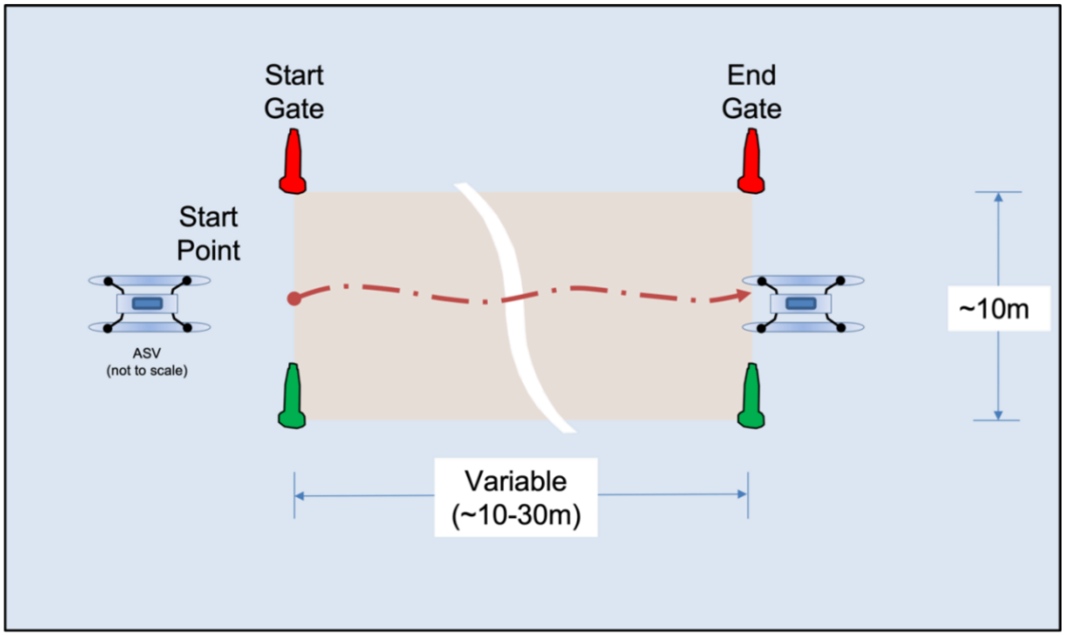


Figure 2. Dynamic Navigation Demonstration

Task Element	Description	Model No.	Color	Overall Height	Ht. Above Waterline	Base Diam.
Port Marker Buoy	Taylor Made Sur-Mark Buoy	950410	Red	49 in	39 in	18 in
Starboard Marker Buoy	Taylor Made Sur-Mark Buoy	950400	Green	49 in	39 in	18 in
Buoys are supplied from Taylor Made, www.taylormadeproducts.com.						

Table 3. Task Elements for Dynamic Navigation Demonstration

2.4.2 UAV Demonstration

FAA Requirements
Teams must meet all requirements mandated by the Federal Aviation Association (FAA).

FAA Vehicle Registration: The vehicle used at competition must be registered using the FAADroneZone, the certificate must be presented at safety inspection and at the flight line, and an external surface of the vehicle must be labeled with the registration number.

FAA TRUST: The Safety Pilot must complete The Recreational UAS Safety Test (TRUST) and present the certificate of completion at safety inspection and at the UAV field.

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

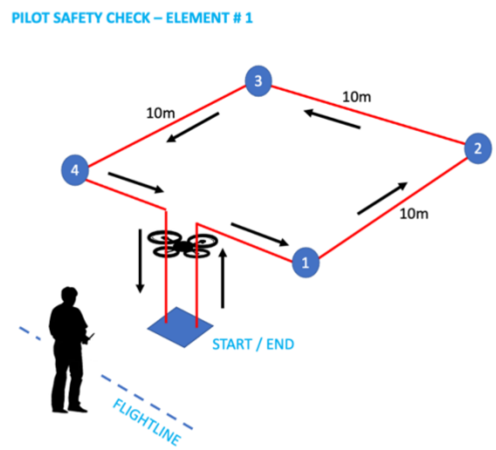
- Meets the limitations for size and weight;
- Safety issues related to, but not limited to, propellers, motor mounts, general airframe and wiring integrity, battery security, and battery capacity checks;
- All sub-systems are properly secured; and
- Autonomous flight control disconnected to enable manual flight control mode.

FAA Remote ID: The vehicle used at competition must comply with FAA Remote Identification for Drone Pilots (Remote ID). At a minimum, the Remote ID broadcast must include a unique ID for the vehicle and the vehicle position. The broadcast will be verified at safety inspection.

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

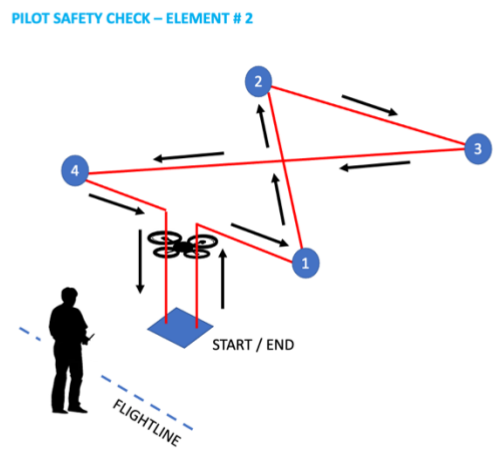
Pilot Flight Proficiency Test

On the first day of competition, each team safety pilot must pass a flight test as supervised by the TD staff. The objective of the Pilot Flight Proficiency Test is to demonstrate the pilot's ability to take control of the UAV if required and land it safely.



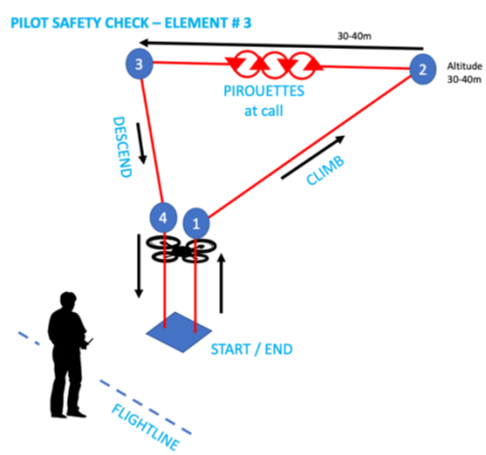
INSTRUCTIONS

a) Take-off and establish a hover at an altitude of 2 - 3 metres
b) Maintain this altitude for the entirety of the course.
c) With the done facing AWAY from the pilot, complete a square circuit in either direction through each point 1-2-3-4 (or 4-3-2-1).
d) Return to the take-off position, hover and land.
e) Render the Drone / Aircraft SAFE



INSTRUCTIONS

a) Take-off and establish a hover at an altitude of 2 - 3 metres.
b) Maintain this altitude for the entirety of the course.
c) With the done facing AWAY from the pilot, commence hour glass flight in either direction to each point 1-2-3-4 (or 4-3-2-1).
d) On return to the take-off position, hover and land.
e) Render Drone / Aircraft SAFE.



INSTRUCTIONS

a) Take-off and establish a hover at an altitude of 2 - 3 metres.
b) Climb up and out to point (2) 30 – 40 metres out at an altitude of 30 – 40 metres.
c) Commence towards point (3) assessor will call for 3 – 4 stationary pirouettes, re-orientate and continue to point (3).
d) Descend at a 45-degree angle towards the landing area at POINT (4).
e) Establish a hover at an altitude of 2 – 3 metres and land.
f) Render Drone / Aircraft SAFE.

2.5 Task Descriptions

This section provides details of the RobotX 2024 Autonomy Challenge tasks and the proficiency requirements for each round of competition. Teams are encouraged to develop a strategy to approach these tasks that best suits their AMS.

2.5.1 Task 1 – Situational Awareness & Reporting

This task provides a situational awareness standard between the AMS and Technical Directors. The AMS is required to transmit a heartbeat message to the Technical Director (TD) Network (see Appendix D) to ensure that all required messages and reporting can be achieved.

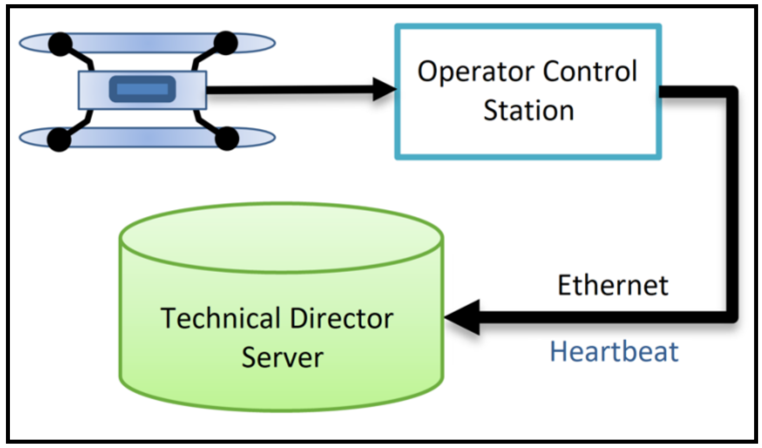


Figure 3: AMS Heartbeat

During Semi-Finals and Finals, the AMS transmits specific messages reporting various activity and data collected throughout the run. The message formatting and requirements are outlined in Appendix D.

At each course operations tent, teams are provided with a wired RJ45 connection to connect to the TD Network. Information from the team's Operator Control Station (OCS) is transmitted to the TD network, using the RJ45 connection. Teams are expected to provide their own wireless link for information exchange between the AMS and the course OCS.

Qualifying Criteria

Qualification on this task is **mandatory for advancement** to the Semi-Finals Round. The AMS must transmit the heartbeat message as defined in Appendix D. The TD team confirms to the judges the heartbeat message has been received. Additionally, teams are highly encouraged to transmit the reporting component for the other Autonomy Challenge tasks.

2.5.2 Task 2 – Entrance and Exit Gates

This task requires the AMS to enter and exit the course through the gates. The three gates are marked by four colored buoys (see Figure 4); in between each set of buoys is an underwater beacon. The AMS should detect the beacon and enter the course through those gates before proceeding to other tasks. The complexity of this task is raised between each of the rounds, incorporating other task's elements (for example, in past years the scan the code light tower replaced the placement of the black buoy).

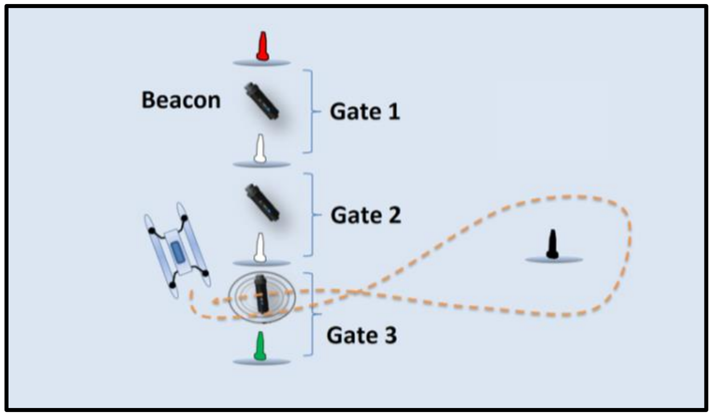


Figure 4: Example Entrance and Exit Gate Task

There are four 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).

In between each of the gates is a submerged beacon (specifications available in Appendix C: Beacon Specifications). The red, white and green buoys are approximately 10m apart, with the black buoy being approximately 20m from the gates. The beacon frequencies for each course are separated by at least 2kHz and staggered in time and frequency. Only one beacon on each course will be activated at any time – when the task is being attempted by an AMS; frequencies for each instance of will be posted daily.

Qualifying Criteria

The AMS should pass through an entry gate, circle the black buoy and exit back through the same gate.

Task Element	**Description**	**Color**	**Overall Height**	**Ht. Above Waterline**	**Base Diam.**
Port Buoy	Taylor Made Sur-Mark Buoy	Red	49 in	39 in	18 in
	Possible alternative: *Rolyan Nun Channel Marker B961RC*		60 in	*TBA*	9 in
Gate Buoys (Quantity: 2)	Taylor Made Sur-Mark Buoy	White	49 in	39 in	18 in
Starboard Buoy	Taylor Made Sur-Mark Buoy	Green	49 in	39 in	18 in
	Possible alternative: *Rolyan Channel Marker B961GC*		60 in	*TBA*	9 in
Buoy to Circle	Taylor Made Sur-Mark Buoy Black Buoy Sock	Black	49 in	39 in	18 in
Buoys are supplied from Taylor Made, www.taylormadeproducts.com. ***Possible alternative:*** *Taylor Made is backlogged in their manufacturing due to new ownership. While we are prioritizing sourcing the Taylor Made buoys, we have identified a back-up option with Rolyan buoys, www.rolyanbuoys.com*					

Table 4: Task Elements for Entrance and Exit Gates

2.5.3 Task 3 – Follow the Path

This task consists of a pathway of six pairs of red and green buoys, with a single buoy on either end. This buoy could be any combination of red/blue, green/blue, or red/green. The AMS navigates the pathway by either exiting or returning to the harbor, considering the expression, "red right returning."

> **Exit Harbor:** red buoys on port (left) side during navigation
> **Return to Harbor:** red buoys on starboard (right) side during navigation

The AMS navigates the pathway without making contact with any obstacles (black buoys). These obstacles are randomly placed within the task area. Teams may use a UAV to assist with this task.

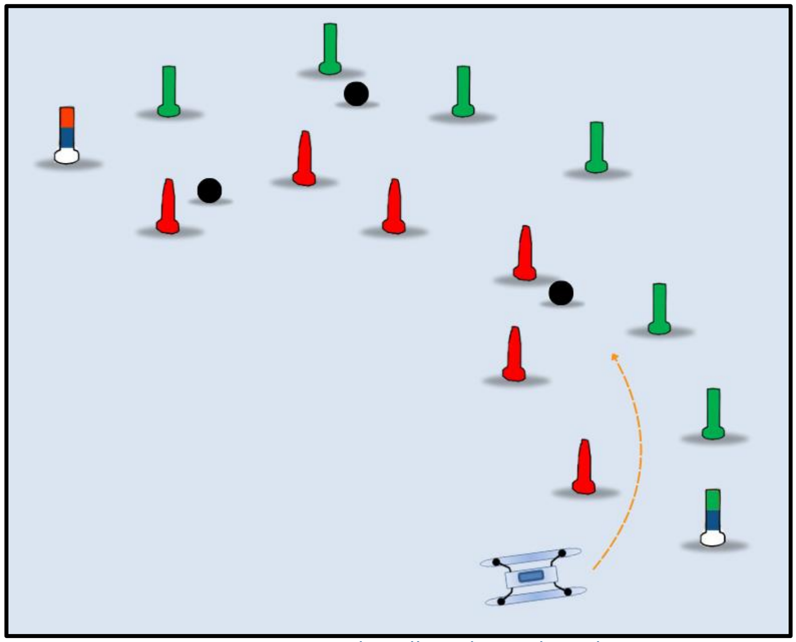


Figure 5: Example Follow the Path Task

Qualifying Criteria

The AMS must navigate through two consecutive sets of gates, at a minimum.

Task Element	Description	Color	Overall Height	Ht. Above Waterline	Base Diam.
Port Marker Buoy	Taylor Made Sur-Mark Buoy	Red	49 in	39 in	18 in
	Possible alternative: *Rolyan Nun Channel Marker B961RC*		60 in	*TBA*	9 in
Starboard Marker Buoy	Taylor Made Sur-Mark Buoy	Green	49 in	39 in	18 in
	Possible alternative: *Rolyan Channel Marker B961GC*		60 in	*TBA*	9 in
Exit/Return Buoys	Taylor Made Sur-Mark Buoy Red/Blue, Green/Blue, Green/Red Buoy Sock	Red, Green, or Blue	49 in	39 in	18 in
Obstacle Buoys	Polyform A-3, A-5	Black		12 in	14.5 in
Buoys are supplied from Taylor Made, www.taylormadeproducts.com and Polyform US, shop.polyformus.com. ***Possible alternative:*** *Taylor Made is backlogged in their manufacturing due to new ownership. While we are prioritizing sourcing the Taylor Made buoys, we have identified a back-up option with Rolyan buoys, www.rolyanbuoys.com*					

Table 5: Task Elements for Follow the Path

2.5.4 Task 4 – Wildlife Encounter

The Wildlife Encounter task consists of three round buoys, which represent three different Florida marine creatures: a python, manatee and iguana (see Figure 6). The AMS identifies, reacts and maneuvers around the buoys. Teams may use their UAV to aid in accomplishing this task.

After the AMS detects and classifies the colors of each buoy, the USV uses the information to (as an example):

- Circle the manatee (blue buoy) in a clockwise direction;
- Circle the iguana (green buoy) in a counterclockwise direction; and
- Circle the python (red buoy) twice in any direction.

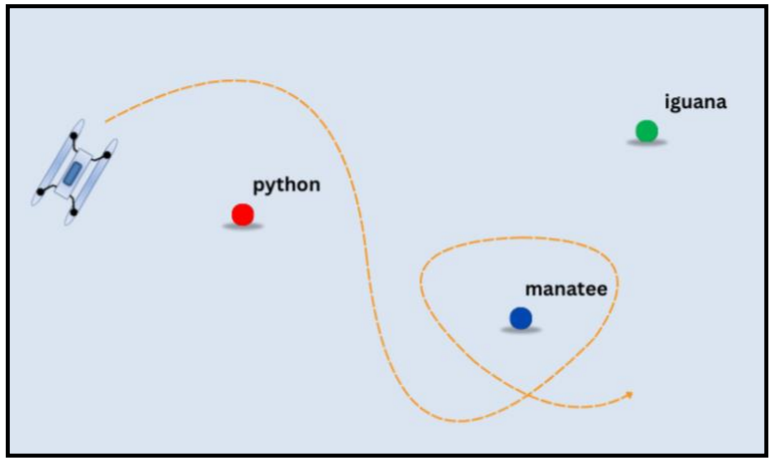


Figure 6: Example Wildlife Encounter Task

Visual Display

In addition, the AMS reports the location of each marine creature. Data and a graphic display is submitted to the judges for consideration to earn additional points. The Wildlife Encounter report must be available for judges to see in the team's course operations area.

Qualifying Criteria

The AMS must detect and circumnavigate at least one wildlife.

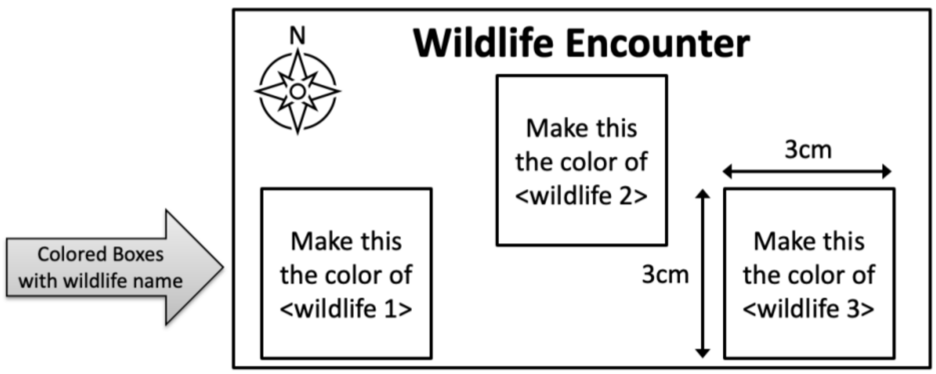


Figure 7: Wildlife Encounter Task Visual Display Specifications

Task Element	Description	Color	Ht. Above Waterline	Base Diam.
"Manatee" Creature	Polyform A-2	Blue	12 in	14.5 in
"Iguana" Creature	Polyform A-2	Green	12 in	14.5 in
"Python" Creature	Polyform A-2	Classic Red	12 in	14.5 in
Buoys are supplied from Polyform US, shop.polyformus.com.				

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

2.5.5 Task 5 – Scan the Code

This task consists of a light tower with three faces, atop a floating platform, which displays an RGB light sequence. The AMS observes the three-light sequence displayed, and reports the colors observed and the sequence of their occurrence. The AMS may use the light sequence to complete other tasks during the Semi-Finals and Finals Rounds.

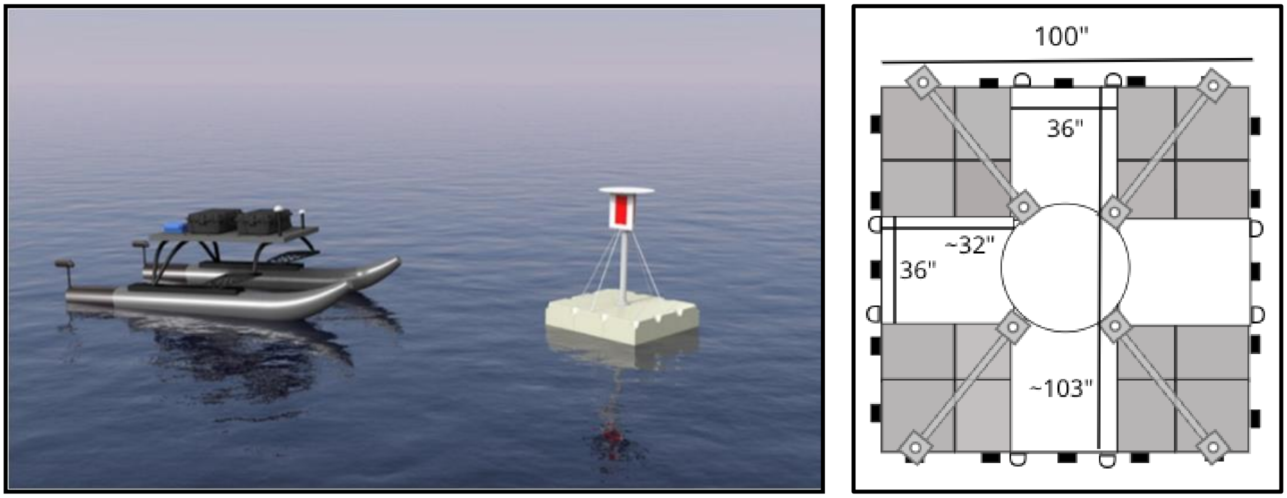


Figure 8: Example Scan the Code Task

Note: The light tower platform consists of 5x5 (25 total) blocks (see above for dimensions). On the northern face of the platform will be a solar panel pack raised at ~30 degrees and a battery pack behind.

1 sec	1 sec	1 sec	2 sec	1 sec	1 sec	1 sec	2 sec	1 sec	1 sec	1 sec

Figure 9: Example light pattern and timing sequence

The light tower is no more than 3m above the surface of the water, and within a 40m x 40m task area. The light appears black when off/inactive. When activated the light displays colors one at a time, and randomly generates a three-color sequence (e.g. red-green-blue). Each color appears for 1 second, followed by the second and third. After this the light remains off (black) for 2 seconds (see Figure 9). The 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 (see Figure 10). The sequence may change between each run.

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 10: Example light pattern color combinations

Visual Display
Teams may provide a Scan the Code graphical display as detailed in Figure 11: Scan the Code Visual Display Example. The example Scan the Code in Figure 12 shows the report of Red, Green, Blue for the light buoy. The Scan the Code report must be available for judges to see in the team's course operations area.

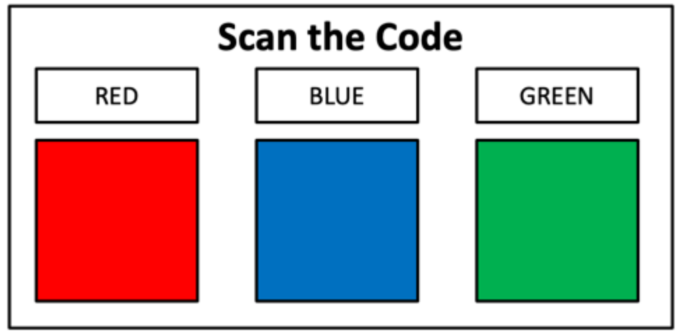


Figure 11: Scan the Code Visual Display Example

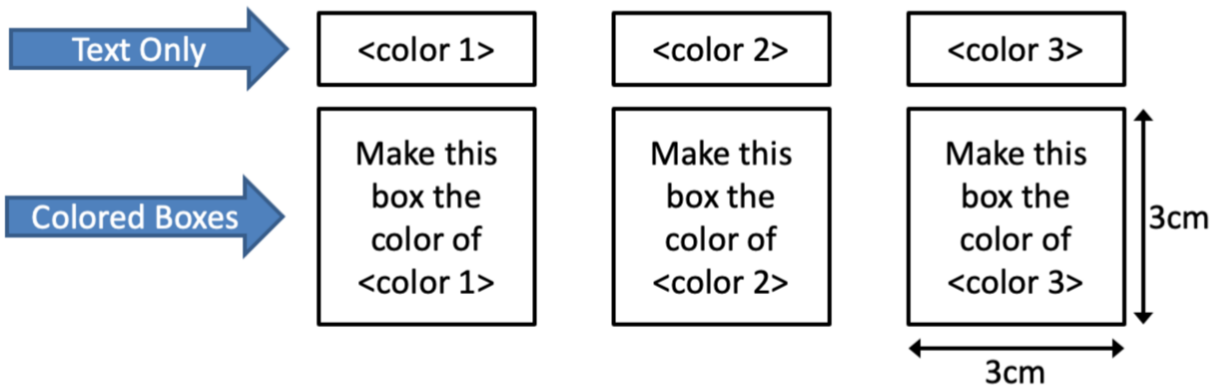


Figure 12: Scan the Code Visual Display Specifications

Qualifying Criteria
The AMS must perceive the three-color light sequence and report correctly via the TD Network using the protocol outlined in Appendix D and on the Judge's Display.

Task Element	Description	Dimensions
Floating Dock	Floating platform that holds tower structure * Supplied from Jet Docks	Base: 100 in. W x 100 in. L *Individual Cube:* 20 in. x 20 in. x 16 in. H
Light Tower	Specifications are detailed in Appendix B: Light Tower Specifications	N/A

Table 7: Task Elements for Scan the Code Task

2.5.6 Task 6 – Dock and Deliver

This task consists of a floating platform with three docking bays as shown in Figure 14. Each bay has a different colored panel (red, green, or blue) and two square holes. The AMS detects the designated color, docks within the corresponding bay, and flings racquetballs into either of the two holes.

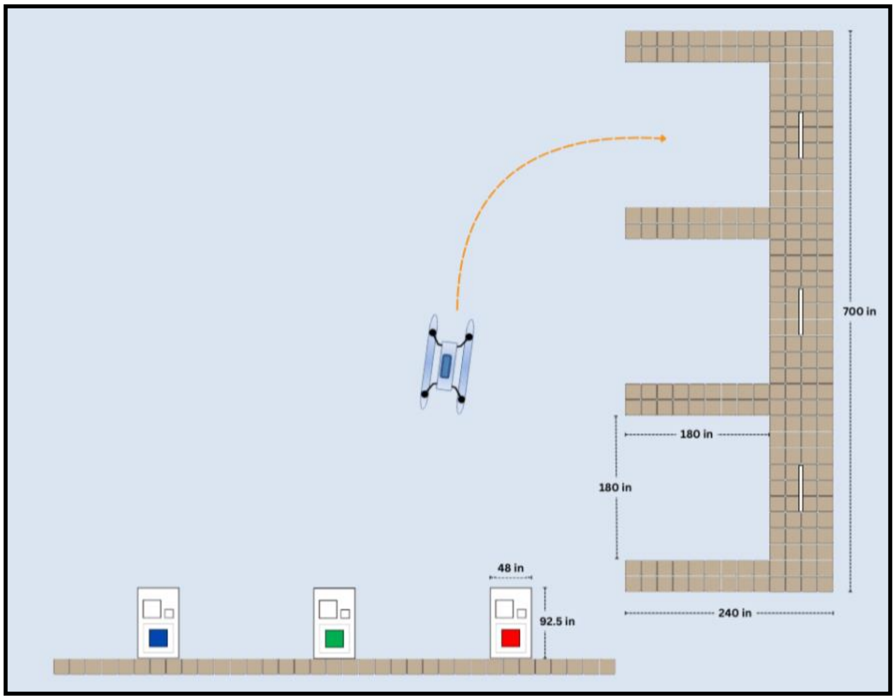


Figure 14: Example Dock and Deliver

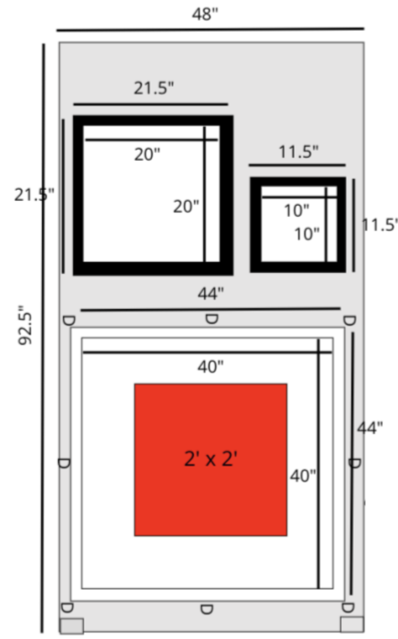


Figure 13: Dock and Deliver Task panel structure dimensions

This task has three side-by-side docking bays, as shown in Figure 14 floating at the water's surface. The panels in each bay have a 40-inch square vinyl panel with a 24-inch color square in the center of a white background. The panel has two square openings (holes) cut out at the top. The larger square is 20 inches, and the smaller square is 10 inches. Both squares have an approximately 0.75-inch-thick black outline. The holes are located next to one another above the color square.

Qualifying Criteria

The AMS must detect the designated color and dock within the corresponding bay. For this round, the correct color is determined by the Technical Director and announced daily.

Task Element	Description	Dimensions
Floating Dock	Floating platform that holds panels * Supplied from Jet Docks	Task: 700 in x 240 in Bays: 180 in x 180 in *Individual Cube:* 20 in. x 20 in. x 16 in. H
Flat-Panel Structure	Panels with color display (red, green, or blue)	• Panel: 48in x 92.5in • Vinyl banner: 40in x 40in; 24in square • Large Square: 20in x 20in • Small Square: 10in x 10in
Netting	22mm Golf Impact Ball Stop Netting *Supplied from Net World Sports	N/A
Projectile	Penn Ultra-Blue Racquetball *Supplied from Amazon	N/A

Table 8: Task Elements for Dock and Deliver

2.5.7 Task 7 – UAV Replenishment

This task is designed to be accomplished using a UAV. The UAV launches from the USV, locates a floating helipad and collects a small colored tin (see Figure 16). The UAV delivers the tin to the circular target area on another floating helipad, then returns to the USV.

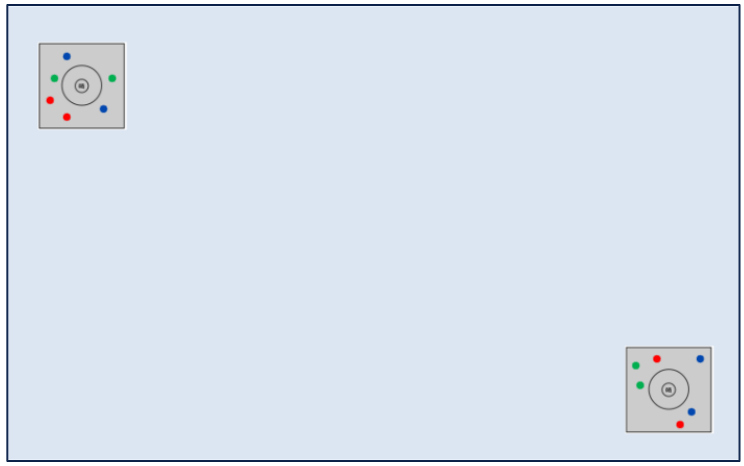


Figure 15: Example UAV Replenishment

Each floating helipad is an 80-inch square and is marked with concentric rings painted onyx black on a background painted sidewalk grey. The helipad has a small PVC lip around the outer edge. The center ring has a 24-inch diameter, and the outer ring has a 60-inch diameter. The center of the helipad has a RoboNation logo painted onyx black, approximately 12 inches by 12 inches. The composition of the colored disks is described in Table 9. There may be multiple-colored discs on each helipad, (red, green, or blue).

Qualifying Criteria

The UAV must launch from the AMS, pick up the colored tin from the floating helipad, and deliver it to the other floating helipad. The color of the tin to be collected is determined by the Technical Director.

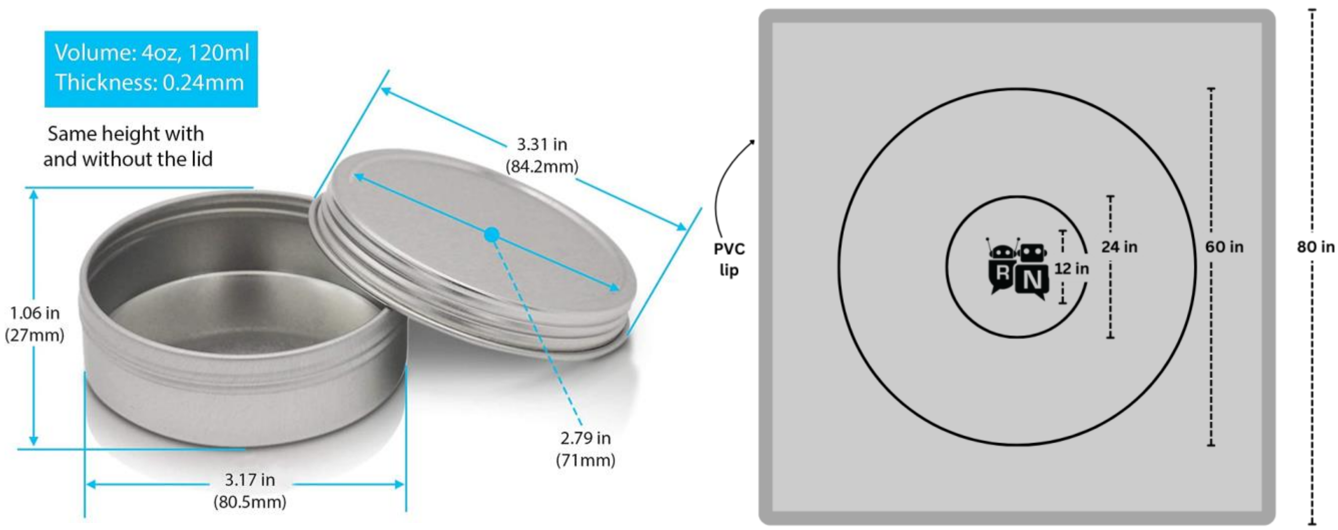


Figure 16: Colored Disk and Preliminary Helipad

Task Element	Description	Dimensions	Weight
Floating Dock	Floating platform that holds panels * Supplied from Jet Docks	Task: 80in x 80in *Individual Cube:* 20 in. x 20 in. x 16 in. H	N/A
Helipad (Figure 16)	Helipad will be secured on a hard, flat, raised surface floating on the water.	80in x 80in	N/A
Colored Disks (Figure 16)	SimbaLux Screw Top Round Steel Tin Cans 4 oz (120 ml). * Supplied from Amazon	N/A	40-45 grams
Dock units are supplied from Jet Docks: jetdock.com			

Table 9: Task Elements for UAV Replenishment

2.5.8 Task 8 – UAV Search and Report

This task can be attempted by any team once they have been cleared for safe operations of their UAV (Section 2.4 Mandatory Activities). This UAV task is conducted on land and on water, designed to mimic that of a search and rescue.

For this task, the UAV launches from a designated start point (helipad on land or AMS on water), conducts a search, detects and determines the location of two distinct objects in the field, and lands at the designated end point (back on helipad on land or AMS on water). 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.

The start and end points for this task on land is a grey helipad and on water is the AMS. The helipad is an 80-inch square and is marked with concentric rings painted onyx black on a background painted sidewalk grey. The center ring has a 24-inch diameter, and the outer ring has a 60-inch diameter. The center of the helipad has a RoboNation logo painted onyx black, approximately 12 inches by 12 inches.

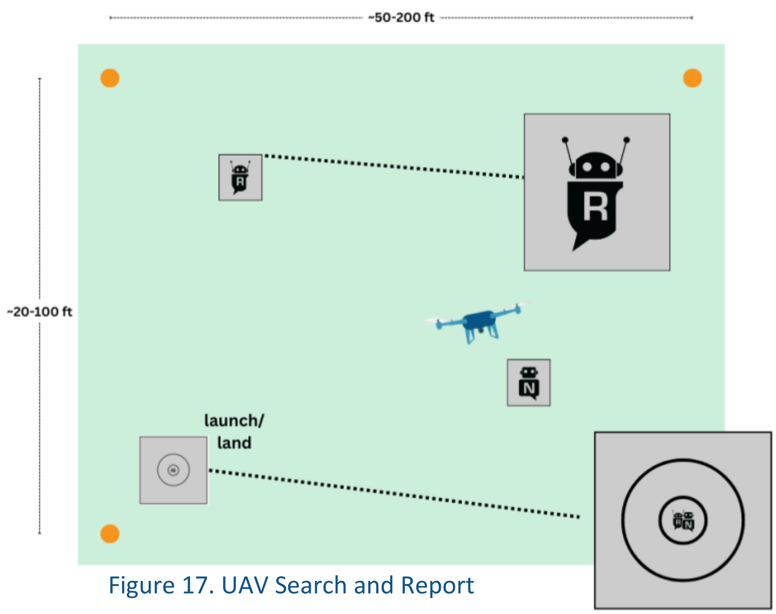


Figure 17. UAV Search and Report

There are two objects placed randomly within the field. The objects are RoboNation 'R' and an 'N' that are approximately 30 inches x 40 inches on a 60-inch square background. The logos are painted onyx black on a background painted sidewalk grey. The land-based field is marked by 4 orange markers affixed to the ground and is approximately 100 feet by 200 feet.

Qualifying Criteria

The UAV must launch from the designated launch site, complete a search pattern within the task boundary, report the location of the objects, and land at the designated landing site.

Task Element	Description	Color	Dimensions
Floating Dock (on water)	Floating platform that holds objects * Supplied from Jet Docks	N/A	Task: 60in x 60in *Individual Cube:* 20 in. x 20 in. x 16 in. H
Field Boundary (land-based)	Marker (Traffic Cone)	Stock Orange	N/A
Objects (Figure 17)	Grey panel with black 'R' or 'N' RoboNation symbols	Sidewalk Grey Onyx Black	~30in x ~40in
Helipad (Figure 17)	Grey helipad	Sidewalk Grey	80in x 80in

Table 10: Task Elements for UAV Search and Report

2.6 Qualifying Round

Three Qualifying and Practice Courses are available for teams to practice, demonstrate proficiency, and qualify for the Semi-Finals Round. These courses consist of all eight (8) tasks. Multiple teams may be on a Qualifying and Practice Course at the same time. Teams may schedule times to practice or qualify on individual tasks on these courses, with the Technical Director. Teams may attempt qualification on individual tasks in any order.

Once a team demonstrates proficiency on 5 of the 8 tasks, they qualify for the Semi-Finals Round. Once a team qualifies for the Semi-Finals Round, they may continue to use the Qualifying and Practice Courses for practice on individual tasks. Teams who have not yet qualified for the next round, may continue to use the Qualifying and Practice Course to practice.

The minimum success criteria for qualifying on the individual Autonomy Challenges are detailed in Section 3: Scoring.

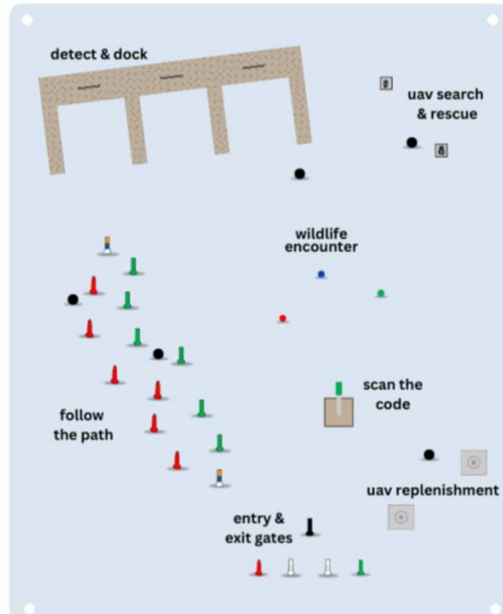


Figure 18: Preliminary Qualifying & Practice Course Layout

2.7 Semi-Finals and Finals Rounds

Teams that qualify for the Semi-Finals will have access to the Semi-Finals Courses; these courses consist of eight (8) tasks, Tasks 1-8. Only one team may be on a Semi-Finals Course and a Finals Course at a time.

During Semi-Finals and Finals runs the AMS must:

- operate autonomously throughout the entire run;
- transmit a heartbeat message to begin the run (as described in Appendix D);
- enter the course through one of the gates in Entrance and Exit Gates task;
- perceive Entrance and Exit Gates task; attempt the remaining Tasks 3-9 of their choice, in any order.

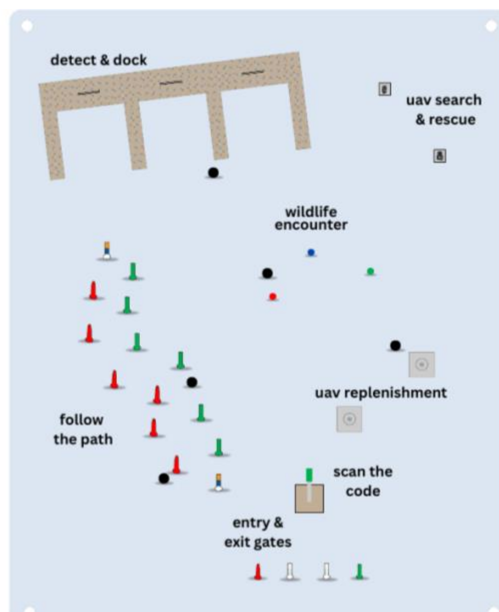


Figure 19: Preliminary Semi-Finals & Finals Course Layout

The scoring criteria for Semi-Finals and Finals are detailed in Section 3: Scoring.

SECTION 3: Scoring & Awards

3.1 Scoring

This section provides a description of judging criteria and scoring for Design Documentation and the Autonomy Challenge. 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, RoboNation will issue the overall standings. Any team accepted into the Finals Round will be ranked ahead of all teams that did not participate in the Finals Round.

3.1.1 Design Documentation Scoring

Design Documentation must be submitted in accordance to the requirements outlined in Section 2.2 Design Documentation and the dates outlined in Section 5.3 Timeline section, to be eligible for full points. After the competition, overall standings for design documentation will be published.

Design Documentation	Maximum Points
Technical Design Report	200
Team Website	180
Team Introduction Video	120
Design Presentation	180
System Assessment	180
Total Potential Points	**860**

3.1.2 Autonomy Challenge Scoring

The Autonomy Challenge occurs in three rounds: Qualifying Round, Semi-Finals, and Finals. The scoring is structured to provide an overall balance of potential points based on the expected degree of difficulty for each task. For the Qualifying Round minimum performance criteria is specified and no points are awarded. For the Semi-Final and Final Rounds points are awarded, as outlined in this section.

All scoring decisions made by the judges are final. Teams may request clarification of any scoring decision through their Embedded Team Judge.

Summary of Scoring Approach

During the Qualifying Round, individual tasks are judged in a binary manner. There are no scores collected in this round. Teams may attempt tasks multiple times until they successfully qualify on the task. Judges keep record as a team's AMS successfully qualifies on tasks. Once a team demonstrates proficiency on 5 of the 9 tasks, they qualify for the Semi-Finals Round. Teams are encouraged to continue attempting qualification on additional tasks.

Qualifying Round Judging Criteria
Minimum success criteria for qualifying on the individual Autonomy Challenges are detailed in each task description. Teams may use remote control to position their AMS near the start of each task during the Qualifying Round only.

Semi-Finals and Finals Round Judging Criteria
In the Semi-Finals and Finals Round the AMS is required to demonstrate autonomy and perception by completing tasks using information obtained from one or more prior tasks. The scoring breakdown will be provided in V2 of this Handbook.

During Semi-Finals and Finals runs the AMS must:

- operate autonomously throughout the entire run;
- transmit a heartbeat message to begin the run (as described in Appendix D);
- enter the course through one of the gates in Entrance and Exit Gates task;
- perceive and use the light sequence from Scan the Code task to inform execution of other tasks;
- attempt the remaining Tasks 3-8 of their choice, in any order.

The scoring breakdown is summarized in the table below. Note that Design Documentation points are included as part of the Semi-Finals and Finals total scores.

Task Name	Max Points
Situational Awareness	100
Entrance and Exit Gates	1200
Follow the Path	1200
Wildlife Encounter and Report	1100
Scan the Code	600
Detect and Dock	2000
UAV Replenishment	2300
UAV Search and Rescue	1000
UAV Launch/Recovery	1500
Design Documentation	860
MAX Possible Points	**11,860**

UAV Launch / Recovery
Teams are encouraged to use a UAV to assist in completing the Autonomy Challenge tasks. Points for the autonomous launch and recovery of a UAV will be awarded once during each run.

Points are awarded as follows:

- 500 points for launching UAV from USV.
- 1000 points for landing UAV back on USV.
- OR 500 points for landing UAV in recovery zone.

MAXIMUM Total Points = 1500 points

Task 1 – Situational Awareness and Reporting
The AMS must begin transmitting the heartbeat message when it starts a run. Additionally, teams are highly encouraged to transmit the reporting component for the other Autonomy Challenge tasks (see Appendix D: Communications Protocol).

Points are awarded as follows:

- 100 points for transmitting first heartbeat message.
- *Additional points are awarded for each heartbeat message sent for each task, outlined below.*

MAXIMUM Total Points = 100 points

Task 2 – Entrance and Exit Gates
On the Semi-Finals and Finals course, the black buoy in this task will be replaced with the Scan the Code light tower. The AMS should detect the active beacon to enter the course through the correct entry gate, before proceeding to the other tasks. At the end of Semi-Finals and Finals runs, the AMS must exit the course through the same set of gates as it entered (see Entrance and Exit Gates Task Description).

ENTRY Gate: The AMS must detect the ENTRY gate with the active beacon and successfully pass through that gate to start their run on a Semi-Finals and Finals Course.

EXIT Gate: At the end of the Semi-Finals and Finals runs, the AMS must successfully pass through the EXIT gate, the same gate as it used to enter the course, to exit the course.

Points are awarded as follows:

- 50 points for course entry through any ENTRY gate.
- + 350 points for the CORRECT ENTRY gate (hydrophone must be on system to earn points).
- + 100 points for clean course entry, no buoy strikes.
- 50 points for course exit through any EXIT gate.
- + 350 points for the CORRECT EXIT gate (hydrophone must be on system to earn points).
- + 100 points for clean course exit, no buoy strikes.
- 100 points for transmitting a heartbeat message reporting the ENTRY gate.
- 100 points for transmitting a heartbeat message reporting the EXIT gate.

MAXIMUM Total Points = 1200 points

Task 3 – Follow the Path

The AMS must navigate the pathway by either exiting or returning to the harbor, considering the expression, "red right returning." Teams must navigate through the pathway and avoid all black obstacle buoys. The AMS may choose to deploy a UAV to assist with this task (see Follow the Path Task Description).

The CORRECT navigation direction is determined by the **first color** in the light sequence from Scan the Code. The AMS enters pathway past the CORRECT marker buoy (top color of the buoy).

Points are awarded as follows:

- 100 points for entering pathway.
- + 200 points for entering near the CORRECT marker buoy.
- + 100 points for each pair of buoys successfully navigated, in sequence (maximum: 600).
- + 200 points for successfully navigating the full path in a single run with no buoy strikes (without exiting the path and returning).
- 100 points for transmitting a heartbeat message reporting completed path.

MAXIMUM Total Points = 1200 points

Task 4 – Wildlife Encounter

The AMS must detect and classify the colors of each buoy, signaling the USV to circle one designated marine creature (see Wildlife Encounter Task Description). The AMS must locate the CORRECT marine creature floating platform and circumnavigate it in the correct direction.

To successfully circle the floating platform, the AMS must transit around the marine creature until it has crossed its approach path, transiting at least 360 degrees. The floating platforms must be circumnavigated as follows:

- Circle the manatee in a clockwise direction.
- Circle the iguana in an counter-clockwise direction.
- Circle the python twice in any direction.

The CORRECT marine creature is determined by the **first color** in the light sequence from Scan the Code. The corresponding colors are as follows:

- Blue corresponds to the manatee (blue buoy).
- Green corresponds to the iguana (green buoy).
- Red corresponds to the python (red buoy).

Points are awarded as follows:

- 100 points for circling marine creature in any direction.
- + 100 points for circling CORRECT marine creature in any direction.
- + 400 points for circling CORRECT marine creature in CORRECT direction.
- 100 points for transmitting a correct heartbeat message.
- 400 points for correctly formatted creature map.

MAXIMUM Total Points = 1100 points

Task 5 – Scan the Code:
In the Semi-Finals Round the Scan the Code light buoy will be located beyond the set of entry gates. The AMS must perceive the three-color light sequence and convert data to inform execution of other tasks (see <u>Scan the Code Task Description</u>). The AMS must demonstrate correct perception of the light pattern through behaviors in other tasks. Additional points are awarded for reporting the color pattern detected.

Points are awarded as follows:

- 100 points for transmitting a heartbeat message reporting light sequence.
- + 200 points for transmitting a heartbeat message reporting CORRECT light sequence.
- 100 points for displaying light sequence on team console for Judges' Display.
- + 200 points for displaying CORRECT light sequence on team console for Judges' Display.

MAXIMUM Total Points = 600 points
Additional points awarded in Tasks 3, 4, 6, and 7 for correct perception of light pattern.

Task 6 –Dock and Deliver
The AMS must detect the designated color, dock within the corresponding bay, and fling a maximum of four (4) racquetballs in either of the holes in the panel (see <u>Dock and Deliver Task Description</u>). The color of the panel is determined by the **second color** in the light sequence from Scan the Code.

A docking attempt is considered successful when the AMS fully enters a docking bay between two of the adjacent pontoons. A docking attempt in which the AMS straddles a pontoon will not be considered successful.

Points are awarded as follows:

- 100 points for successfully docking in ANY docking bay (only awarded once).
- + 500 points for successfully docking in CORRECT docking bay (only counts toward first docking).
- 100 points for launching racquetball (only awarded once).
- 75 points for each racquetball delivered into the larger hole (maximum: 300).
- + 100 points for each racquetball delivered in the CORRECT larger hole (maximum: 400).
- 150 points for each racquetball delivered into the smaller hole (maximum: 600).
- + 150 points for each racquetball delivered into the CORRECT smaller hole (maximum: 600).
- 100 points for transmitting a heartbeat message reporting detected color.

MAXIMUM Total Points = 2000 points

Task 7 – UAV Replenishment
The UAV must launch from the AMS, pick up the colored tin from the floating helipad, and deliver it to the other floating helipad (see UAV Replenishment Task Description). The color of the tin to be collected is determined by the **third color** in the light sequence from Scan the Code.

Points are awarded as follows:

- 200 points for picking up any disc.
- + 500 points for picking up CORRECT disc.
- 200 points for delivering any disc.
- + 500 points for delivering CORRECT disc.
- + 300 points for delivering any disc within larger target circle.
- + 500 points for delivering any disc within smaller target circle.
- 100 points for transmitting a heartbeat message reporting the status of the UAV.

MAXIMUM Total Points = 2300 points

Task 8 – UAV Search and Report
The UAV launches from the AMS on water, conducts a search, detects and determines the location of two distinct objects in the field, and lands at the designated back on the AMS.

- 100 points for transmitting a heartbeat message reporting the status of the UAV.
- + 300 points for reporting the correct geographic location (within 15 meters) of the two objects. (UAV must be used to collect data to earn points)
- + 600 points for reporting the correct geographic location (within 5 meters) of the two objects. (UAV must be used to collect data to earn points)

MAXIMUM Total Points = 1000 points

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 Special Awards
Throughout the competition, teams, judges, and staff are asked to be on the lookout for exemplary behavior from teams to acknowledge with special awards. The digital nomination form can be found here and is scheduled to close at 9:00pm ET on Thursday, November 7.

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. Teams may use a UAV to aid in the execution of any task; however, notification must be given to the Technical Director Team prior to the task being attempted.
11. All decisions of the judges are final.
12. RobotX organizers are not responsible for any damage to a team's AMS, including all subsystems, as the consequences of participating in the competition.

4.2 Safety

The safe operation of all equipment is a priority for the RobotX staff. All considerations to maintain safety for operators, spectators, 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.
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, task and/or course operations at any time for safety considerations. The staff are not required to advise teams prior to the decision to terminate the run attempt or other operations. In all matters of safety, the decisions of the RobotX staff are final.

4.2.1 Safety Inspections

Before operating in or over the water and land courses, 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 of the USV and UAV.
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. Teams bringing a UAV will be required to have each licensed pilot pass a flight test as supervised by MAAA. (Section 2.4 Mandatory Activities)

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 provide battery specifications, Material Safety Data Sheets (MSDS), and proper disposal procedures, sourced from the battery manufacturer for all batteries. These will be collected in the Pre-Competition Requirements.
2. Teams must provide battery specifications for shipments that include batteries, in the Shipping Plan which is part of the On-Site Requirements in in the Pre-Competition Requirements.
3. Teams must keep a hard copy of the battery safety documentation for all batteries in Team Village (on-site) at all times, for reference.
4. Li-Po (Lithium Polymer) battery packs need cell level safety and balancing circuits and must be labeled HAZMAT when/if shipped.

- Each team must understand and follow their own country's regulations as well as those of the host nation.

5. All batteries must be stored, used, and maintained in accordance with manufacturer guidelines.
6. Students are required to inspect their batteries daily for signs of swelling, heat, leaking, venting, burning or any other irregularities.
    a. Lithium batteries that become too warm during use or have become swollen or malformed must be removed from use and reported to RobotX staff.
    b. Lithium batteries that do not hold a charge must be removed from use and reported to RobotX staff.
    c. Any loss of battery (i.e. dropped into the lake) must be reported immediately to RobotX staff.
7. A team member must be present at all times to monitor charging batteries. Batteries must not be left to charge overnight.
8. At the competition site, if any of the above battery conditions are observed students must immediately notify RobotX staff and provide the battery specifications and MSDS information.
9. 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.
10. Teams are only permitted to change or replace AMS batteries in designated areas.

4.2.3 Kill Switch (Emergency Stop) Requirements

The AMS must comply with the kill switch requirements detailed below. The 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.
- Off-Board: A wireless remote emergency stop, located off-board and on or near the operator control station.

Upon activation of either emergency stop switch, the system must instantaneously (less than 1 second) disconnect power from the vehicle's thrusters. 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 thrusters. An example of how to implement this is shown in Figure 20. Systems should be designed so that power, to the thrusters, cannot be restored until the emergency switch is reset.

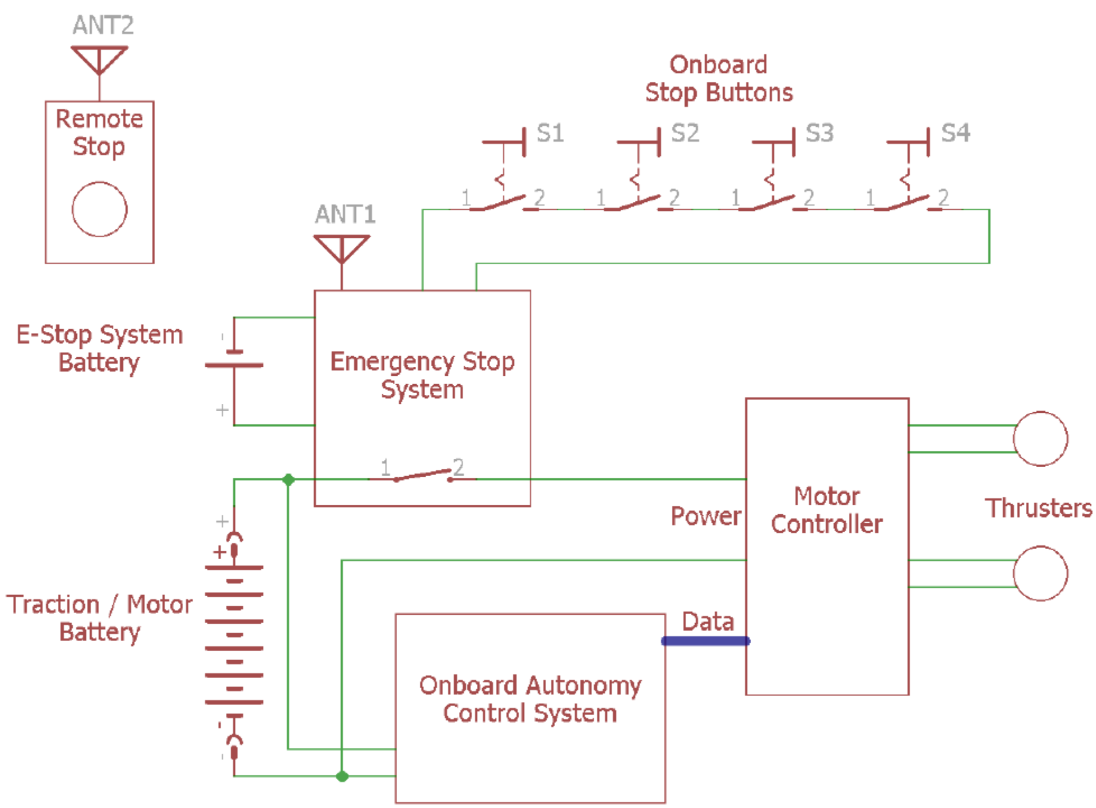


Figure 20: Example Emergency Stop Circuit

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 as, and when requested.

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 activated from a distance by a wooden or plastic pole/paddle, from a surface craft. Keeping this in mind, teams should select durable 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 21. This switch must be demonstrated to disable AMS thrusters within 1 second of activation in all AMS operating modes.

Figure 21: 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 see and operate the button. The engage/disengage button should be red in color and have a ‘press to activate and twist/pull to reset’ feature. This button, momentary contact switch or not, should cut power to the thrusters immediately (within 1 second) on activation. 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 22 and can be found at www.mcmaster.com.

Figure 22: Example Kill Switch

Wireless Emergency Stop (USV)
All USVs must be equipped with a remote Wireless Emergency Stop controller.
This controller must immediately (less than 1 second) disconnect power to the vehicle’s thrusters when activated. This system must also meet the host country RF guidelines for frequency and transmit power. All UAVs must have an emergency manual over-ride which can be operated remotely off-board, operating on its unique frequency and link. Upon activation of the manual over-ride, the UAV must instantaneously stop all other tasks, be ascended to 25m above ground level, return under manual control of the pilot to a designated safe landing area.

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 event support operations. This lighting system will serve as a visual status indicator to anyone in the vicinity of each team's USV. It is 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/yellow, and green/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 11. 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
Green or Blue	Autonomous operation
Red	E-Stop active (propulsion disabled)

Table 11: Light Color and Correlating Modes

Several visual indicator examples are shown in Figure 23, including off-the-shelf and custom LED array approaches; however, design and selection of the final system is the team's decision.

Figure 23: 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 light sections with standard light bulbs.

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 (Figure 24). The tow points are 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.

Figure 24: Example tow points

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 (estimated height: 9 ft). Additional masts are acceptable but must be removable or capable of being folded down to ensure tent height clearance.

4.3.2 UAV Requirements

During RobotX, RoboNation will oversee all drone activities during the competition. For the purposes of this document, the terms Drone, Unmanned Aerial Vehicle (UAV) and model aircraft are used synonymously.

1. Any instruction given by a RobotX staff around the safe operation of drones must be immediately complied with.
2. **General Aircraft Restirctions:** The team may only fly a single aircraft during the mission. The aircraft must be capable of heavier-than-air flight and be free flying without any encumbrances like tethers. The max takeoff weight is 55lbs. The UAS must have autonomous flight capabilities to compete.
3. **FAA Vehicle Registration:** The vehicle used at competition must be registered using the FAADroneZone, the certificate must be presented at safety inspection and at the flight line, and an external surface of the vehicle must be labeled with the registration number.
    a. If your UAS is already registered in your home country, you must submit a Notice of Identification (NOI) on the FAADroneZone website. Just create an account and follow the steps.
    b. If your UAS is NOT registered in your country, you still need to access the DroneZone website and register it to obtain a Certificate of Ownership Acknowledgement.
4. **FAA TRUST:** The Safety Pilot must complete The Recreational UAS Safety Test (TRUST) and present the certificate of completion at safety inspection and at the flight line.

5. **FAA Remote ID:** The vehicle used at competition must comply with FAA Remote Identification for Drone Pilots (Remote ID). At a minimum, the Remote ID broadcast must include a unique ID for the vehicle and the vehicle position. The broadcast will be verified at safety inspection.
6. **AMA Safety Code:** The aircraft must comply with the AMA Model Aircraft Safety Code except that autonomous operation is authorized at competition, and both free flight and control line are not applicable.
7. **No Personnel Near Prop Arc When Powered:** Personnel must be clear of the propeller arc whenever the motors have the ability to receive power. For example, if the batteries powering the electric motor are connected, personnel are not allowed to be near the prop arc. Software based disarm is not sufficient. Propeller power must be disconnected in order to physically work on the UAS. Teams violating this safety rule may be disqualified.
8. **Fuel and Batteries:** Exotic fuels or batteries will not be allowed. Any option deemed by the organizers as high risk will be denied. All batteries must be brightly colored for identification in a crash, and it is preferred if they are wrapped in bright colored tape.
9. **Fasteners:** All fasteners must have either safety wire, loctite (fluid), or nylon nuts.
10. **No Foreign Object Debris:** No pieces may depart from the aircraft while in flight. Foreign object debris (FOD), like nuts and bolts, must be cleared from the operating area.
11. **Return to Home and Flight Termination Failsafes:** The UAS must have either autonomous return to home (RTH) or return to land (RTL), and autonomous flight termination. Both must be activatable by either the Safety Pilot. After 30 seconds of communications loss, the aircraft must automatically RTH or RTL. After 3 minutes of communication loss, the aircraft must automatically terminate flight. For fixed wing aircraft, flight termination must be: throttle closed, full up elevator, full right rudder, full right or left aileron, and full flaps down (if equipped). For non fixed wing aircraft, throttle must be closed and all actuators off. The termination system must be designed to touch ground within 500ft over ground of the termination point.
12. **Flight Boundary:** The UAS must stay within the designated flying area on land or the three courses on the water. No flying is permitted outside of these designated flying areas.
13. **Operational Requirements:**
    a. 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.
    b. 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 Section 4.2.3 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 RJ45 Ethernet connection, to be provided in the team operations tent. Protocols for this communication are outlined in Appendix D.
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 Section 4.2.4 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 at random throughout the operating areas in an effort to provide a more representative real-world challenge. Figure 25 provides an example of the AMS avoiding the obstacles surrounding the task area.

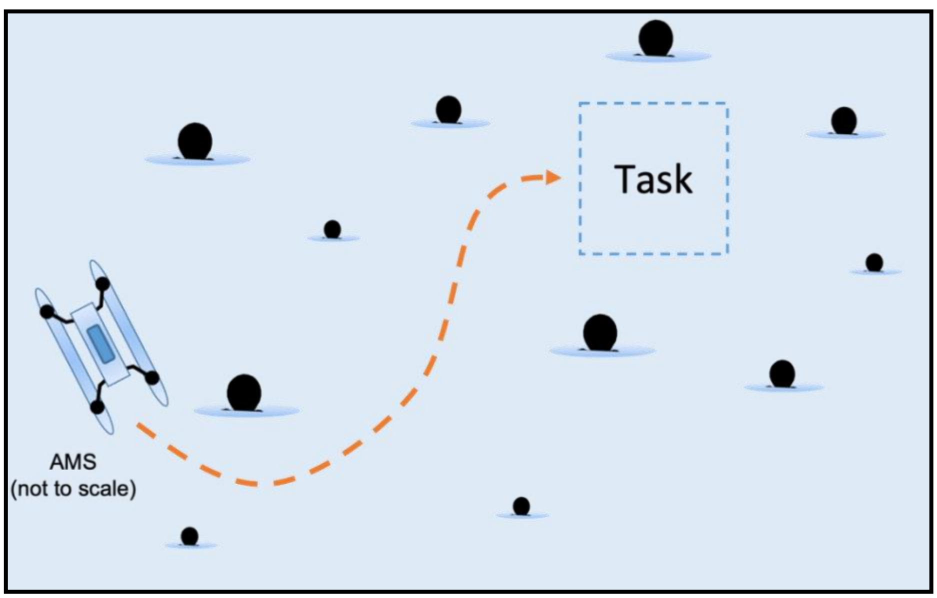


Figure 25: Example Obstacle Avoidance

SECTION 5: How to Compete

5.1 Register and Intent to Compete

5.1.1 Register to Compete (Closed - March 18)

Teams must register to compete using the Registration form found on the RobotX website, robotx.org/2024. 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.

5.1.2 Data Sharing Access Requirements

During registration, 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 2-10 characters, abbreviating the team's school or organization. Examples of the team acronym are RN or ROBOTEAM.

Teams that complete the Intent to Compete form or Registration form will gain access to the Data Sharing project. After registration closes, only registered teams will maintain access to the Data Sharing project.

5.2 Pre-Competition Requirements

The following information will be collected during registration, prior to participation on-site at the competition.

5.2.1 Team Information Package

Teams must submit a team roster including all participants that support the teams' RobotX 2024 effort, liability waivers, forms, and other contact information.

5.2.2 Battery Safety Requirements

Teams must 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.

5.2.3 Shipping Plan

Teams must submit a shipping plan to facilitate shipment receipt/handling at the competition. Shipping guidelines can be found on the RobotX website. This shipping plan must include:

1. Name and contact information for Team Shipping Point of Contact
2. Number of boxes/crates in the shipment
3. Weight of each box/crate
4. Dimensions of each box/crate
5. Name of shipping company
6. Estimated shipping date
7. Pick-up Address
8. Return Address
9. Type of shipment – Air, ground, ocean

10. Battery specific provisions for shipments that include batteries.
11. Additional information for shipment, if needed

(Note: Shipping guidelines for lithium batteries differ by country and by shipping company. Check with your shipping company to determine requirements for shipping new batteries vs. used batteries AND make sure that you are familiar with your shipper's facilities, operating hours, and requirements shipping your vehicle / batteries back home after the competition.)

5.2.5 Design Documentation Package

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

5.3 Logistics

5.3.1 Travel + Lodging

Teams are responsible for coordinating their own lodging and travel plans.

Lodging—Hotels

RoboNation has contracted with a local hotel to provide a special rate for teams. The selected event hotel is Ameniti Bay, BW Signature Collection. The booking link can be accessed here. The booking deadline is October 7.

International Travel

Invitation Letter – During the registration process, teams may request an invitation letter issued by RoboNation in the registration portal.

VISA Process – It is recommended for international students to acquire a B-1 Visitor VISA to attend the competition. If other activities or travel beyond the competition are planned, individuals may choose to investigate other types of visa. For more information on visas, visit travel.state.gov.

5.3.2 Shipping

Teams are responsible for coordinating shipping for their equipment. Teams are required to submit a shipping plan (Section 5.2.3). RoboNation staff are available to provide support to ensure that teams' equipment can be received and staged for competition. Shipping guidelines and additional information can be found on the RobotX website.

5.3.3 On-Site Logistics

Team Village

Team Village is a group of tents with sidewalls that reside on a flat grassy field surface. Each team will be provided with a 15 foot x 25 foot working area in a tent that includes two tables, seven chairs, one electrical outlet (120V 60 Hz 15A), and a wireless internet connection. The tent has an approximate height of 10 feet. Although the covered workspace is weather resistant, teams are discouraged from leaving sensitive electronics/equipment exposed in the tent.

Teams should conduct development, maintenance, and repair of their systems in their designated area in Team Village. 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 to set up their shore equipment. Each course will have a 10’ x 10’ tent-covered area with a single table, 120V 60Hz 15A power, and a hard-wired Ethernet connection to the Technical Director network. The power provided will be for Operator Control Station (OCS) use only and shall not be extended to any platforms on the beach. This space will be shared between all teams utilizing the course.

Power
The United States uses a 120V 60Hz 15A electrical outlet plug, usually consisting of three pins, two parallel blades (one wider than the other), and an offset semi-round pin. The wider blade is Neutral, the shorter blade is Hot/Line and the third pin is Ground**.** Teams will only be allocated one 15A service and should not connect more load than that.


Figure 26: US electrical outlets

Transporting AMSs at the Competition Venue
RoboNation will provide a trailer for each team’s AMS. Trailers must be used when moving the AMS around the event and during launch and recovery using the designated boat ramp.

During launch and recovery and any other movement of the AMS trailer by vehicle, the vehicle must be operated by event staff using an event vehicle. For short distance maneuvers within the team's working space in Team Village, teams may move their trailered AMS by hand.

Figure 27: Provided Trailer for Teams

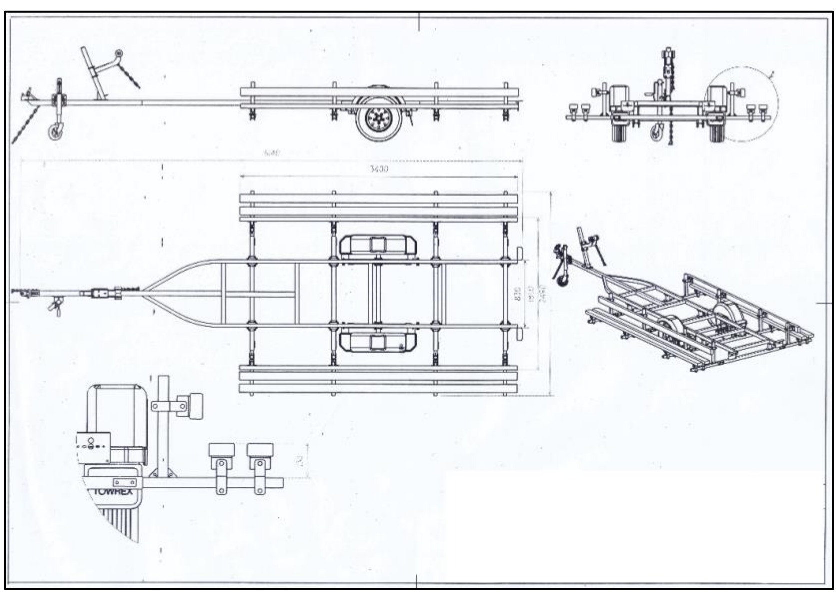


Figure 28: Trailer Specs

5.4 Communications

5.4.1 Pre-Competition Communications

Teams have a variety of opportunities to interact with each other and RoboNation staff.

Team Time Meetings

Prior to the on-site competition, RoboNation will host virtual meetings that teams are asked to have a team representative join. These Team Time meetings provide competing teams with competition updates and the opportunity to ask questions. The schedule for these Team Time meetings and access information is available on the RobotX website.

RobotX Discord

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

5.4.2 On-site Communications

Team Lead

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

RobotX Staff

All event staff are identified with "Staff" shirts.

The Technical Director Team is a part of the event staff team and consists of a Technical Director, Deputy Technical Director, Safety Inspectors, and Course Managers.

5.4.3 RobotX Website

The official competition website is robotx.org/2024. This website includes all official documents and a list of the registered RobotX 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.

5.5 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. Teams are prohibited to share any harmful code, including any virus, malicious code, or other destructive code. 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).
Event Staff or RobotX Staff	RobotX support personnel.
Judge	Subject Matter Experts that observe and score the Autonomy Challenge and Design Documentation. Judges are also members of the event staff.
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.
Sponsor	Organizations that provide support to RobotX.
Team Lead	Designated spokesperson for each team.
Technical Director Team	Technical team that runs the courses, safety inspections, set-up, and tear-down.
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.
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.

6.2 Acronyms

Acronym	Definition
AMS	Autonomous Maritime System
MSDS	Material Safety Data Sheets
N/A	Not available
NMEA	National Marine Electronics Association
OCS	Operator Control Station
RGB	Red, Green, Blue
RF	Radio Frequency
SME	Subject matter expert
UAV	Unmanned Aerial Vehicle (the terms drone, and model aircraft are used synonymously in this document)
USV	Unmanned Surface Vehicle
WAM-V	Wave Adaptive Modular Vessel

Appendix A: Technical Design Report (TDR)

Maritime RobotX Challenge 2024 *www.robotx.org*

A.1. Paper Preparation Overview

Each team is required to submit a TDR that describes the team's design principles and competition priorities. The report should address the rationale for which autonomy challenge tasks have been chosen to attempt and how this competition strategy influenced the design decisions for the entire system and subsystems. Teams must follow the TDR instructions provided below. To be eligible for full points, teams must submit their TDR by the deadline found in Section 5.3.

A strong TDR provides a coherent narrative and addresses the elements of the rubric as well as possible, including citing references used. The competition strategy justifies the choices of autonomy challenge tasks and design decisions that trace back to those task choices. The report also identifies which software tools allow the team to accomplish the tasks chosen.

The technical design report is worth a total of 200 points. The outline of each content section includes a scoring weight with guidance for scoring considerations that are provided to the judges during evaluations.

A.2. Format

The format of the written paper shall adhere to the following guidelines:

- **6 page limit** (excluding References and Appendices)
- 8.5 x 11 in. page size
- Margins ≥ 0.8 in.
- Font: Times New Roman 12pt
- Header on every page including team name and page number
- Submitted in .pdf format

RoboNation Tip: It is recommended that papers be peer-reviewed prior to submission. For example, teams can utilize resources at their institution, fellow students, or professional editing services.

Optional Formatting: Teams may choose to follow the two-column format, editorial style for IEEE Conference Proceedings: www.ieee.org/conferences/publishing/templates.html.

Formatting Scoring Metrics *(5% of score)*

Strong	Paper follows page limit, and all formatting guidelines are followed. The document is professionally organized. All required sections are included and easy to identify. All grammar, punctuation, and spelling are correct. The style follows that expected of a scientific paper submitted for publication.
Requirements Not Met	Formatting guidelines are not followed and the layout is unorganized.

A.3. Paper Contents

The TDR consists of the following mandatory sections: abstract, technical content, acknowledgements, references, appendix A, and appendix B.

A.3.1 Abstract

The abstract is a short summary of the main points in the paper. The abstract should summarize the linkage between overall competition strategy and system architecture, design, and engineering decisions.

Abstract Scoring Metrics *(10% of score)*

Outstanding	Abstract is engaging, lists the scope of the work, and provides a thorough summary of the paper.
Strong	Abstract provides a strong overview of the scope of work and a detailed summary of the paper.
Average	An adequate explanation of the scope of work is included with a brief summary of the paper.
Below Average	Abstract provides a basic summary of the paper.
Poor	Abstract section is included but does not serve the intent of an abstract. The abstract is treated as an introduction and provides no summary of the paper.
Requirements Not Met	No abstract is included.

A.3.2 Acknowledgements

Participating in the competition, as in all research projects, involves leveraging resources and support beyond the efforts of individual team members. This support can take many forms such as technical advice, labor, equipment, facilities, and monetary contributions. Acknowledging those who have supported efforts is important.

Acknowledgements Scoring Metrics *(5% of score)*

Strong	Acknowledgements detail supporting personnel and their contributions as well as resources. Sponsors and their contributions are acknowledged.
Average	Acknowledgements include a list of supporters and sponsors with little or no detail of the support provided.
Poor	Acknowledgements provide a general thank you but do not specify particular contributions.
Requirements Not Met	No acknowledgements are included.

A.3.3 References

As with any technical publication, original ideas and content not generated by the paper's authors should be properly cited. The references should follow the IEEE Conference Proceedings citation style.

References Scoring Metrics *(5% of score)*

Strong	Sources include notable technical references including technical papers and articles. Use of the source materials are evident in the TDR. Sources are thoroughly documented. The IEEE citation style is correctly utilized.
Average	Sources are adequate and documented correctly with the IEEE citation style is utilized.
Poor	Limited sources are documented but there is no adherence to the IEEE citation style.
Requirements Not Met	No sources or citations are documented.

A.3.4 Technical Content

The technical content of the paper outlines the goals determined for the competition, and strategy for the system design and the testing approach. This portion of the paper should not include detailed descriptions of components as it can distract from understanding the team's underlying strategic thinking, design and engineering decisions, or novel contributions.

A.3.4.1 Competition Strategy

The paper must include details on the team's strategy for the competition, including the plans for approaching the course and how the vehicle design relates to this approach. The course consists of multiple tasks with associated points for accomplished behaviors. Teams may choose to attempt a combination of tasks in any order. The more tasks a vehicle is designed and engineered to accomplish, the more complex the overall vehicle system will be.

Consider the trade-offs between system complexity and reliability. For example, teams have a limited number of working hours to prepare for the competition; this time could be spent adding additional capabilities or testing and improving the reliability of an existing capability. As system complexity grows, changes in subsystems can propagate in unmanageable ways when time is limited. Based on history and the system engineering talents of the team, include a description the team's strategic vision.

Competition Strategy Scoring Metrics *(25% of score)*

Outstanding	Detailed description of the team's strategic vision and how the vehicle design compliments their goals. Detailed discussion on trade-off studies between system complexity and reliability during design development process.
Strong	The team's goals are clearly evident but not discussed in detail. Trade-off studies evident but lacking details.
Average	Brief mention of team's strategic goals and/or trade-off studies.
Below Average	Document hints at a goal for competition and/or trade-off studies.
Poor	Discussion of the team's vision is incoherent; rationale for competition goals is not discussed.
Requirements Not Met	No mention of competition goals.

A.3.4.2 Design Strategy

Given the strategy for success at the competition and the approach to managing complexity, the paper must include a description of the system design to meet the goals they established for the competition. Justification for design choices should be clear. Discuss how components and sub-systems were selected and integrated on the system. For teams that are working with a previous iteration of the system, discuss how the design meets the current competition strategy and any modifications needed at the component, subsystem, and/or integrated system levels. Describe the experience in making both architectural/design decisions and system engineering decisions.

This section should **not** include detailed component descriptions and/or specifications not of original design. The latter should be described in Appendix B.

Design Strategy Scoring Metrics *(25% of score)*

Outstanding	Provides in-depth explanations on design strategy and clearly identifies creative aspects of system. Creative design methodology is justified with required calculation steps and visual aids. Content clearly exhibits a Systems Engineering approach.
Strong	Provides explanations on design strategy and identifies creative aspects of system. Creative design methodology is justified with calculation steps and visual aids. Content hints at a Systems Engineering approach.
Average	Provides some information on design strategy and creative aspects of system. Creative design methodology is supported with a few calculations. Content could be justified as a Systems Engineering approach.
Below Average	Provides little information on design and creative design methodology. Little evidence to support applications of a Systems Engineering approach.
Poor	Provides limited information on the creative aspects of system. Creative design methodology is hypothesized. No evidence to support application of Systems Engineering principles.
Requirements Not Met	Creative aspects of design are not described.

A.3.4.3 Testing Strategy

Testing and experimentation is a crucial step to preparing and innovating a system design that strongly correlates with a competitive performance in the arena. The paper must include the approach to a testing strategy, including various test plans, both in-water and in simulation. There is a strong correlation between in-water testing time and competitive performance in the arena.

Consider the time needed to thoroughly test to meet the determined goals. Additionally, consider the demands of design and engineering with those of testing and experimentation.

Testing Strategy Scoring Metrics *(25% of score)*

Outstanding	Testing approach is presented in great detail, to include test strategy and plans. Component testing, sensor and control systems testing (bench tests and in-water) done in accordance with a test plan.
Strong	Detailed testing approach, test strategy, and plans. Documentation shows good overview of components, sensors and control system testing (bench tests and in-water).
Average	Testing approach is presented with sufficient detail, including mention of test strategy and plans. Documentation shows components, sensors and control system testing.
Below Average	Testing approach is presented with little to no detail. No mention of components or sensors testing.
Poor	Testing is done to a certain degree. No components and sensors are tested independently. There are no test plans.
Requirements Not Met	No mention of testing or connection with the system design.

A.3.5 Appendices

A.3.5.1 Appendix A: Component List

This appendix documents a list of all components utilized in the system design. In cases where components were developed by the team versus purchased off the shelf, this information should be included. Additionally, if commercial off the shelf equipment were significantly modified this should be noted. Under the column marked "Specs" a web link to the manufacturer's specifications may be provided. This standardized table will help document and track trends in component (hardware and software) usage and team metrics.

Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of Purchase	Reasoning
Waterproof Connectors							
Propulsion							
Power System							
Motor Controls							
CPU							
Teleoperation							
Compass							
Intertial Measurement Unit (IMU)							
Doppler Velocity Logger (DVL)							
Camera(s)							
Hydrophones							
Algorithms							
Vision							
Localization and Mapping							
Autonomy							
Open-Source Software							

A.3.5.2 Appendix B: Test Plan & Results (Optional)

Based off the testing approach outlined in the paper, this appendix showcases the test plan that was developed and the detailed results that came out of testing. Teams should present their plans for testing, including algorithm testing in a virtual environment, component testing in a laboratory setting, sub-system testing in a relevant environment, and full system testing in a pseudo-competition environment. Test set up should be included and results presented. Any design modifications or changes in competition strategy as a result of testing should be discussed.

While this appendix is not required, excellence seen in this section can be eligible for a special award.

The appendix may include detailed documentation covering the following areas:

- *Scope:* Objectives and test cases (this may also specify what was not included in tests)
- *Schedule:* Start/end dates and deadlines
- *Resource and Tools:* Resources and tools needed to conduct tests and assess results
- *Environment:* Description of the test environment, configurations, and availability
- *Risk Management:* Outline potential risks that could occur throughout testing
- *Results:* Detailed outcomes of test cases

Appendix B: Light Tower Specifications

This appendix provides an overview of the light tower task element that is used in Task 5: Scan the Code.

B.1. Description

The light tower 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 black (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.

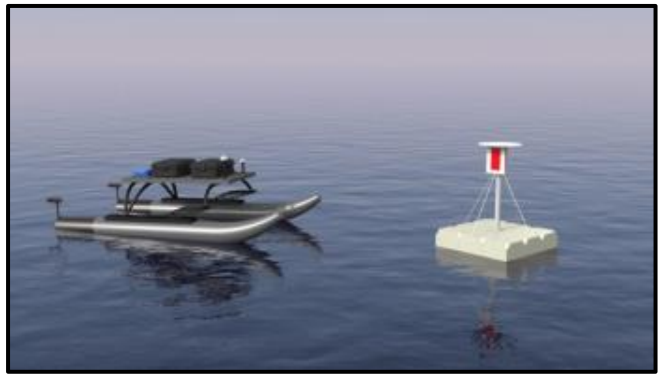


Figure 29. Light Buoy Concept

B.2. Specifications

The dimensions of one of the three identical faces are shown in Figure 30. 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.

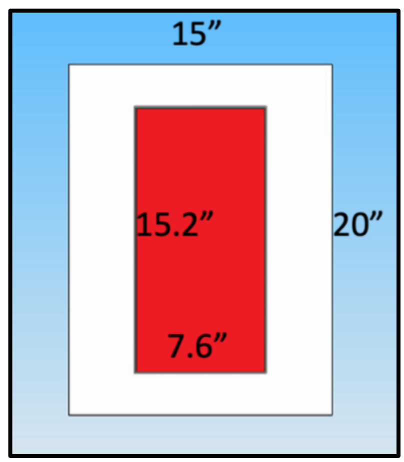


Figure 30. Light Buoy Face

A.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 C: Beacon Specifications

Each team that plans to attempt the Entrance & Exit Gates task may 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.

C.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 31: 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.

Appendix D: Communications Protocols

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.

D.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).

D.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 U.S. Eastern Daylight Time (EST, GMT -3).
- 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.

D.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 task during its run attempt. The fields for the heartbeat message are shown in Table 12, and followed by an example heartbeat message.

Name	Example	Description	Notes
Message ID	$RXHRB	Protocol Header	
EST Date	031124	ddmmyy	Use U.S. Eastern Standard Time (EST)
EST Time	161229	hhmmss (24hr time format)	Use U.S. Eastern Standard Time (EST)
Latitude	27.37498	Decimal degrees	Provides ~1.11m accuracy
N/S indicator	N	N=north, S=South	
Longitude	82.45100	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	24	Bitwise XOR	
<CR><LF>		End of message	

Table 12. RobotX 2024 Heartbeat Message Fields

Heartbeat Example Message: $RXHRB,031124,161229,27.37498,N,82.45100,W,ROBOT,2,1*24

D.4. Entrance and Exit Gates Message

The Entrance and Exit Gates task message provides a method for the AMS to report the gate where it detects an active beacon using the protocol specified in Table 13. 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
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
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	39	Bitwise XOR
<CR><LF>		End of message

Table 13. Entrance and Exit Gate Message Fields

Entrance and Exit Gate Example Message: $RXGAT,031124,161229,ROBOT,1,2*39

D.5. Follow the Path Message

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 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	$RXPTH	Protocol Header
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
Team ID	ROBOT	5-character code assigned by Technical Director
Entry Color	R	Color of Follow the Path Entry Buoy
Status	1	1 = In Progress 2 = Completed
Checksum	47	Bitwise XOR
<CR><LF>		End of message

Table 14. Follow the Path Message Fields

Follow the Path Example Message: $RXPTH,031124,161229,ROBOT,R,1*47

D.6. Wildlife Encounter Message

The Wildlife Encounter 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 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	$RXENC	Protocol Header
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
Team ID	ROBOT	5-character code assigned by Technical Director
Wildlife to be Circled	M	Classification of 1st Wildlife Object P=Python, M=Manatee, I=Iguana
Direction to Circle	CW	Direction to circle wildlife CW=Clockwise, CCW=Counter-Clockwise
Number of Circles	1	Number of times to circle Wildlife (1 or 2)
Checksum	64	Bitwise XOR
<CR><LF>		End of message

Table 15. Wildlife Encounter Message Fields

Wildlife Encounter Example Message: $RXENC,031124,161229,ROBOT,M,CW,1*64

D.7. Scan the Code Message

The Scan the Code task requires that the AMS locate and observe a light tower to determine the light sequence displayed. The AMS may transmit the detected light pattern 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	$RXCOD	Protocol Header
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
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	5B	Bitwise XOR
<CR><LF>		End of message

Table 16. Scan the Code Message Fields

Scan the Code Message Example: $RXCOD,031124,161229,ROBOT,RBG*5B

D.8. Dock and Deliver Message

The Dock and Deliver 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 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	$RXDOK	Protocol Header
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
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=Complete
Delivery Status	2	Status of Delivery S=Scanning, D=Delivering
Checksum	55	Bitwise XOR
<CR><LF>		End of message

Table 17. Dock and Deliver Message Fields

Dock and Deliver Example Message: $RXDOK,031124,161229,ROBOT,R,1,2*55

D.9. UAV Replenishment Message

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 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	$RXUAV	Protocol Header
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
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.
Item Color	B	Color of item picked up/delivered R=Red; B=Blue; G=Green
Checksum	47	Bitwise XOR
<CR><LF>		End of message

Table 18. UAV Replenishment Message Fields

UAV Replenishment Example Message: $RXUAV,031124,161229,ROBOT,2,1,B*47

D.10. UAV Search and Report Message

The UAV Search and Report task requires the UAV to launch from a designated start point, conducts a search of a field on land or water, detects and determines the location of 2 distinct objects in the field. Teams may implement any search pattern; however, the UAV must stay within the boundary of the task. 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	$RXSAR	Protocol Header
EST Date	031124	ddmmyy
EST Time	161229	hhmmss (24hr time format)
Object being reported	R	“R” or “N”
Object Latitude	27.37498	Decimal degrees
N/S indicator	N	N=north, S=south
Object Longitude	82.45100	Decimal degrees
E/W indicator	W	E=east, W=west
Object being reported	N	“R” or “N”
Object Latitude	27.37488	Decimal degrees
N/S indicator	N	N=north, S=South
Object Longitude	82.45130	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	08	Bitwise XOR
<CR><LF>		End of message

Table 19. UAV Search and Report Message Fields

UAV Search and Report Example Message:

$RXSAR,031124,161229,R,27.37498,N,82.45100,W,N, 27.37488,N,82.45130,W,ROBOT,2*08