Flight of the Loon-E
Robobat 2025 Technical Design Report

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***Abstract*— This paper presents the design and development strategy of Loon-E, an autonomous boat designed for the 2025 RoboBoat competition. The team's primary objective was to focus on the foundational mechanical, electrical, and software systems. The vessel is designed to complete a series of autonomous challenges, such as navigation of a path, docking, and object delivery. Through testing and iterative design, the team optimized the vessel for stability, efficiency, and reliability. The project serves as an opportunity to explore the practical application of robotics and autonomous technologies in marine environments, showcasing innovative approaches to engineering challenges.**

I. Introduction

Humber ASV is a design team made up of five students in Humber Polytechnic's Bachelor of Engineering program, majoring in mechatronics.

Humber ASV's first entry into the RoboBoat competition, the Loon-E, is a unibody catamaran boat with a streamlined hull to help reduce drag and improve the effectiveness of the rear thrusters. The Loon-E vision system can navigate nautical environments using a combination of camera and lidar inputs. It also includes modular components to achieve the various tasks that can change year-to-year in the competition.

II. Competition Strategy

As a new team, the team's primary goal was to complete the mechanical and electrical design of the Loon-E, as well as the software design for more fundamental actions such as propulsion, simultaneous localization and mapping (SLAM), and object detection. As such, minor focus was placed on the execution of the tasks laid out by RoboNation.

Despite this, however, some consideration was given to the strategy through which each task would be undertaken, as this would provide a general framework for the design. By identifying the types of actions the Loon-E will eventually be expected to execute, the team can ensure that any decisions made during the design process will work towards the eventual execution of these tasks. While the exact mechanics through which each of these actions would be executed have not been discussed, they serve as a useful starting point.

A. Navigation Channel and Follow the Path

For each pair of buoys, the center point between these will be identified and the boat will navigate towards this waypoint. If multiple pairs of buoys are detected, the closest green and red buoy will be used; this will repeat until no more buoys are detected. This methodology will also apply to the simpler Navigation Channel task.

When a yellow buoy is found, its position can be estimated based on the boat's current position and LiDAR data. It will then be compared to a list of found buoys and added to this list if not already present. The number of items in the list, once completed, will correspond to the number of yellow buoys found.

B. Docking

When the Docking task is found, the status of a dock is determined using computer vision algorithms. Depending on the object detected (black boat, orange boat, sign with matching symbol/colour, or sign without matching symbol/colour), the boat will shoot a racquetball or water (See *Object and Water Delivery*), dock, or do nothing. This will be repeated for all docks to ensure that all possible boats are accounted for.

C. Speed Challenge

Once the boat has entered the holding bay, it will save its GPS location. It will wait looking at the light panel and the colour it is displaying. Once the light turns green, the Loon-E will identify the blue buoy with the camera and drive towards and around the blue buoy, identifying any black buoys with camera and LiDAR, taking adequate maneuvers to avoid collision with them.

Once the blue buoy is reached the boat will go around it, keeping it to the left of the boat until the heading is lined back towards the saved starting position, then proceed return to the saved coordinates. Movement in and towards the holding bay can be done similarly to movement as described in the Navigation Channel and Follow the Path section.

D. Water and Object Delivery

If a boat is found outside of a dock, the Loon-E will reorient itself to face the side of the boat if it is not currently executing a task; if the boat is found while another task is being executed, the Loon-E will return to this position after completion of the previous task. Regardless of the position of the boat, the associated action (the firing of water or a racquetball) will be executed.

III. Design Strategy

Due to the size of the team and short time before the competition, it was important for the team to simplify the design as much as possible, while still allowing for some amount of control over the design. Given that the team's experience was strongest in mechanical design, it was determined that this would be done through the design of the hull, rudders, and water cannon; these are described in greater detail in *Mechanical Design*.

A. Mechanical Design

The hull is designed such that it can be 3D printed in one piece on the Fortus 900mc, which is able to print ABS Plastic in a volume of 36 in x 24 in by 36 in. This is more than sufficient for this first iteration of the boat hull. Additionally, the ABS plastic can be coated with a 2-part epoxy to ensure that the hull is watertight and electronics will be safe.

In order to reduce lateral and yaw motion in the boat, the team designed a two fuselage catamaran hull. Each fuselage has a T200 Thrusters mounted near the rear of the boat.

Mounted behind each propeller are fishtail rudders controlled by servos to steer the boat. The fishtail design utilizes the slipstream created by the thruster and the unique tail geometry to generate more steering control at larger attack angles.

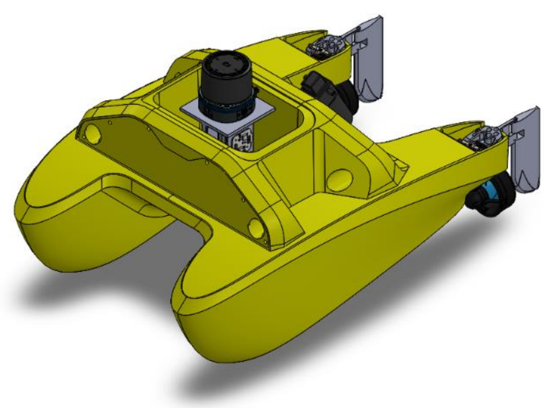

Figure 1: Finalized Hull Design

Using insert plates on the exterior of the boat, the water cannon and any future modules can be quickly designed and attached. The cannon uses a nozzle design to form a pressurized stream of water. The cannon can also be connected to standard housing so that it can be quickly disconnected from the water source if required.

The water cannon extracts filtered water from its surroundings using a 12V water pump, pressurizing and holding it at 60psi until a solenoid valve opens to release the water through the nozzle. A check valve is placed between the pump and the solenoid to ensure that the water cannot reverse direction and depressurize.

Once the boat is aimed accordingly, the solenoid is triggered, leading the stream of high pressure water toward the nozzle. The nozzle has a tapered inner diameter which will increase the speed of the water entering it. This water speed aimed at an angle of 45° will allow a burst of water to travel the required distance. The construction of the water cannon system consists of a combination of 3D printed and stainless steel brackets to fasten each device to the insert plates on the boat. Using these materials, it is ensured that the system is corrosion resistant.

The second module planned for this year's competition is a racquetball launcher. The racquetball launcher is designed to hold three balls and fire them individually. The magazine is controlled by an electromagnet linear actuating solenoid, which ensures that a ball is only allowed into the firing barrel when the barrel is clear.

The firing barrel is equipped with a spring-loaded plunger that is primed with a motorized rack and pinion gear system. Connecting the plunger to the gear system is another electromagnet linear actuating solenoid, which can disconnect the two parts at any desired moment. This strategy gives the ability to control the amount of force directed at the racquetball to adjust the projection or hit targets at different distances.

The housing of the launcher will be fabricated with 3D printed ABS, the firing barrel and magazine will be 56mm diameter clear acrylic, and the plunger will be machined in-house from aluminum. These materials will offer strength and corrosion resistance against the surrounding environment.

While a previous design of the racquetball launcher was proposed in which both the water cannon and racquetball launcher could be combined, this proved not to work (see Appendix D2); as such the new racquetball launcher design has not yet been tested.

B. Electrical Design

1) Operation

The boat is operated remotely using a FlySky-i6X transmitter paired with its corresponding iA10B receiver, which communicates with the Jetson Nano via serial IBUS communication. Six channels from the receiver are mapped to specific actions that the boat can perform. The input values from each channel are continuously analyzed and translated into outputs for various peripherals. These include:

- Water valve solenoid, used in the Water Delivery task.
- Servo motors controlling the rudders.
- ESC (Electronic Speed Controller) for driving the propellers.

To generate the necessary control signals for the PWM-driven peripherals (like the ESC and servo motors), a PCA9685 servo driver module is used. Functions inside the code map the inputs received from the RC receiver and give a value that is later used to provide the corresponding level of the signals necessary to execute the command.

2) Navigation

Navigation is achieved through a combination of rudder operation and propeller control. The boat can turn by using differential thrust, where one propeller runs at a fraction of the speed of the other, creating an imbalance in forces causing the boat to turn. Additionally, the rudders, which can move within a range of ±45 degrees from their neutral position, further aid in steering.

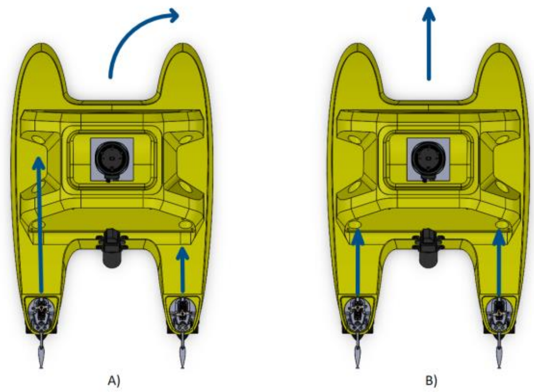

Figure 2: Driving modes
A) Differential Thrust B) Straight motion

3) Connections

To facilitate testing and maintenance, a modular wiring approach was adopted using non-permanent connectors. This approach simplifies modifications and troubleshooting during the development and testing phases. The types of connectors used include:

- WAGO Connectors, employed for joining multiple wires securely while maintaining the ability to quickly disconnect or rearrange connections.
- Screw-On Terminals and Crimped Ferrules, used for interfacing with boards and modules where reliable connections are required. The crimped ferrules prevent frayed wires from causing shorts or poor conductivity.
- Quick Connectors, these connectors allow for rapid assembly and disassembly of single wire connections

4) Cell Safety

The system is powered by one 4S Lithium-Ion Battery, supplying 14.8V and up to 18,000 mAh. The voltages are stepped down through a High Current Power Distribution Board to 5V and 12V to power most of the electronics.

To avoid damage to the battery by discharging it below its minimum voltage a Battery Protection Board is used. These monitor the voltage of each cell in the battery. If one of the cells reaches the minimum safety threshold, power is cut from all cells.

5) Remote E-stop

As part of the safety requirements, a remotely activated Emergency Stop (E-Stop) system is used. This system is designed to instantly cut power to the propellers to prevent unintended operation in case of an emergency. The E-Stop system consists of:

- Normally Open (NO) relay module: This relay remains open by default, meaning no current flows to the propellers unless the relay is actively triggered. This configuration ensures that the vessel cannot operate if the relay fails or loses signal, enhancing safety.
- RC Receiver: The relay is controlled by one of the FlySky iA10B receiver channels. Unlike the other receiver channels, which are processed through the Jetson Nano, the E-Stop channel bypasses the computer entirely. The PWM signal from the receiver is directly used to control the relay.
- PWM Switch: This is used to sink the input of the corresponding phototransistor triggering the relay module with a PWM signal.

This design decision ensures that the E-Stop system is completely independent of the Jetson Nano, making it fail-safe in the event of a software crash, communication issue, or power failure affecting the computer.

The use of a Normally Open relay ensures that if the relay fails or the receiver loses signal, the default state is to cut power to the propellers. This configuration prevents the vessel from operating unsafely in scenarios where remote control or autonomous control is compromised.

D. Software Design

Programming for the Loon-E was done in Python due to the ability for this language to be used in ROS 2 Humble[2] and the team's familiarity with the language. This included the development of a PID controller which would be used to control the speed of the Loon-E, as well as a method for mapping the Loon-E's surroundings using point cloud data obtained from the SICK multiScan 136 LiDAR.

1) Object and Colour Detection

Object detection can be done by training a YOLO11 model to recognize objects such as the various buoys, dock cubes, and boats. Further information regarding these objects such as their colour or the shape on dock and boat signs can then be identified using OpenCV using a variety of image filtering methods.

Additionally, by identifying the colour of the pixel at the center of the bounding box, which defines these objects, it is possible to identify the colour of the object given all possible colours using Euclidean colour distance.

Upon identification of these objects, their position can be mapped relative to the boat using a coordinate system allowing the system to make decisions for navigation or recognition of relevant items depending on the task, ensuring efficient decision making.

IV. Testing Strategy

A. Water Cannon Testing

In the early design phases different concepts were tested mainly for the racquetball cannon. Concepts such as a water propelled cannon using the existing water delivery system, or a spring loaded cannon, were prototyped and tested to asses the feasibility of each idea. After the testing phase the most promising concept was chosen and developed further.

A test was also conducted to determine the required amount of pressure for the system. To be as efficient as possible with battery power the minimum amount of pressure possible to shoot the water 2 meters was used. Using less pressure will result in the pump consuming less battery power. This test will allow to measure the maximum distance that each pressure can reach (see Appendix D1). Appropriate amount of pressure to use for the system can be selected.

B. Racquetball Launcher Testing

We plan to test the racquetball launcher by pulling the plunger back by increasing lengths and measuring the distance that the ball travels after being fired. This test will give data on the relationship between the servo motors rotational angle and the target that it will hit. Using this data, an algorithm can be created to automatically calculate the required servo angle to hit a target that is a known distance away, measured by the LiDAR.

C. Safety Systems

Testing procedures for safety features, namely E-stop were developed, to ensure proper function before proceeding to do in-water testing. Procedures for testing ideas for the water cannon and racquetball cannon were developed to determine system settings and characteristics (see Appendix D1 & D2).

D. Object Detection

Testing of software was done by isolating individual sections of the code and testing them, such as the shape and colour detection algorithm (see results of testing in Figure 3 below). From there, testing of the full object detection algorithm could be tested once implemented.

Figure 3. Shape Detection Algorithm

V. CONCLUSION

The design and development of Loon-E represents Humber ASV's first effort to participate in the RoboBoat 2025 competition. Through iterative testing focusing on the foundational aspects such as mechanical, electrical and software systems, the team designed an autonomous boat capable of tackling various challenges serving as a platform for future competitions.

VI. ACKNOWLEGEMENTS

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The team would also like to acknowledge David Balsdon for his support in regards to hull design and printing techniques.

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APPENDIX A: Component List

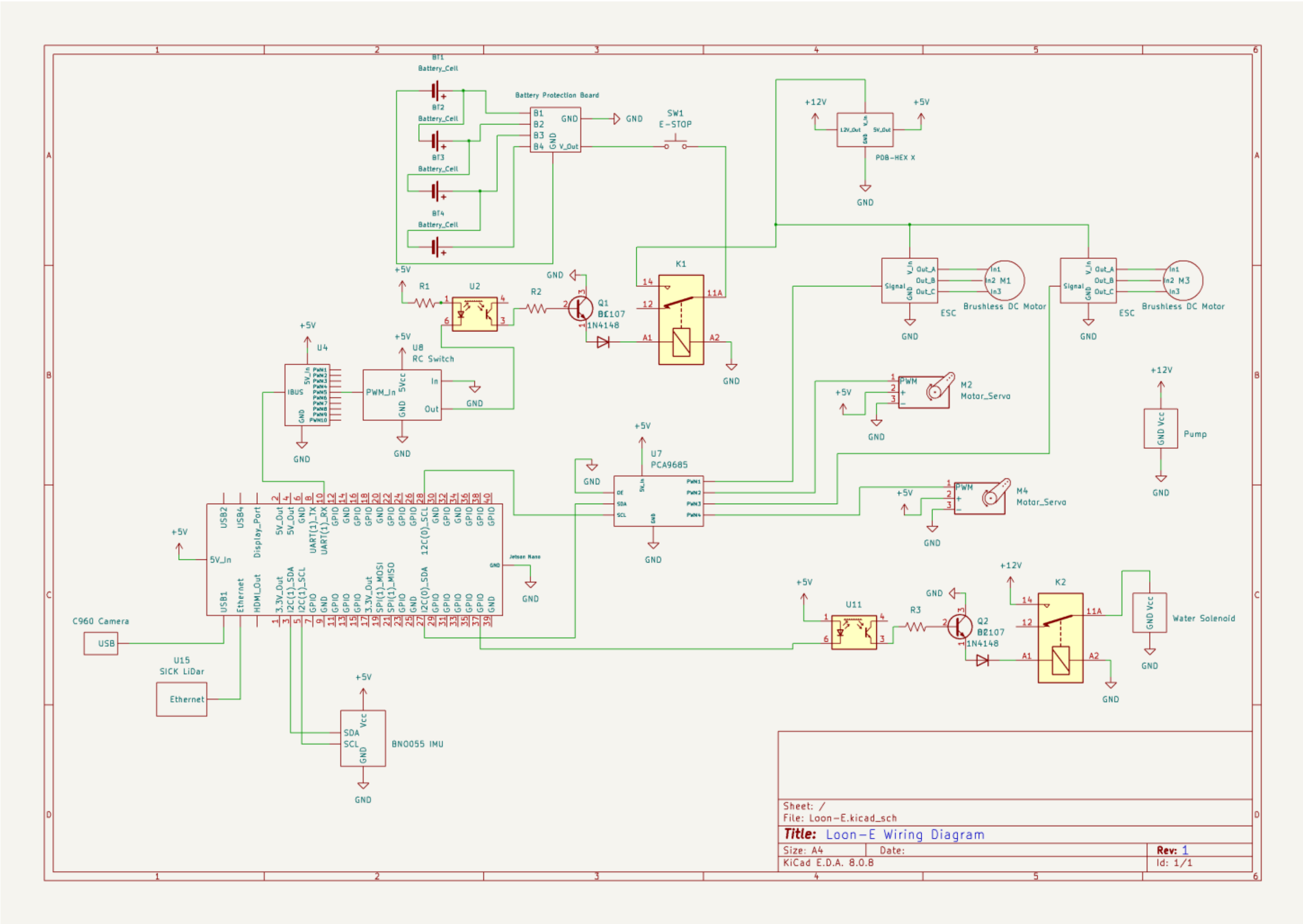
AREA	COMPONENT	VENDOR	CHARACTERISTICS	COST (USD)
Propulsion	T200	Blue Robotics	31.21 A @ 20V	238
	Basic ESC	Blue Robotics	7-26 V	38
	Servo Motor	Miuzei	5V, 20 kg	15.32
	H6 PRO Lithium Battery Charger	Blue Robotics	10A	185
Hull	Custom Hull	-	ABS	Donated
	Epoxy Resin	Ark Composites	1/2 Gal	55.41
	Epoxy Hardener Medium	Ark Composites	1 Quart	44.66
Teleoperation	FS-i6X	FlySky	10 channels	69.66
Navigation	Ultimate GPS Breakout	Adafruit	1575.42MHz	31.68
	BNO055	Adafruit	9-DOF	44.75
	C960	EMEET	90 degree	Donated
	Jetson Orin Nano	Nvidia	8GB	Donated
	multiScan136	SICK	16 scan layers	Donated
Electrical	Lithium-ion Battery	Blue Robotics	14.8V, 18Ah	380
	PCA9685	Adafruit	16 Channels	11.15
	Relay Module	YWBL-WH	30A	19.83
	CP2102 Module USB to TTL	Izokee	115200 bps	8.36
	PDB-HEX X	Matek	<12S	25
	Remote Control Electronic Switch	Fockety	3-30V, 20A	11.15
	E-Stop	McMasterCarr	2.5 A @ 24 V DC	52.44
	Battery Protection Board	ACEIRMC	25 A 21V	6.89
	40 Pin breakout board + Ribbon cable	Hilitand Store	1A	20.65
	Wago Connectors	New Age Agency		19.85
	JST-XH Connectors	Elechawk		14.63
Water system	Diaphragm Pump	Auhafaly	1.2 GPM	16.72
	Electric Solenoid Valve	BAOMAIN	12V 2W, 3/8"	21.45
	Filter	Opzour	3/8"	7.66
	One way check Valve	Wolfride	3/8"	9.75
	Custom Nozzle	-	ABS	Donated

APPENDIX B: Battery Life Expectancy Calculations

No.	Component	Voltage (V)	Current (mA)	Quantity	Total Current	Notes
1	Sick LiDAR	12	2000	1	2000	Supply Voltage: 9v - 30v
2	T200 Thruster	14.8	15000	2	30000	Supply Voltage: 10v - 20v
3	Pump	12	3000	1	3000	
4	Solenoid	12	5	1	5	
5	Jetson Nano	5	2000	1	2000	
6	PCA9685 (PWM)	5	25	1	25	
7	BNO055 (IMU)	5	12.3	1	12.3	
8	RC Receiver	5	5	1	5	
9	20kg/cm Servo	5	1800	2	3600	
Required Voltage		14.8	Total Current		40,647	

Battery	Voltage	Current (mAh)	Quantity	Total Current	Max Current (mA)	Life Expectancy (mins)
BR-100842	14.8	18,000	1	18,000	60,000	26.570

APPENDIX C: Electrical Diagram



APPENDIX D: Testing Procedures

1) Water Cannon Testing Procedure

1) Place boat on a test stand outdoors
2) Place water filter inside water tank
3) Connect battery inside the boat
4) Set pump pressure switch to 30psi
5) Wait until the pump reaches the desired pressure and turns itself off
6) Manually open the solenoid valve to shoot the water
7) Measure and record the distance the water travelled
8) Repeat steps 4-7 increasing the pressure by 15psi each time until 75psi is tested
9) Disconnect the battery from the circuit
10) Remove the boat from the water tank

2) Racquetball Launcher Prototype Testing

In early phases of testing, we developed a prototype to assess the feasibility of launching racquetball with the same water cannon used for the water delivery task. The prototype consisted of a pump, a pressure gauge, a manual valve, a custom 3D printed PLA nozzle and a clear acrylic tube to act as a barrel.

From this test we observed that the racquetball was being impeded as it moved down the barrel, possibly due to a seal created by the ball since the clearance between the two was very low. To compensate for this, holes we drilled throughout the barrel ensuring a constant flow of air into the cannon as the ball was shot. This improved results slightly, but the observed trajectory was far from what was expected, even at different pressures. As such, this idea was scrapped in favour of the mechanical cannon described in the report that presented better results.

Racquetball Launcher Testing Procedure

1) Place boat on a test stand
2) Connect battery inside the boat
3) Insert the 1st ball into the firing barrel
4) Set servo motor pinion angle to 45° (25% spring power)
5) Manually release Solenoid 2 to fire the racquetball
6) Measure and record the distance the racquetball travelled
7) Insert the 2nd ball into the firing barrel
8) Set servo motor pinion angle to 90° (50% spring power)
9) Manually release Solenoid 2 to fire the racquetball
10) Measure and record the distance the racquetball travelled
11) Insert the 3rd ball into the firing barrel
12) Set servo motor pinion angle to 135° (75% spring power)
13) Manually release Solenoid 2 to fire the racquetball
14) Measure and record the distance the racquetball travelled
15) Insert the 4th ball into the firing barrel
16) Set servo motor pinion angle to 180° (100% spring power)
17) Manually release Solenoid 2 to fire the racquetball

18) Measure and record the distance the racquetball travelled
19) Disconnect battery from circuit

3) E-Stop Testing Procedure

1) Place boat on a test stand
2) Turn on RC Transmitter
3) Connect battery inside the boat
4) Enable RC mode
5) Run propellers at low speed
6) Trigger Remote E-Stop. Propellers should stop shortly after
7) Attempt running propellers. Confirm propellers do not run
8) Release remote E-Stop
9) Turn on propellers, confirming power is back on
10) Trigger the physical E-Stop on the boat.
11) Attempt running propellers. Confirm propellers do not run
12) Release physical E-Stop
13) Turn on propellers, confirming power is back on
14) Turn off propellers
15) Disconnect battery from circuit
16) Turn off RC remote