Comprehensive Design Review Report: Lake Guardians

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December 8, 2025

The University of Texas at Austin

Mechanical Engineering Design Methodology

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Section 20295

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Chapter 1 – Project Proposal

Introduction

Plastic pollution in Central Texas lakes has become an increasingly visible environmental challenge. Recent research at the University of Texas at Austin has shown rising microplastic concentrations in lake sediments, with many particles originating from the breakdown of larger floating plastics over time. These macroplastics accumulate most heavily along brush-filled, shallow shoreline zones where existing cleanup boats struggle to maneuver, leaving volunteers and city crews to manually retrieve debris. Our project responds to this gap by developing a small-scale, deployable cleanup system that can reach areas inaccessible to current technologies while reducing the long-term generation of microplastics.

Throughout the semester, our team engaged with multiple stakeholders including UT researchers, frequent lake users, and representatives from the City of Austin Watershed Protection Department to understand pain points in current cleanup operations and identify actionable engineering requirements. These discussions reinforced that an effective solution must be lightweight, safe for wildlife, easy to operate, and able to relocate floating debris without becoming entangled in vegetation. Interviews and field observations highlighted that crews often need a maneuverable tool rather than large, fixed infrastructure, and that volunteers require simple equipment for rapid deployment from shore.

Building on our earlier Preliminary Design Review, the Comprehensive Design Review advances the project from broad concept exploration into detailed system refinement. Using structured design-methodology tools such as functional decomposition, morphological matrices, ideation methods such as 6-3-5, SCAMPER, and design-by-analogy, we generated and evaluated multiple design pathways. Through rotating-datum Pugh chart comparisons, supplemented by back-of-the-envelope performance and cost analyses, the team ultimately selected a remotely operated airboat equipped with a front-mounted comb bulldozer mechanism. This concept demonstrated the strongest alignment with customer needs, budget constraints, and functional requirements while offering meaningful improvements over existing cleanup technologies.

The CDR documents our complete design rationale, including refined functional architecture, FMEA-based risk mitigation, manufacturability considerations, and initial low-fidelity prototyping. Two physical prototypes, a comb bulldozer mechanism and a foam-hull proof-of-concept airboat, provided early validation of debris-capture performance, buoyancy, geometry, and operational feasibility. These results now inform the detailed CAD model, subsystem integration plans, and next-semester roadmap for higher-fidelity fabrication and testing.

Overall, this report represents the full progression of our engineering design effort to date. By combining environmental research, stakeholder engagement, structured concept development, and iterative prototyping, our team aims to deliver a practical, accessible, and ecologically responsible device that improves plastic removal capabilities on Austin's lakes while supporting the long-term health of their ecosystems.

Gantt Chart and Task List

To guide the progress of our project, we developed a Gantt Chart (Appendix A), which outlines all major milestones for the semester and highlights the month of each project deadline. We believe this is the most effective method to organize project deliverables due to individual and group responsibilities outside of the project. This also ensures that all deliverables are submitted on time since the deadlines match the due dates of project progression throughout the semester. The Gantt Chart is updated as tasks found in the task list are completed. The timeline is divided by tasks which contribute to three major deliverables, which are the Proposal, Preliminary Design Review, and Final Report. We have subcategories to define specific action items to ensure an organized workflow.

In addition to the Gantt Chart, we created a Task List (Appendix D) that expands the project tasks outlined within it. The task list provides a more detailed view of day-to-day responsibilities, enabling our team to assign work fairly, track progress, and identify task dependencies that influence the progress of our deliverables. It is updated periodically by team members as we hit our project milestones to ensure accuracy and accountability. Because of the close relationship between the task list and the Gantt Chart, the completion of individual tasks directly affects the progress of corresponding deliverables, allowing us to maintain clear understanding of ownership, timelines, and dependent tasks throughout the semester.

Background Information

Plastic pollution in freshwater environments has become one of the most persistent environmental challenges of the twenty-first century. Once considered primarily a marine issue, it is now clear that rivers and lakes are major pathways and storage zones for plastic waste. These inland systems collect runoff from cities, roadways, and industrial zones, concentrating debris before it ever reaches the ocean [1]. Around the world, scientists have documented increasing levels of plastic contamination in lakes, often in the form of visible litter and microscopic fragments [2]. Urban lakes are particularly vulnerable because they receive continuous inflows of stormwater and road drainage, concentrating debris that persists for decades.

Figure 1. Plastic debris accumulation in Lady Bird Lake following storm runoff (photo credit: KXAN, 2022).

In Austin, Texas, Lady Bird Lake and Lake Austin serve as important recreational and ecological spaces, yet both have become repositories for plastic debris. As the city's population and urban footprint have grown, storm drains and creeks have carried increasing amounts of plastic waste into these reservoirs [3]. After heavy rain, litter such as bottles, bags, and foam containers often accumulates along the lake's edges and under bridges [4]. The dams that impound these lakes slow water movement and trap debris that would otherwise drift downstream. Over time, this process allows plastics to fragment into smaller pieces, making them harder to remove and more likely to affect wildlife and human health [5].

Microplastics, defined as particles smaller than five millimeters, represent an especially concerning form of contamination [6]. They originate from the breakdown of larger plastics as well as from sources like synthetic textiles, vehicle tires, and road surfaces [7]. In rapidly urbanizing regions, tire and road wear particles are among the dominant contributors to microplastic pollution [8]. These particles wash off roadways during rainfall and enter waterways through drainage systems. Once in the water, they can remain suspended or settle into sediments, where they persist for decades. Because of their size and buoyancy, microplastics are easily ingested by fish, invertebrates, and birds, causing physical and chemical harm [9]. Laboratory and field studies have shown that ingestion can lead to digestive damage, malnutrition, and reduced reproductive success [10]. The plastics themselves can carry toxic additives and pollutants, which may bioaccumulate in food webs and potentially reach humans through drinking water or seafood consumption [11].

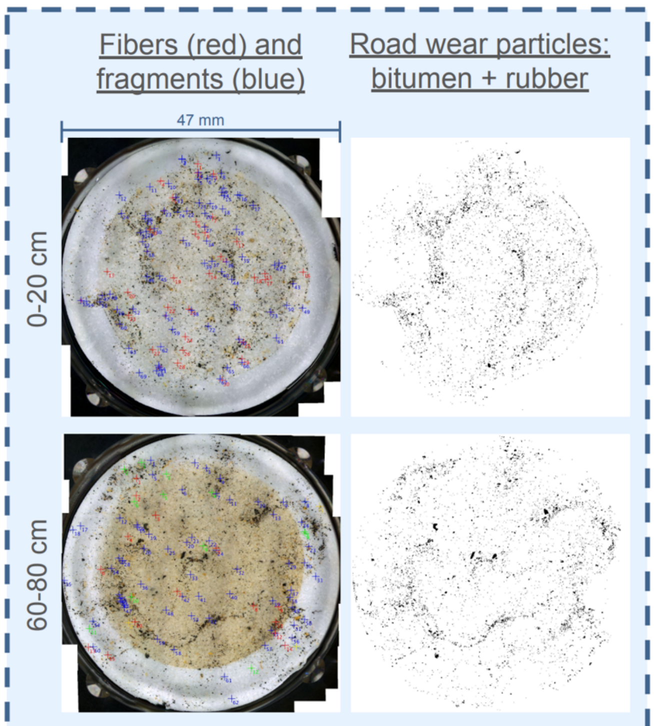

Figure 2. Processed sediment samples from LBL with fibers and fragments highlighted (photo credit: UT Austin School of Geosciences, 2024).

Recent research at The University of Texas at Austin and the City of Austin has revealed the extent of microplastic accumulation in Lady Bird Lake [12]. Researchers collected long sediment cores from the lakebed and found plastic particles in every layer examined. The abundance of these materials increased in the upper sections of the core, suggesting that plastic pollution has risen sharply alongside Austin's urban growth [13]. One section of the core showed a pronounced spike in plastic content that likely corresponds with periods of major infrastructure expansion and increased traffic along Interstate 35 [14]. The dominant type of microplastic identified was the road-wear particle, a mixture of tire rubber and asphalt that reflects the heavy influence of urban runoff [15]. Concentrations were highest near the mouths of creeks draining downtown, confirming that stormwater is a key delivery mechanism [3]. These findings indicate that the sediments of Lady Bird Lake act as a long-term sink for microplastics [12]. Because the reservoir's outflow is regulated by the Longhorn Dam, particles tend to settle rather than wash away. Benthic organisms and fish can ingest these particles directly from sediments, creating a pathway for plastics to enter the aquatic food web. The research underscores both the persistence of plastic contamination and the need for active mitigation strategies [13]. Removing existing debris and preventing new inputs are critical to restoring the ecological balance of the lake

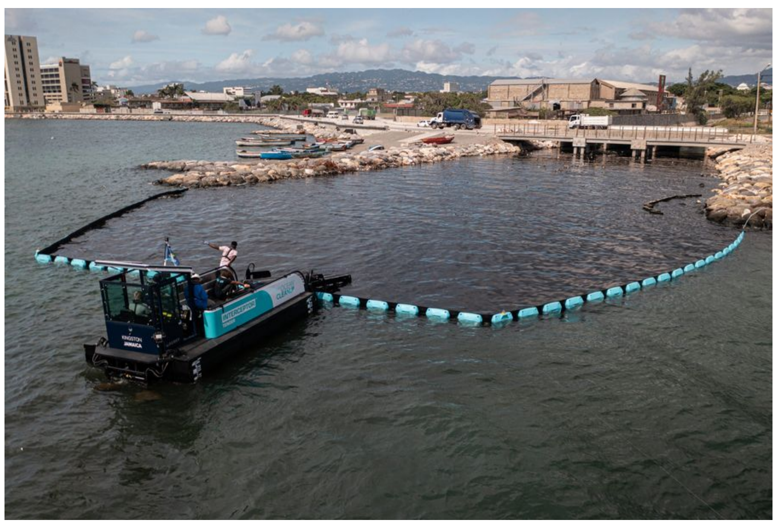

Figure 3. The Ocean Cleanup Interceptor deployed at a river (photo credit: The Ocean Cleanup, 2025).

Globally, several technologies have been developed to capture plastic waste from aquatic environments. One of the most recognized is the Ocean Cleanup Interceptor, a solar-powered barge that collects floating debris in rivers using a guided boom and conveyor system [14]. It can remove tens of thousands of kilograms of trash daily, making it suitable for heavily polluted waterways. Smaller, marina-scale solutions include the Seabin, which uses a submersible pump to draw in surface water and trap floating litter in a mesh bag [10]. Seabins are compact and effective in calm waters but have limited capacity and rely on power availability. Stationary devices like the StormX Netting Trash Trap intercept litter at the ends of storm drains before it reaches open water [11]. These nets capture small pieces of debris while allowing water to pass through and can be serviced easily by maintenance crews. Passive collection systems such as floating booms or trash wheels also guide debris toward collection points using natural currents. Baltimore's Mr. Trash Wheel, for example, has successfully removed hundreds of tons of waste from the city's harbor using a water-powered conveyor [9].

Figure 4. Baltimore's Mr. Trash Wheel (photo credit: Mr. Trash Wheel, 2025).

Each of these technologies demonstrates a different approach to debris interception. Large-scale mechanical systems work well in rivers with continuous flow, while smaller passive traps are more appropriate for calm lake environments [10]. Their common limitation is that most capture visible macroplastics rather than microscopic fragments. Even so, by preventing large plastics from breaking down further, they indirectly reduce microplastic formation. The lessons learned from these systems, such as modular design, ease of maintenance, and resilience to weather, are valuable for any new project focused on lake cleanup [11].

For Lady Bird Lake, several design principles emerge as particularly important. A modular system that can be deployed and serviced in segments would allow flexibility to target different hotspots, such as creek inflows or bridge zones [13]. Maintenance must be simple enough for city crews or volunteers to perform regularly, ensuring consistent operation without requiring specialized expertise. The device should withstand floods and high-water flows, common in Central Texas, without becoming dislodged or damaged [14]. Materials should be corrosion-resistant and capable of withstanding UV exposure and debris impact. The device must not disturb wildlife or natural habitats. Smooth surfaces and passive capture methods can reduce the risk of animal entanglement [15]. If pumps or filters are used, their intake speeds must be low enough to avoid drawing in fish or turtles. The system should also minimize noise and visual intrusion, preserving the lake's natural appeal for recreation [12]. Because Lady Bird Lake is a focal point of downtown Austin, aesthetics and community perception will strongly influence project success [3]. A discreet or visually pleasing design, potentially accompanied by educational signage, can encourage public support and awareness of plastic pollution [11].

Figure 5. Lady Bird Lake Trail (photo credit: Visit Austin, 2025).

Ultimately, the goal of this project is to develop a sustainable, efficient, and locally appropriate method to reduce plastic debris in Lady Bird Lake and similar urban lakes. The problem combines environmental science, public infrastructure, and engineering design. Lessons from global cleanup initiatives and local research provide a clear path forward. By integrating modularity, resilience, wildlife safety, and ease of maintenance, a student-engineered solution can contribute meaningfully to cleaner lakes and a healthier urban ecosystem [15].

Customer Needs Analysis

Our customers include residents and lake users, the City of Austin Watershed Protection Department, Keep Austin Beautiful, environmental activists, the Environmental Protection Agency, and non-human stakeholders such as fish, turtles, birds, and the underwater ecosystem. We conducted solution-neutral interviews with researchers and civilians around the local lake areas and field observations at inflow hotspots and shorelines to better understand the issue and cause of increasing plastics found in lakes. We translated these quotes and notes into interpreted needs and created measurable requirements (Appendices B and C).

We organized our customer needs into capturing performance, ecological safety, deployment and operations, and efficient communication. Capture performance covers the removal of plastics at shorelines or near the surface, preventing hotspot build-up and continuous plastic inflow, and the device's performance to efficiently perform through various weather conditions over time. We want to ensure that the captured debris will stay captured, and our device can help keep lakes free of visible plastics in public-facing areas. Ecological safety covers zero harm to the inhabitants and habitats of the lake. In addition, we must ensure our device doesn't resuspend contaminated sediments, and the lake conditions are safe for pets and lake users. We must be sure to maintain low visual and acoustic intrusion in deployment zones, especially in busy areas, to keep the lake natural and calm. Efficient communication covers helping users easily understand our mission and the status of the lakes, clean on-site device communication, and straightforward tracking to display credible progress.

House of Quality

We used House of Quality (Appendix F) to analyze our customer needs and transform them into design parameters to better plan out the foundation of our device. Through extensive research, we determined that three appropriate competitor benchmarks are Mr. Trash Wheel, StormX Netting Trash Trap, and SeaBin. We assigned Mr. Trash Wheel to *Competitor A* as it presents a proven, semi-autonomous interceptor that is placed at creek mouths. The trash wheel uses floating booms to funnel debris and lift the material into dumpsters, all while running on power from the stream current, augmented by solar when flows are low. It sets up a high bar for retention during storm pulses and reveals limitations such as its large and permanent structure, big visual footprint, and the need for a suitable current.

We designated StormX Netting Trash Trap as *Competitor B* to represent passive, low-energy capture at point inflows. They used heavy-duty nets placed at outfalls and small channels that capture litter flushed during rain events, which are then emptied by crews between storms. StormX highlights modularity and quick installation while also incorporating important engineering safeguards, such as overflow features to avoid back-up and harm to wildlife. Lastly, Seabin is our *Competitor C,* a small electrically driven surface skimmer that draws in floating debris and small fragments using a fine catch bag. These units are mounted on docks and run continuously. Seabin offers a model for a compact footprint with low visual and acoustic intrusion while also revealing limits in need for shore power and overflow management. After establishing competitors, we ranked our customer needs on a scale of 1 to 5 (1 = least important, 5 = most important). Then, we use 0, 3, and 9 (0 = low relation, 9 = high relation) to rank how customer needs relate directly to the methods of achieving the written engineering requirements. Higher-weighted needs mainly regarded visible cleanliness, device performance, and ecological safety. Next, we assigned target values for each engineering requirement, which allowed us to gain insight into priorities and establish what performance our device should achieve. We populated the House of Quality with reference values from public sources, but wherever data was not published, we made estimates by observing deployment videos and site photos. This procedure yielded a testable set of targets that we could use to guide our prototype design.

Engineering Specifications

The list of engineering specifications (Appendix E) was created from customer needs analysis, the engineering requirements within the house of quality, and competitor comparison. The engineering requirements in the house of quality were given the most thought when making the specification list. The competitor comparison was primarily used to set our target values for our metric relative to the scope of our product. For example, the Seabin is a realistic scale to compare our prototype to, as the scale of the Trash Wheel and StormX Netting Trap is unobtainable within the scope of our project. However, all competitors are still important to consider in our design process, as relevant information can still be found from the analysis of all competitors.

The specification was pulled directly from the corresponding requirement. Then a metric and target value were added based on the target value and unit found in the house of quality. For importance, a specification was either assigned a D or W, D correlating to a demand and W correlating to a wish. Demands are considered essential requirements for our product to be considered successful as a modular plastic removal device. Wishes are requirements that improve the device's integration with its use environment, but not essential to its function and purpose. The demands and wishes were assigned based on the ranked importance found within the house of quality.

Furthermore, a verification method was added to verify that the product meets the requirement set. The verification methods range from field testing, field surveys, and visual inspections to lab microscope testing, weight testing, and sound meter testing. These tests will be carried out by all members of the team throughout the whole project. A final date of 11/26/2025 has been assigned to meet all the requirements on our prototype.

A category of plastic removal, environmentally friendly, or ease of use was added to each specification dependent on the purpose behind each specification. To distinguish between the categories, we added a color to each specification. Green correlates with plastic removal, blue correlates with environmentally friendly, and orange correlates with ease of use.

Problem Statement

We aim to design and build a safe, affordable, field-deployable device to address the growing load of large plastic debris and microplastics in Central Texas lakes, especially Lady Bird Lake and Lake Austin. We will look towards urban runoff, litter blown in through the wind and storm, and tire fragments washed in through creeks and storm drains, as these break down into smaller particles. Fish, birds, and pets ingest these plastics, which can transport chemicals and pathogens, and degrade the aesthetic value of the lakes. Therefore, we will ensure our device stays within constraints such as budget, portability and efficiency, and ensuring minimal disturbance to sediment and aquatic life. We will meet customer needs and engineering specifications through a series of engineering design processes and steps.

Chapter 2 – Preliminary Design Review

Function Tree

Our Function Tree (Appendix G) represents our overall goal, to remove plastic from lakes, decomposed into eight primary solution-neutral functions. (1) The system intercepts floating macroplastics by guiding flow toward a capture path and separating debris from water. (2) It protects wildlife and pets by preventing bycatch and enabling safe passages to meet regulations. (3) It retains captured debris by preventing backflow and providing a secure, drainable container. (4) The system supports modular deployment and relocation by keeping modules light and standardizing connections to enable quick release and redeployment. (5) We will inform the public and communicate results by explaining its purpose, measuring outcomes, and providing simple ways to access data and give feedback. (6) It limits acoustic and visual intrusion by isolating vibrations, controlling glare/lighting, and reducing visual contrast. (7) It enables quick maintenance with tool-light access and short service times, so uptime stays high. (8) Finally, it will filter microplastics by capturing small particles and preventing resuspension into the lakes. Together, these functions represent a system that can deliver meaningful lake cleanup in a way that is gentle to its environment, simple to maintain, unobtrusive, and accountable through clear, public results.

Concept Generation

To develop innovative yet feasible approaches for removing plastics from Lady Bird Lake, the team employed a structured concept generation process. Multiple ideation methods were used to ensure creativity, functional diversity, and solution neutrality before moving into concept selection. The activities, 6-3-5 Brainwriting, Design-by-Analogy, and a supplementary SCAMPER exercise (Appendix H), allowed us to translate stakeholder needs and engineering functions into actionable design concepts. These methods produced a range of ideas addressing macroplastic interception, retention, propulsion, and wildlife safety, ultimately informing the morphological matrix and concept variants developed in later phases.

The team conducted a 6-3-5 Brainwriting session with five members over five rounds, generating and building upon one another's ideas. Each participant created three unique concepts per round, then passed their sheet to the next teammate for iteration, resulting in several dozen total idea variations. This structured process ensured equal participation and a balance between divergent and convergent thinking. The session was text-based, completed by hand to encourage speed and focus on function rather than form. Notable ideas included an autonomous mapping drone capable of surveying and collecting debris and a 3-in-1 trash-grabbing tool that integrates a net launcher, retractable reel, and puncture probe for manual cleanup. These and other recurring themes such as automation, modularity, and simplicity guided subsequent concept refinement.

To expand beyond conventional approaches, the team conducted Design-by-Analogy across three key subfunctions: intercepting floating macroplastics, retaining captured debris, and enabling safe wildlife passage. By examining mechanisms from natural and engineered systems, the team extracted transferable insights. For debris interception, analogies such as fishing nets, baleen whales, and river beavers inspired passive funneling and flow-guided filtering mechanisms. Retention mechanisms drew from check valves, lobster traps, and Velcro closures, suggesting one-way entry and self-sealing containment. To ensure wildlife safety, analogies to pet doors, aquarium baffles, and highway wildlife overpasses informed design elements that allow species-specific safe passage while maintaining capture efficiency. This exercise helped identify non-clogging, low-resistance collection strategies and self-regulating containment principles that will influence the prototype's mechanical layout.

As an optional exploration, the team applied the SCAMPER technique to the existing Mr. Trash Wheel concept, which had proven success at the macro scale. Through the categories of Substitute, Combine, Adapt, Minify, Put to Another Use, Eliminate, and Reverse, the team proposed modifications to enhance portability and adaptability. Key ideas included miniaturizing the system for small-lake applications, replacing hydropower with battery-electric operation, and relocating the debris-comb mechanism from the main conveyor to the floating arms for improved capture at varying water levels. Although a shorter activity, this exercise reinforced design principles for scaling down proven systems while maintaining performance.

As global awareness of aquatic plastic pollution has grown, engineers and researchers have developed a wide variety of devices that aim to remove, divert, or prevent debris accumulation. Beyond well-known systems like the Seabin, Mr. Trash Wheel, and StormX Trap discussed earlier, a new generation of autonomous, bio-inspired, and hybrid technologies has emerged. These approaches target different aspects of the problem, mobility, fine-particle capture, or modular scalability, and inform our team's design direction for lake environments such as Lady Bird Lake.

Figure 6. WasteShark (photo credit: RanMarine, 2025).

Modern developments have shifted toward autonomous or semi-autonomous vessels capable of navigating across variable water conditions. The WasteShark, designed by RanMarine Technology in the Netherlands, is a compact electric catamaran that can collect up to 500 kg of floating debris per day while simultaneously gathering water-quality data [13]. Similarly, Clearbot, developed in Hong Kong, employs onboard AI and computer vision to detect and intercept floating waste with minimal human oversight [14]. These systems are battery-powered, emission-free, and programmable to follow GPS routes, making them ideal for harbors or small lakes where continuous manual cleanup is impractical.

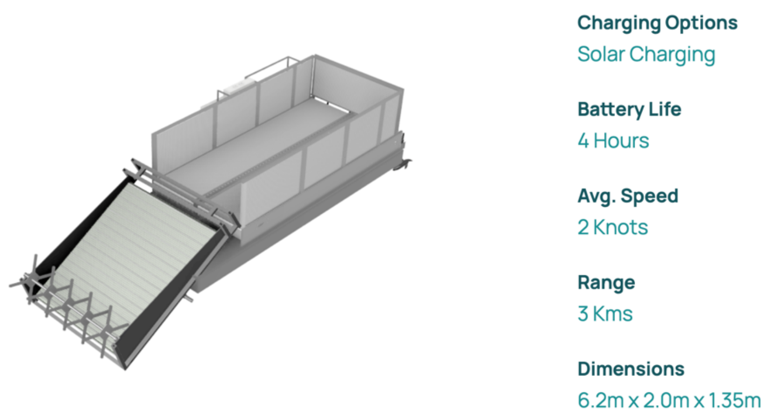

Figure 7. Clearbot Alligator with base specifications (photo credit: Clear Robotics, 2025).

A newer variant, the PixieDrone (by The Searial Cleaners), integrates sonar obstacle detection and can collect plastics, algae, or organic debris from both surface and subsurface layers [15]. Such robots demonstrate how autonomous control can complement passive barriers by targeting areas where currents fail to concentrate debris. However, these designs tend to have limited runtime and small onboard storage, requiring frequent emptying or docking to unload waste.

Several innovative systems exploit fluid dynamics rather than mechanical conveyance to redirect plastics. The Great Bubble Barrier uses a perforated air-tube placed across the riverbed to release fine bubbles that create an upward-flowing curtain, pushing buoyant plastics toward a side collection point [16]. Trials in Amsterdam and Rotterdam have shown removal efficiencies exceeding 85 percent for surface litter without obstructing fish migration.

Another strategy involves vortex separation, where circular or spiral flow fields cause debris to accumulate near the center of a containment chamber. The Vortex Sweep System, described in a 2022 Japanese patent, creates a self-sustaining swirl that concentrates floating plastics into a removable compartment while letting clean water exit radially [17]. Laboratory prototypes have demonstrated high efficiency in separating floating debris with minimal energy input, suggesting potential scalability for stationary lake installations.

Several recent prototypes draw inspiration from natural filtering mechanisms. Engineers at Virginia Tech modeled a manta-ray-inspired filtration array using flexible polymer "gill rakers" that guide particles along a curved channel rather than trapping them directly, preventing clogging and lowering flow resistance [18]. Likewise, whale-mouth skimmers mimic baleen filtration, employing parallel slats to separate plastics of varying buoyancy. At the smaller scale, microfiltration systems modeled after mangrove root networks are being tested to slow water velocity and allow particles to settle out naturally [19]. These passive biomimetic concepts demonstrate efficient separation without active suction or power demand, providing valuable lessons for wildlife-safe design in sensitive lake habitats.

While macroplastic recovery remains the most feasible near-term objective, researchers are developing methods to address sub-millimeter microplastics. Experimental approaches include magnetically assisted filtration, in which iron-oxide-coated particles bond with plastics and are removed via magnetic fields [20], and electrostatic meshes that attract charged fragments using low-voltage fields [21]. Recent work at the University of Toronto demonstrated that fine nanofiber filters can capture particles down to 50 µm with over 90 percent efficiency, though clogging and energy use remain obstacles [22]. Although such systems are currently impractical for open-lake environments, they provide insight into potential hybrid solutions, such as combining coarse surface skimming with fine-mesh filtration modules at inflow points or treatment outlets.

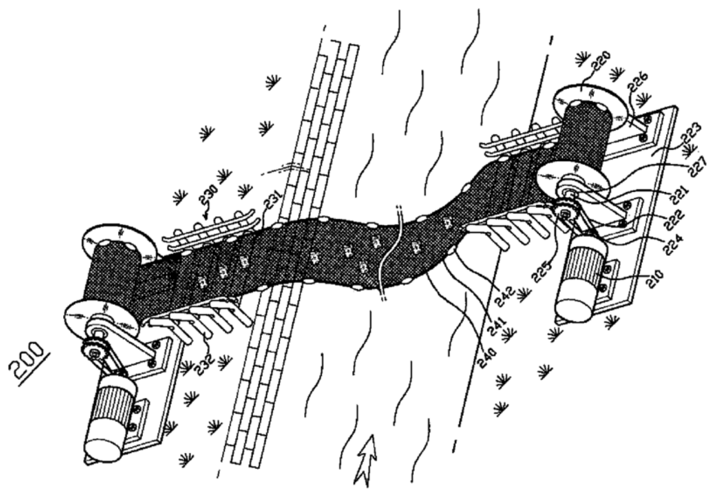

Figure 8. River collection system outlined in WO 2012/074240 A2 (photo credit: Google Patents, 2025).

A review of U.S. and international patent databases reveals steady innovation in modular, mobile, and autonomous water-cleanup systems. U.S. Patent No. 5,439,600 describes a vessel-mounted conveyor mechanism for skimming and lifting floating debris from the water surface into onboard storage bins, forming the basis for many modern skimmer boats [23]. International Patent WO 2012/074240 A2 details a passive, flow-assisted river collector that channels debris into a buoyant capture container without relying on external power [24]. Academic teams in Singapore, India, and the Philippines have developed robotic skimmers that use microcontrollers, GPS, and vision sensors to autonomously navigate and collect litter, including prototypes such as the “Sala Autonomous Trash Skimmer” and the NIT-Surathkal floating waste robot, both designed for real-time path planning and water-quality monitoring [25]. These advances highlight a clear global trend toward sensor-integrated, networked systems that emphasize efficiency, modularity, and operational transparency in aquatic cleanup efforts.

Across these diverse solutions, several themes emerge: the shift toward autonomy and data-driven operation, the exploration of passive flow manipulation to cut energy use and growing attention to modular scalability. Yet gaps remain, especially for mid-scale lake environments like Lady Bird Lake, which require equipment smaller than industrial interceptors but more capable than static nets or skimmers.

Morphological Matrix

After completing the ideation phase, the team constructed a morphological matrix (Appendix I) to systematically combine potential solutions for key subfunctions of the lake cleanup system. The matrix organizes eighteen subfunctions, including guiding flow of plastic, separating debris from water, preventing bycatch, enabling safe passage, retaining and containing debris, modular deployment, communication, and maintenance, and lists a range of mechanisms for each. This method allowed the team to visualize how different solutions could be mixed and matched into cohesive system designs before final concept selection. While early ideation included a subfunction for filtering microplastics, this pathway was excluded from the morphological matrix due to the technical and environmental challenges of implementing fine filtration within a dynamic lake system.

Each row of the matrix represents one subfunction, and each column presents alternative solutions derived from ideation sessions. For example, under Guide Flow of Plastic, options such as arms, funnels, vacuums, fans, paddles, and water socks were explored. Separate Debris from Water included combs, claw grabbers, filters, nets, and mesh; while Prevent Bycatch integrated concepts like motion sensors, cameras, and acoustic deterrents to improve wildlife safety.

Retention and containment mechanisms ranged from lobster traps and servo-actuated closures to latching lids and check valves. Subfunctions related to deployment and handling included floating nets, modular clips, anchor releases, and standardized parts, while communication-focused elements such as posted signs, websites, and QR codes provided ways to share cleanup data with the public.

By combining these options, we could explore dozens of possible design configurations while staying within realistic project constraints. The morphological matrix served as the bridge between creative idea generation and structured evaluation, enabling us to identify promising concept combinations that balanced functionality, maintainability, and ecological safety. The strongest configurations from this matrix were developed into detailed concept variants for further evaluation.

Concept Variants

After constructing the morphological matrix, the team systematically generated full concept variants (Appendix J) by combining solutions from each subfunction row to form cohesive system-level designs. The process began with identifying compatible selections from the matrix, for example, pairing flow-guiding mechanisms (arms, funnels, or fans) with debris separation methods (filters, combs, or claw grabbers) and retention features (lobster traps, dump boxes, or check valves). For each configuration, the team evaluated functional compatibility, feasibility for fabrication within project constraints, and balance between manual and autonomous operation.

This method yielded five primary concepts representing different cleanup strategies and levels of automation:

- Floating Channel: a buoyant passive system using guided surface flow, internal fans, and a one-way filter channel to capture plastics.
- Air Boat: a remote-controlled surface vessel powered by an air fan and equipped with front-mounted combs and wipers for active debris collection.
- Autonomous Clean-Up Drone: a multi-rotor aerial/skimming robot designed to locate and retrieve debris using computer vision and servo-actuated grabbers.
- 3-in-1 Trash Cleaning Tool: a manually operated extendable tool integrating a claw grabber, puncture probe, and retractable net for shoreline crews.
- Creek Crawler: a wheeled, semi-autonomous ground-based rover for clearing debris from shallow or dry creek zones near inflows.

To strengthen the evaluation, the team also documented how each concept achieves the core functions defined in the function tree. For the Floating Channel, debris interception occurs through passive surface flow guided by floating arms, while separation is achieved through an internal sloped filter lane that traps plastics while allowing water to pass. Retention is maintained through a one-way capture chamber that prevents backflow, but mobility is limited since the system must be anchored and cleaned frequently. The Air Boat executes interception by sweeping debris with a front-mounted comb bulldozer mechanism, separates debris by pushing it through vegetation without relying on suction or fine filters, and retains waste by corralling it into accessible areas for extraction. Its elevated fan propulsion also protects wildlife by avoiding submerged intakes and allows crews to reach shoreline pockets that larger boats cannot access.

The Autonomous Drone concept performs interception using downward-facing cameras to identify floating debris, with separation handled by servo-driven claws or nets that grasp individual items. Retention is achieved by carrying debris to a designated container onshore. Although the drone can reach remote locations, it introduces significant technical complexity and wildlife risk due to rotor blades and low-altitude flight. The 3-in-1 Trash Cleaning Tool addresses interception through manual reach extension, separation using a puncture probe or grabber to isolate items, and retention through the retractable net that stores debris until emptied. While simple and inexpensive, it is limited to arm's-reach cleanup and cannot address debris accumulation in deeper or more vegetated zones.

Finally, the Creek Crawler uses a front rake to intercept debris in shallow inflow areas, separating trash by sweeping it into a mesh collection bin as it moves. Retention occurs within this onboard bin, which must be emptied manually. Its wheeled, low-profile design enables access to areas where water levels fluctuate, but its dependence on ground contact restricts use to specific locations rather than open-lake deployment. Across all concepts, these functional mappings ensured that each variant was analyzed not only by its high-level idea but by its ability to perform required engineering functions such as debris interception, safe wildlife interaction, maintainability, mobility, and debris retention.

Each concept was sketched by hand to visualize major components and layout while referencing the chosen morphological combinations circled in the matrix. The team prioritized functional clarity over detailed geometry, ensuring that each concept directly reflected the engineering functions established in the function tree. These sketches now serve as the foundation for comparative evaluation in the upcoming Pugh chart analysis, where performance, maintainability, and ecological impact will be weighed to identify the leading prototype for development.

Pugh Charts

To systematically compare the five proposed designs the team conducted a series of five Pugh charts (Appendix K). In this evaluation method, each concept was treated once as the datum, serving as the baseline against which the other four were judged. This rotating-datum approach reduced bias and helped reveal which designs performed consistently well across multiple comparisons.

Each concept was evaluated according to eleven key criteria derived from our engineering specifications and customer needs:

1. Plastic Removal Effectiveness
2. Wildlife Safety
3. Public Transparency
4. Collection Capacity
5. Ease of Maintenance
6. Ease of Deployment and Relocation
7. Durability and Reliability
8. Noise and Visual Intrusion
9. Cost and Ease of Manufacturing
10. Mobility and Scalability
11. Risk of Technical Development

For each criterion, designs were rated as “+” (better than datum), “0” (about the same), or “–” (worse than datum). The total number of positive and negative marks was then tallied to calculate a Total Sum score for each concept in every chart. By repeating this process with a new datum each time, we identified which concepts consistently ranked high or low across varying baselines.

To ground our evaluation in realistic expectations, the team conducted several quick, back-of-the-envelope analyses (Appendix L) to baseline judgments for specific criteria. For Plastic Removal Effectiveness, simple throughput estimates were made based on expected intake width, capture efficiency, and surface coverage area per pass. Collection Capacity was approximated using containment volume and debris density assumptions. Ease of Maintenance was evaluated by estimating the number of moving parts, frequency of cleaning, and time per maintenance visit. For Cost and Ease of Manufacturing, rough bill-of-materials (BOM) estimates were calculated for each concept using unit pricing for major materials such as HDPE sheet, aluminum framing, fasteners, RC electronics, and sensors. Durability and Reliability considered exposure to environmental loads, material selection, and failure-prone components. Qualitative judgment guided assessments of Noise and Visual Intrusion, with passive systems scoring higher than propeller- or motor-driven ones. Wildlife Safety was also qualitatively assessed based on whether the concept featured enclosed collection zones, low intake velocities, or large mesh openings to prevent entrapment. Finally, Risk of Technical Development reflected how much of the concept depended on novel mechanisms or autonomous control features. This systematic, multi-datum Pugh analysis provided a balanced and transparent method for comparing design performance. Rather than favoring one baseline, it revealed which designs demonstrated robustness across multiple contexts.

The team also examined the patterns behind negative scores to identify whether weaknesses could be mitigated through design changes. For instance, several concepts scored poorly on Ease of Maintenance due to high part counts or complex mechanisms; however, these weaknesses were not easily correctable without fundamentally altering the concept architecture. In contrast, the Air Boat's low score in Noise and Visual Intrusion was considered manageable because future iterations could incorporate quieter motors, shrouded propellers, or visual masking. Negative marks for the 3-in-1 Tool, mainly its limited Collection Capacity, were inherent to its manual nature and could not be overcome without turning it into a different system. This assessment helped distinguish fixable drawbacks from structural limitations, giving more weight to concepts whose weaknesses were practically addressable.

Ultimately, the top two concepts were the Air Boat and the 3-in-1 Trash Cleaning Tool. These two concepts led in robustness for multiple categories and scored relatively better than the other three concepts. In particular, cost is a big consideration for the selection of a concept. The drone and creek crawler would be very costly compared to the other concepts. Furthermore, the question of maintenance of reliability comes up with the floating channel, as it would be very quick to dirty in the lake. This would require frequent maintenance and special consideration in the design of the concept.

The Air Boat was decided over the net gun for our leading concept, as we believe the Air Boat will provide a unique solution to the teams that keep Austin waters clean. The net gun would essentially be a tool for the current teams to use within their current arsenal for individual cleanup crews. This would be convenient and a great help for cleanup operations. However, the Air Boat tackles a problem the net gun cannot solve, and that is remote cleanup from a distance. The Air Boat would allow teams to deploy the boat and relocate plastic to a new location without having to wade through water or move a larger boat into tight areas and heavy vegetation. There is also a large number of possibilities for the innovation of this air boat to improve upon our initial design if the budget permits.

Leading Concept

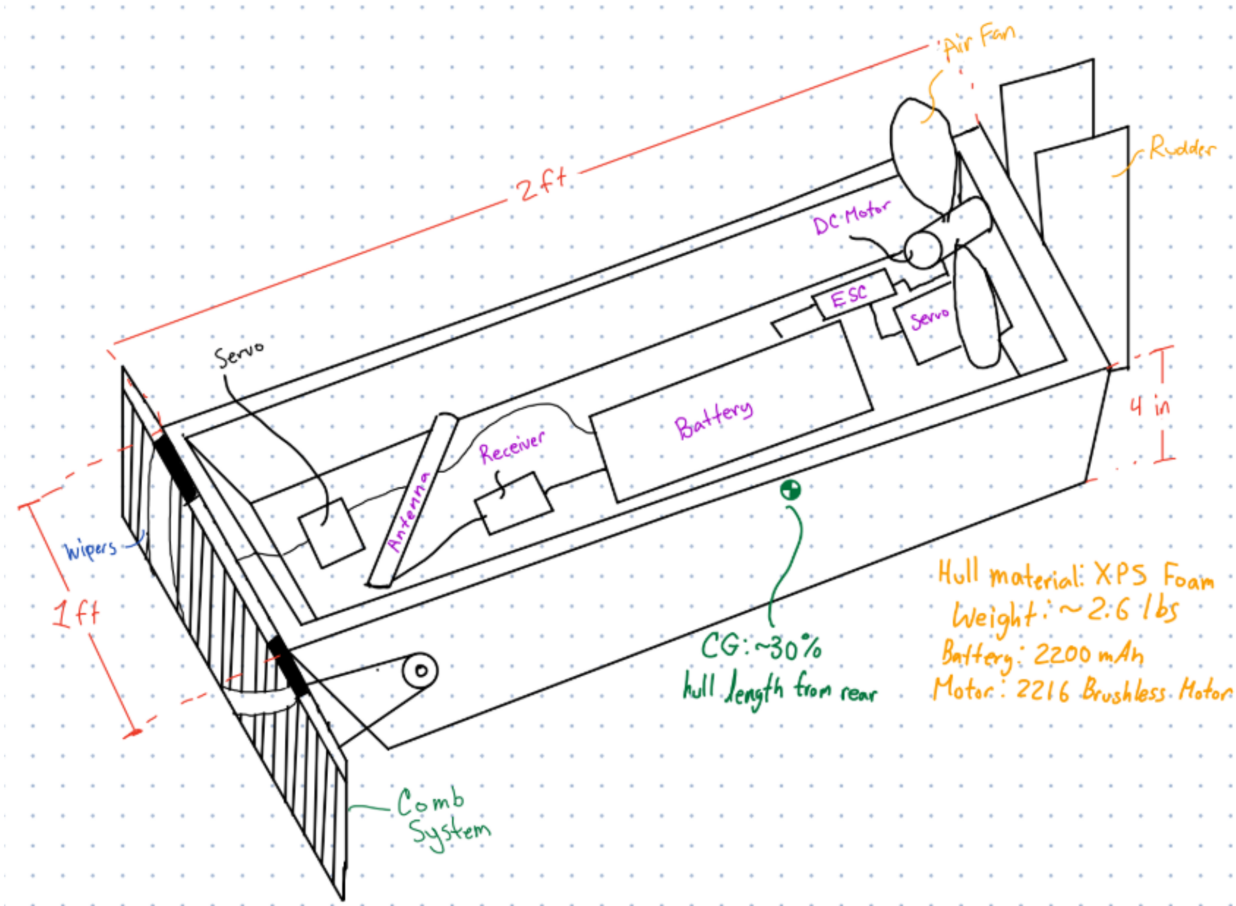

Figure 9. Air Boat Leading Concept Design.

Through the Pugh Chart analysis, it was concluded that the Air Boat design was favored the most across the various criteria compared to other designs. According to the pugh chart, the team believes that the Air Boat is effective at removing plastic from the water, mobile, and easy to deploy and relocate compared to other designs. The Air Boat will aid cleanup crews, such as Keep Austin Beautiful, that clean bodies of water, specifically Lady Bird Lake. It is designed to traverse with ease through water close to the shore that is difficult to reach due to shallow water and vegetation that may ruin cleanup crew boats. The Air Boat is operated through an RC system to avoid the need of an external power supply which may cause complications during operation. The RC system will consist of a power supply, receiver, antenna, electronic speed control, servo(s), DC motor(s), and a remote control or transmitter. The DC motor in the RC system will be attached to a fan system on top of the boat that will induce thrust to propel the boat forward through the water. Rudders attached to a servo will steer the boat. The boat was designed with a propulsion system above water to traverse through vegetation dense water with ease. A comb system is attached to the front of the boat to push surface plastic to an area for the operator to collect with ease. To avoid vegetation entanglement on the comb, the Air Boat has a wiper system to clean any brush during operation.

Some of the limitations of the airboat design are found in the noise created from the propulsion system, and the difficulty in maneuverability. The team is reducing the noise by powering the Air Boat with a battery source instead of an engine. Moreover, maneuverability will be a design limitation that will affect the design. However, if the design depends on a water thrust system, it will be at risk of entanglement from vegetation. Moreover, the boat will contain a hull design compared to a flat bottom hull for higher surface area to optimize stability and higher weight capacity compared to a v hull design that is typically found in speed boat that offers higher speed. These design parameters will reduce the difficulty in maneuverability through vegetation dense shorelines.

A modification to the size of the airboat was made with consideration to the estimated cost of a prototype. As our budget is only $250, our original plan for the size of the airboat would be over this budget by hundreds of dollars. We then decided that a smaller air boat would be more suitable given our monetary constraint. We have decided that the new size of the boat will be 2ft length by 1ft length roughly and still use a wide comb system. This reduction in size will allow us to have a lower material cost and purchase cheaper electronics allowing us to stay under the prototyping budget. Other possible improvements that could be added if the budget permits include cameras for easier sight across far distances and autonomizing the system to automatically locate and relocate plastic.

Gantt Chart and Task List

As previously mentioned, the Gantt Chart and Task List the team follows was created with an emphasis on the approaching deadlines of project milestones separated in monthly sections. This proved effective when project deadlines were pushed 1-2 weeks from the previous deadline. The PDR Report is now due on 11/12 to allow teams more breathing room in creating reports on top of any presentations or assignment deadlines either in or outside the project. This also pushed the deadline for the PDR Peer Evaluation to 11/17. On top of any changes in deadlines, the Task list was updated with more information on specific tasks each member will complete for project assignments. The updated Gantt Chart and Task List can be found in Appendix A and Appendix D respectively.

Chapter 3 – Comprehensive Design Review

Prototyping

To evaluate the feasibility of our Air Boat design, the team developed two low-fidelity prototypes: (1) a comb bulldozer system for debris capture, and (2) a foam-based mini-hull proof-of-concept (PoC) to assess buoyancy, geometry, and overall physical scale. These prototypes allowed us to explore the physical behavior of both the front-end trash collection mechanism and the foundational airboat hull architecture before committing to higher-fidelity fabrication. The following subsections describe the construction approach, methodology, testing environment, and the insights gained from each prototype.

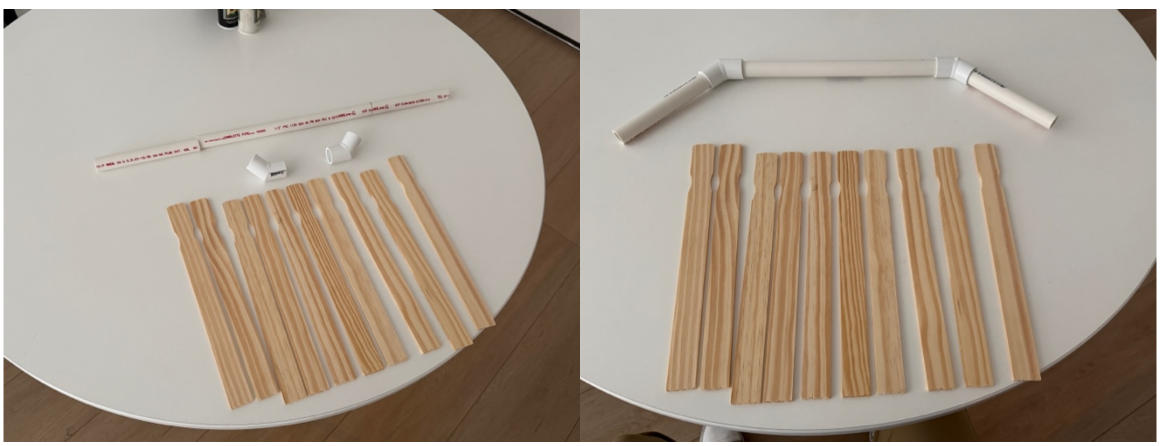

Figure 10. Raw materials for the comb prototype (left) and the assembled PVC support frame (right).

Figure 11. Wooden paint-stick teeth taped in place along the PVC crossbar during initial spacing trials (left) and the secondary angled support members to establish the intended rake geometry (right).

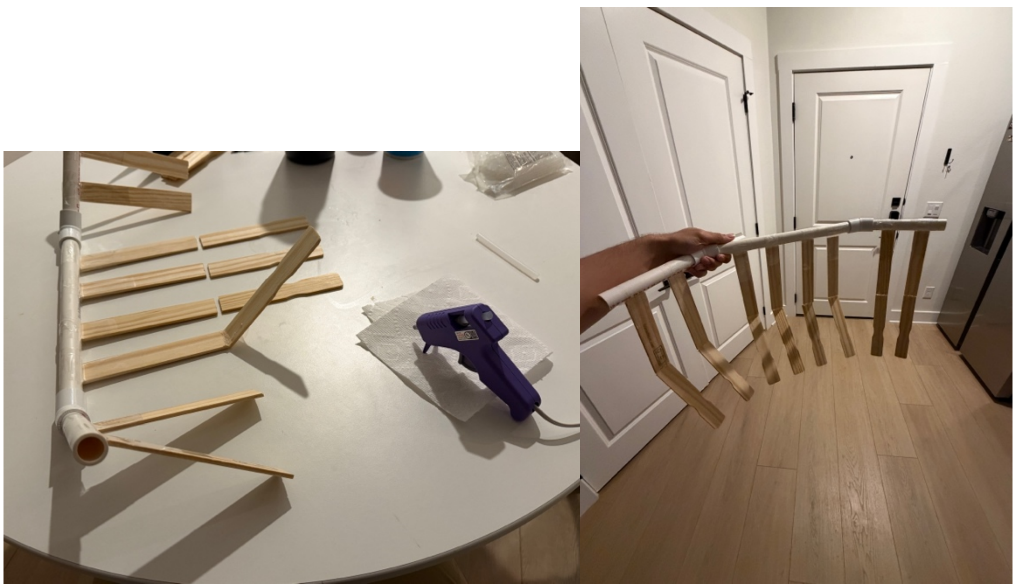

Figure 12. Hot-glued assembly of the angled support members and lower comb elements (left) and completed low-fidelity comb prototype held in operating orientation (right).

The first prototype focused on validating our debris-collection subsystem. We constructed a low-fidelity version using readily available materials: ½-inch diameter PVC pipe, 45° PVC elbow connectors, and wooden paint sticks that served as comb “teeth.” The PVC pipe was cut into a 1-ft center section and two 6-inch angled sections, which were joined together using the 45° elbows to establish the outward-splayed geometry needed for wide surface coverage.

Once the frame was assembled, each paint stick was cut in half to form a set of stiff, narrow comb elements. These were evenly spaced along the top PVC crossbar and secured with tape, allowing us to quickly modify spacing and alignment during testing. A secondary angled support piece was then attached using hot glue to represent the rake-like leading edge that will connect the comb to the airboat hull. This provided the correct angle of attack needed to push floating trash while navigating through vegetation.

The comb prototype was tested in a brushy lake-like environment, using clumps of floating vegetation and standard plastic debris (bottles and wrappers) to simulate Lady Bird Lake shoreline conditions. The comb successfully pushed plastic waste through the artificial vegetation and funneled debris toward a centralized collection path. During extended testing, individual comb teeth began to break off or loosen, indicating that paint-stick stiffness and attachment durability were insufficient for long-term use. This confirmed the need for stronger materials, improved fastening methods, and potentially a flexible-but-tough plastic in the final design.

Overall, this prototype validated the geometric effectiveness of the comb system, demonstrated the required stiffness and spacing ranges for debris capture, and revealed important failure modes—including tooth fatigue and detachment—that we later addressed in our FMEA analysis and CAD revisions.

To evaluate buoyancy, stability, and general hull geometry, the team built a small-scale foam airboat hull proof-of-concept using inexpensive materials: pink insulation foam, a plastic water-bottle sprayer (repurposed for its integrated fan), hot glue, heavy-duty packing tape, and a hand saw.

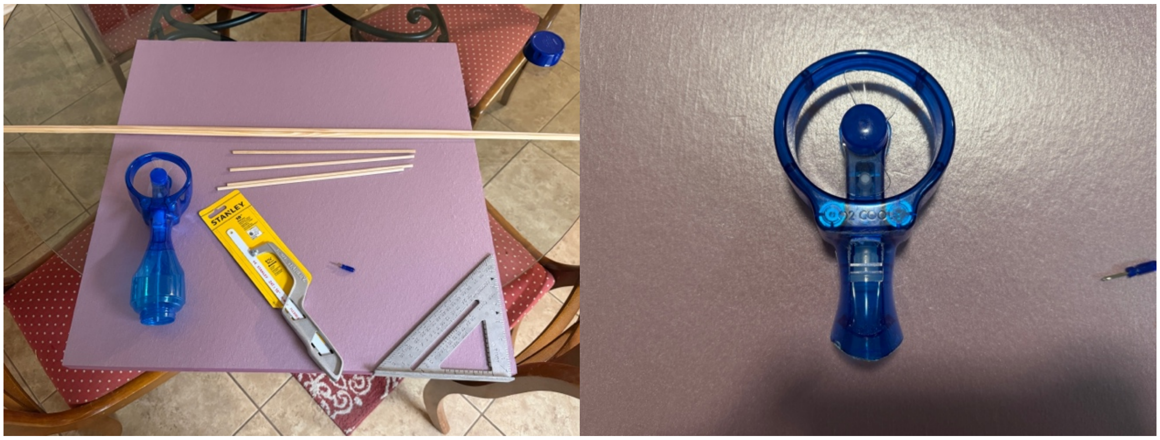

Figure 13. Raw materials for the foam hull proof-of-concept, including insulation foam, handheld fan sprayer, and cutting tools (left), and close-up view of the fan sprayer after modification (right).

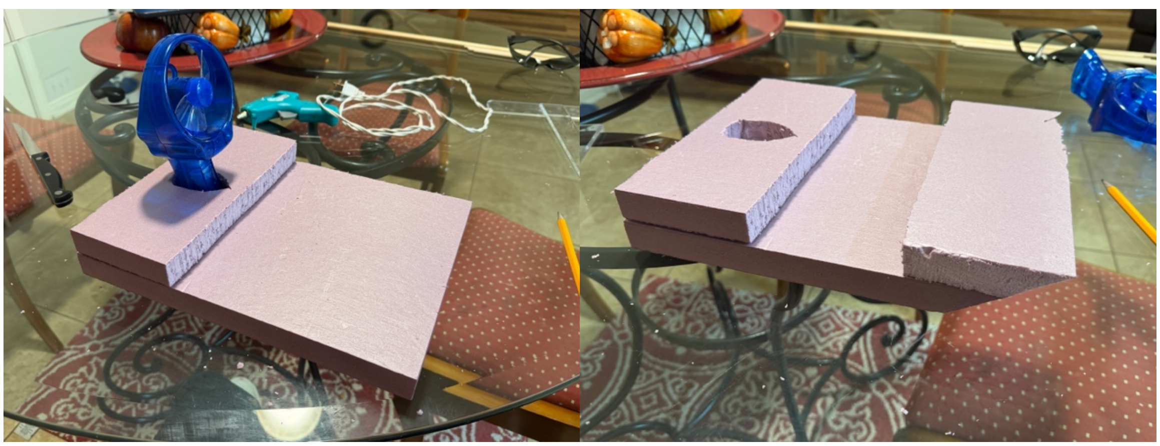

Figure 14. Initial assembly of the foam hull prototype with the rear fan mount inserted into the cut housing (left) and carved foam deck sections showing the rear mount opening and beveled front geometry (right).

Figure 15. Completed low-fidelity foam hull proof-of-concept featuring the mounted fan sprayer and stepped deck geometry (left) and rear-facing view of the assembled prototype showing fan alignment and hull profile (right).

The sprayer bottle's water reservoir was first removed and sanded flush so that the remaining fan housing could be mounted cleanly against the foam structure. The primary hull body began as a 9 × 12-inch sheet of insulation foam to serve as the base. Two additional 9 × 4-inch foam sections were cut and hot-glued onto the front and rear of the main piece to create the raised deck profile characteristic of an airboat. A precisely measured opening was then cut into the rear deck so that the handheld fan could be seated upright and securely glued into place. On the front end, we beveled the foam at an angle to emulate the sloped bow geometry planned for the full-scale boat, reducing frontal drag and improving the boat's ability to glide over shallow water or surface debris. Finally, heavy-duty moving tape was applied to seal the underside, particularly along raw foam edges, to improve water resistance and structural integrity during testing.

This prototype was tested in a bathtub environment to evaluate buoyancy and dynamic stability. The hull floated reliably under static conditions and maintained stability even when manually rocked side-to-side and front-to-back. These results confirmed that the chosen geometry provides sufficient displacement and that a foam-based or HDPE-based construction would be viable at full scale. While this PoC model did not include a steering subsystem, the objective was strictly to validate floating behavior, weight support, and general form factor—which it successfully achieved.

Collectively, the two prototypes provided early physical validation of both major subsystems of the Air Boat. The comb prototype confirmed that a rigid, angled debris-pushing mechanism can navigate through vegetation and reliably direct floating trash, while also revealing structural vulnerabilities that shaped materials and attachment choices in the CAD model. The mini-hull prototype demonstrated that our planned hull geometry is buoyant and stable, supporting the fan mass and resisting pitch under small disturbances. It also verified that the raised deck and sloped bow are appropriate for an airboat form factor.

The insights gained from these prototypes directly influenced design updates in the CDR stage, including:

- reinforcing comb elements and revising tooth geometry,
- adjusting mounting points to improve front-rear weight distribution,
- modifying the hull width for greater lateral stability, and
- refining the propulsion mount height for proper airflow alignment.

These results provide confidence that our concept is physically feasible and ready for progression into medium-fidelity prototyping and CAD-driven fabrication next semester.

Failure/Risk Analysis

To ensure that the final concept we chose, the air boat, can be an effective and dependable device in real lake environments, we conducted a comprehensive Failure Modes and Effect Analysis (FMEA). This process allowed us to evaluate where the design is the most vulnerable and calculate a numerical risk associated with each potential failure mode. The comprehensive FMEA can be seen in Appendix M. We established our three primary areas of concern: vegetation jams in the comb mechanism, flooding of onboard electronics, and signal loss affecting control and communication. Each of these failure modes were labeled as having the highest initial Risk Priority Number (RPN), indicating a need for engineering improvements to lower this RPN and ensure safety.

For the comb subsystem, jamming was a major threat to the available functions of the device, for the thick vegetation and debris is something very apparent in Lady Bird Lake and is a large stalling block for the air boat. We decided to modify the geometry of the comb and incorporate angled features and potentially a wiper system to reduce the probability of this failure mode. These modifications lowered the risk probability to low and changed the RPN from 252 to 84.

		Risk Severity			
		Negligible	Marginal	Critical	Catastrophic
Risk Probability	Certain	High	High	Extreme	Extreme
	Likely	Moderate	High	High	Extreme
	Possible	Low	Moderate	High	Extreme
	Unlikely	Low	Low	Moderate	Extreme
	Rare	Low	Low	Moderate	High

Figure 16. Risk Matrix for vegetation jam in comb system. Risk probability dropped from High to Low.

Similarly, electronics flooding was identified as a critical risk due to the air boat's low profile, frequent exposure to splashing, and our limited budget for replacements. Sealing the ESC, receiver, and battery in a waterproof enclosure lowered the risk probability to moderate and brought the RPN down from 180 to 54.

		Risk Severity			
		Negligible	Marginal	Critical	Catastrophic
Risk Probability	Certain	High	High	Extreme	Extreme
	Likely	Moderate	High	High	Extreme
	Possible	Low	Moderate	High	Extreme
	Unlikely	Low	Low	Moderate	Extreme
	Rare	Low	Low	Moderate	High

Figure 17. Risk Matrix for electronics flooding. Risk probability dropped from High to Moderate.

Lastly, signal loss was addressed by implementing a communication failsafe and raising the antenna to a more optimal position, lowering the risk probability to low and the RPN from 240 to 96.

		Risk Severity			
		Negligible	Marginal	Critical	Catastrophic
Risk Probability	Certain	High	High	Extreme	Extreme
	Likely	Moderate	High	High	Extreme
	Possible	Low	Moderate	High	Extreme
	Unlikely	Low	Low	Moderate	Extreme
	Rare	Low	Low	Moderate	High

Figure 18. Risk Matrix for signal loss. Risk probability dropped from High to Low.

These improvements and risk analysis allowed us to modify our design, resulting in a more robust and field-ready system. By mitigating severe failure modes, the air boat now offers higher operational reliability and will reduce unexpected downtime in the future manufacturing process. Ultimately, the FMEA ensured the air boat can operate safely and consistently in dynamic lake environments, aligning with our goal of creating an effective plastic removal device for Central Texas lakes.

Design for Manufacturing

To ensure the air boat could be produced consistently and within the project's budget constraints, the team applied several core DFM heuristics. The priority was minimizing manufacturing complexity, following the common guideline to "avoid unnecessary part features and reduce the number of machining operations." [26] The hull was designed around flat-stock XPS foam sheets, enabling the entire geometry to be produced using simple 2D cuts. This aligns with the heuristic of using off-the-shelf stock sizes to reduce material waste and allowed us to avoid complex molds or multistep forming processes. An epoxy surface coat was selected because it bonds well to foam and requires no specialized equipment beyond brushes and mixing containers.

The comb subsystem was re-designed using the DFM principle of standardizing part geometries. Instead of individually shaped tines, we reduced the design to a small number of repeated laser-cut panels. This decision reflects the heuristic to minimize part variety, a change that lowers fabrication time, simplifies inspection, and ensures that replacements can be produced quickly with consistent tolerances. Additionally, laser cutting supports fast iteration and is cost-effective for low-volume production. A further DFM focus was reducing fastener diversity, based on the guideline to "minimize the number of distinct fastening methods." [26] By using the same bolt type across the comb mount, hull reinforcements, and electronic enclosure, we eliminated the need for multiple tool sizes, simplified the bill of materials, and reduced the likelihood of assembly errors in the field.

Material selection also reflected DFM considerations. XPS foam, plywood, and PVC were chosen because they are easily machinable, widely available, and inexpensive. These materials allow the system to be manufactured in academic shops or local makerspaces without specialized tooling, supporting the goal of scalable and accessible production for community cleanup organizations.

Design for Assembly

Complementing DFM, the team applied Design for Assembly heuristics to reduce assembly time, improve reliability, and ensure that the device can be maintained by users with minimal training. A major DFA principle used was reducing part count, which directly decreases assembly steps and failure modes. The hull was simplified into stacked foam layers, reducing the number of frame components, while the comb structure was redesigned into modular panels that attach as a single unit rather than many individually placed tines. We also implemented the DFA guideline of ensuring top-down assembly whenever possible. All major assemblies, including the propulsion module, electronics enclosure, and comb attachment, can be installed from above without flipping the boat or accessing hidden surfaces. This supports faster servicing and aligns with the heuristic to "avoid operations that require reorientation." [26]

To prevent misalignment and reduce the need for measurement during assembly, we incorporated self-locating features such as slotted interfaces for the comb panels and press-fit recesses for rudders and the antenna. These choices follow the principle to "design parts so they cannot be assembled incorrectly," [26] reducing assembly error rates and making the boat field serviceable. Fasteners were minimized following DFA best practices such as use snap-fits or press-fits where reasonable and minimize total number of fasteners. Where fasteners were still necessary, we consolidated around a single bolt size to decrease tool changes and assembly complexity. The resulting system can be assembled and disassembled quickly using simple tools, making the boat easier to repair after debris entanglement or wear.

By applying these DFA principles, the team ensured that the air boat design supports rapid, intuitive, and reliable assembly, a critical factor for volunteer-based lake cleanup operations that must operate in unpredictable field environments.

Design Updates

The first iteration of our CAD design was a rough assembly to create a 3D visual model of our sketch design(s) and to show the positions of RC components throughout the Airboat. This CAD model was used for the team when presenting CAD and prototype model(s) to faculty and professionals. The team received feedback about the design and discussed if the Airboat meets the engineering specifications to conduct a solution to current Lady Bird Lake plastic pollution. The team also used the first version to conduct an FMEA and DFMA analysis. This led to the creation of a second version of CAD of the Airboat which meet specifications and resolved any concerns that may have come to our attention based on feedback, FMEA, and DFMA analysis.

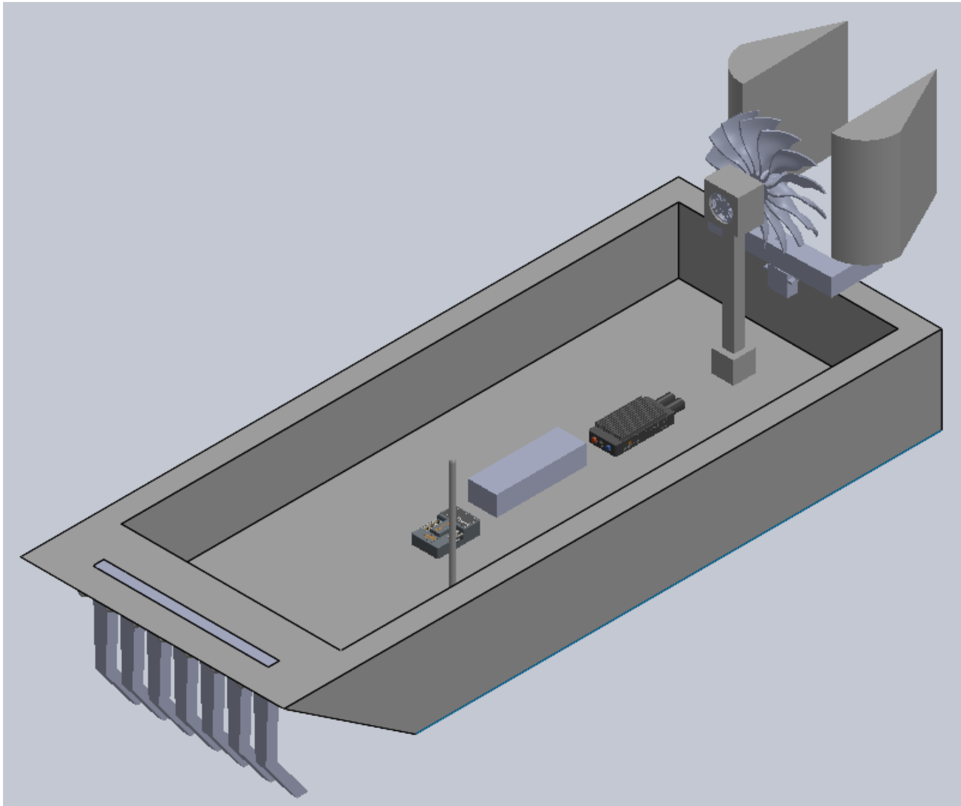

Figure 19. CAD Version 1 of the Airboat

The second version of the Airboat was designed to create a functional Airboat that will meet our engineering specifications and the needs of the Lady Bird Lake clean-up crew. In the second version, the rake design was changed along with the hull of the boat. These updates changed the attachment method of the rake to the Airboat which should be easier to assemble. Any other design discrepancies determined from the first CAD version were also fixed as needed. One example of this are the bolts attaching the rake since the design required shorter bolts. There were still some design issues that were determined by the team, leading to the creation of a third and final Airboat CAD design.

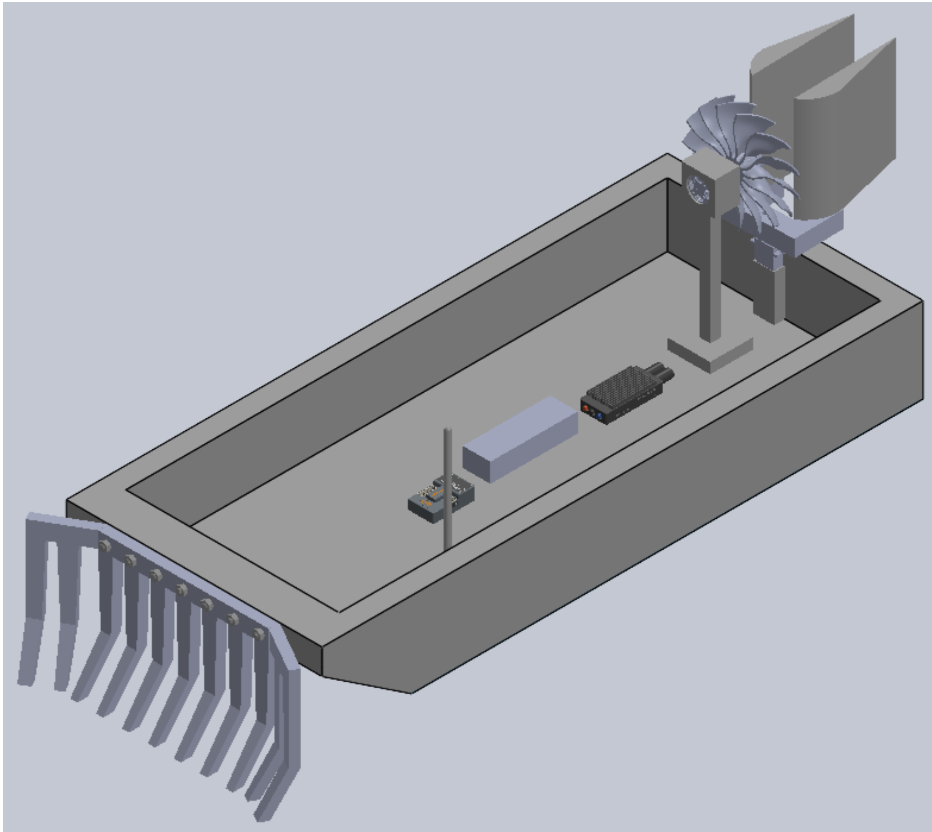

Figure 20. CAD Version 2 of the Airboat

The final design of the Airboat considered the manufacturing and assembly process of the hull. The CAD also now contains various press fit mating methods for the rudders and antenna. In addition, the hull dimensions were fixed to meet the 2 ft by 1 ft footprint. Lastly, the rake was inverted in the second version, which needed to be fixed for operating purposes along with decreasing the number of bolts from 7 to 3 and adding aluminum plates to clamp the rake to the hull of the boat. The change in bolts will positively influence assembly and also decrease the cost. However, the aluminum plates will increase the cost by about $4.00 if the team needs to buy them instead of recycling or reusing scrap, but it will have a positive impact for assembly and operation. These changes to the design helped to create drawings of the Airboat to convey the final design parameters and bill of materials clearly for someone to manufacture and assemble without any other form of guidance regarding the design.

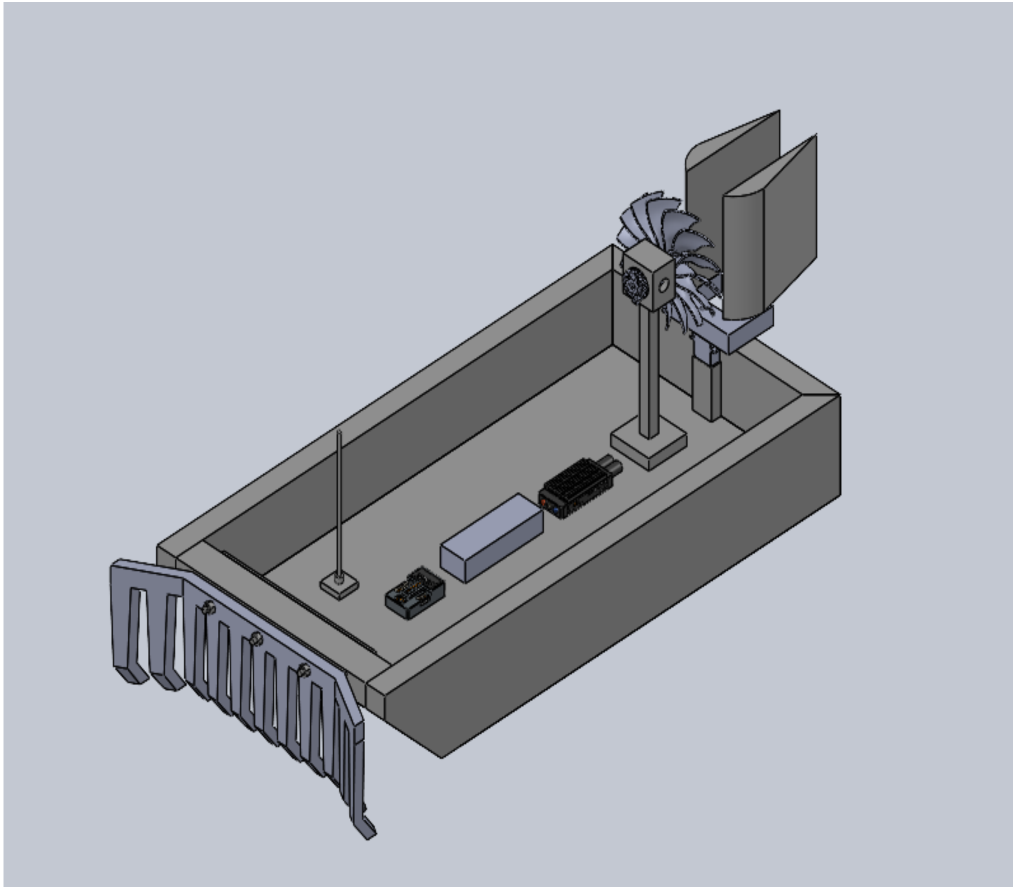
Figure 21. Third and Final CAD version of the Airboat

Final Design

The final design of our air boat system shows a balance between performance, reliability, and maintainability in real lake environments. A defining feature of this concept is the placement of the thrust and rudder system to be entirely above the waterline. This reduces the risk of entanglements with vegetation, a severe failure mode that we established in our FMEA. By relying on an air propulsion system, the boat can easily navigate through areas with dense plant growth and floating debris while maintaining directional control.

Another core advantage of the final design is its modularity, a capability emphasized in our function tree and validated through our concept development process. Major components of the air boat, such as the comb assembly, electronics enclosure, and propulsion module, are interchangeable and can be removed or replaced with minimal tools. This reduces downtime during field operations and enables rapid adjustments based on daily lake conditions.

In addition to its subsystem modularity, the air boat itself functions as a modular cleanup asset. Because it is lightweight, compact, and easily transportable, cleanup crews can deploy it wherever it is most needed along the lake. This operational flexibility allows the system to reach new problem areas, relocate debris between inaccessible zones, and support iterative cleanup campaigns without requiring large vessels or permanent installations. Together, these layers of modularity create a platform that is not only maintainable and upgradeable, but also adaptable to the dynamic environments of Austin's waterways.

The rake-style comb at the front of the boat is a key debris-collection mechanism that is designed to funnel floating plastics toward the hull while navigating through thick vegetation. While the comb may require manual cleaning or an additional wiper system, its simplified geometry and easy access ensure that maintenance demands remain low. Finally, the CAD model is intentionally flexible to leave room for future design iterations. Together, these elements create a robust and adaptable layout that we can rely on to support plastic removal across lake environments.

Engineering drawings for the final air boat assembly, along with all custom-manufactured components, are provided on the following pages and in Appendix N. The complete assembly plan and the project's bill of materials and budget are presented in Appendices O and P, respectively.

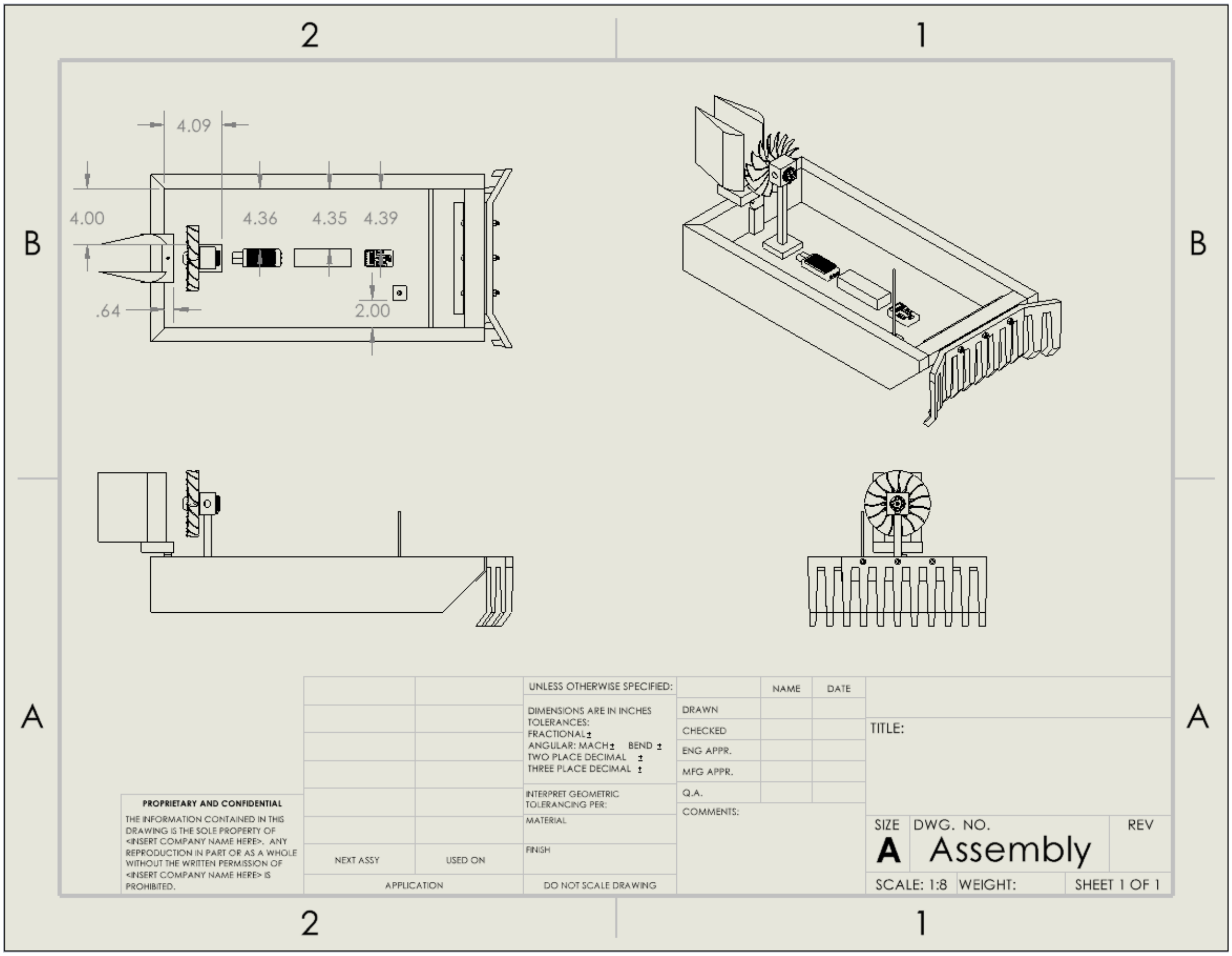

Figure 22. Drawing of Airboat Assembly

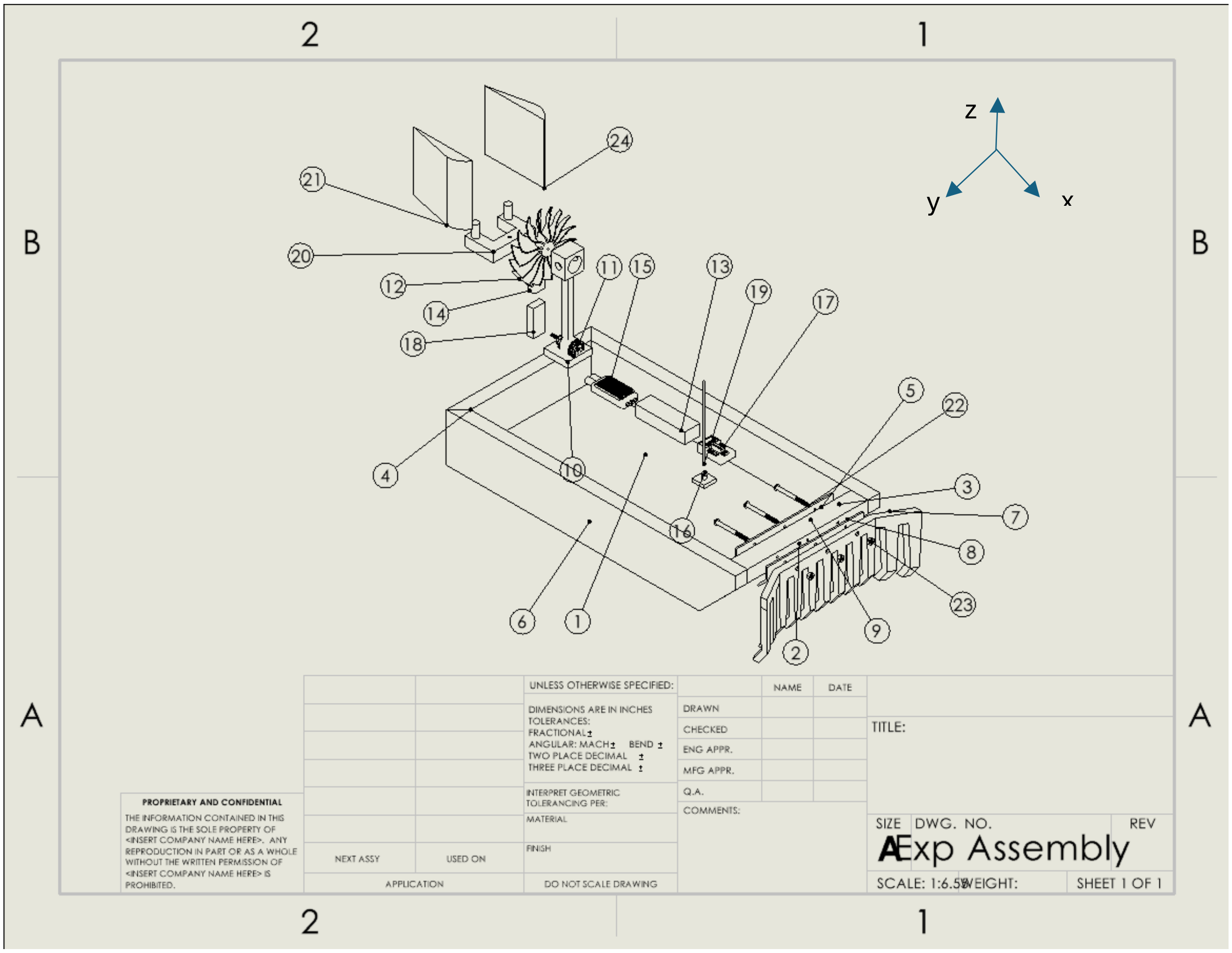

Figure 23. Explosive View of Airboat Assembly

Updated Gantt Chart and Task List

The team has decided to keep the same Gantt Chart and Task List format throughout the project due to the emphasis it creates on the approaching deadlines of project milestones as it is separated in monthly sections. It has been effective as project deadlines were pushed 1-2 weeks. The CDR Report is due on 12/08 along with any other final assignments for the course. The Task list was also updated with more information on specific tasks each member will complete for the CDR. A new Gantt Chart and Task list will be created for the upcoming semester which will focus on manufacturing and testing of the Airboat. The updated Gantt Chart and Task List can be found in Appendix A and Appendix D respectively.

Conclusion

Throughout the semester, our team progressed from an initial exploration of the plastics problem in Central Texas lakes to a fully justified and manufacturable design for an airboat-based debris collection tool. Using structured design methodology, which includes customer needs analysis, functional decomposition, ideation, morphological mapping, Pugh chart evaluation, FMEA, DFMA, and iterative prototyping, we developed and refined a solution that aligns with the environmental, operational, and practical constraints of real lake-cleanup operations.

Early research and stakeholder interviews established the need for a nimble, surface-level tool capable of reaching dense vegetation pockets where existing cleanup boats cannot operate. Over the semester, our concept matured from sketches to prototypes and ultimately to a CAD-driven design that integrates debris-collection geometry, above-water propulsion, and modular subsystems. The two physical prototypes validated key assumptions: the comb can guide debris effectively through vegetation, and the foam-based hull form provides the required buoyancy and stability. These insights directly informed revisions to the geometry, fasteners, and overall assembly strategy.

Feedback from our CDR presentation also guided meaningful refinements. We will adopt a receiver and controller from Dr. Rylander to improve reliability and reduce cost. We also responded to feedback about over-fastening by reducing the number of bolts and simplifying the fastener scheme, reflecting our DFMA goal of minimizing assembly complexity and ensuring that the system remains durable, maintainable, and user-friendly.

Moving into the next phase, the team will focus on manufacturing and testing the system to ensure that it functions as intended and to evaluate performance through hands-on iteration. Planned efforts include constructing a medium-fidelity prototype using epoxy-coated XPS foam, validating thrust and steering performance, testing waterproof electronics enclosures, and refining the comb geometry to prevent jamming under realistic vegetation loads. If the budget permits, we may also explore optional enhancements such as an onboard camera or improved stability features.

Ultimately, our goal is to deliver a practical, durable, and user-friendly tool that measurably reduces plastic waste in Central Texas lakes. This semester established a strong conceptual and technical foundation, and as we transition from design to fabrication, we aim to transform our research and engineering work into a tangible environmental impact that supports the long-term health and sustainability of Austin's waterways.

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Appendix A

Gantt Chart

Figure A.1

Clean Lake

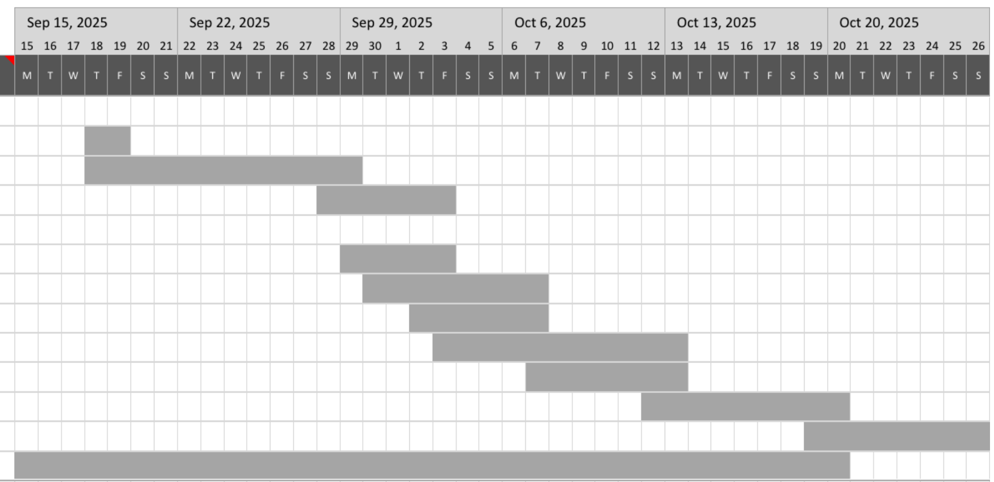
Lake Guardians

Project Start: Thu, 9/18/2025

Today: Wed, 11/12/2025

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS
September					
Faculty Advisor Meeting	All	100%	9/18/25	9/19/25	2
Team Contract	All	100%	9/18/25	9/29/25	12
Draft Interview Questions	Alexander, Christopher	100%	9/28/25	10/3/25	
October					
Field Interviews	All	100%	9/29/25	10/3/25	5
GANTT/Task List	All	100%	9/30/25	10/7/25	8
Proposal Presentation	All	100%	10/2/25	10/7/25	6
House of Quality	All	100%	10/3/25	10/13/25	11
Proposal Report	All	100%	10/7/25	10/13/25	7
Proposal Peer Evaluation	All	100%	10/12/25	10/20/25	
PDR Presentation	All	100%	10/19/25	11/4/25	
Notebook Submission #2	All	100%	9/15/25	10/20/25	



Appendix A

Gantt Chart

Figure A.2

Clean Lake

Lake Guardians

Project Start: Thu, 9/18/2025

Today: Mon, 12/8/2025

Display Week: 1

Nov 3, 2025 | Nov 10, 2025 | Nov 17, 2025 | Nov 24, 2025 | Dec 1, 2025

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS
November					
PDR Report	All	100%	10/27/25	11/12/25	17
PDR Peer Evaluation	All	100%	11/11/25	11/17/25	7
Prototype Check-in	All	100%	11/16/25	11/20/25	5
Notebook Submission #3	All	100%	10/20/25	11/17/25	28
December					
Final Presentation Submission	All	100%	11/17/25	12/2/25	16
Final Prototype Showcase	All	100%	12/1/25	12/2/25	2
Comprehensive Design Review Report	All	100%	12/1/25	12/8/25	
CDR Peer Evaluation	All	100%	12/7/25	12/8/25	
Notebook Submission #4	All	100%	11/17/25	12/8/25	
-	-	-	-	-	-

Appendix B

Customer Needs Worksheets

Figure B.1

Project/Product Name: Clean Lake Customer: Danielle Z, Cornel O Contact Information: drz286@my.utexas.edu; cornelo@jsg.utexas.edu Type of User: Expert stakeholder/research partner		Interviewer(s): Ethan Salazar, Christopher Rodriquez, Sarah Wu Date: 9/26 Currently Uses: N/A	
Topic	**Customer Statement**	**Interpreted Need**	**Importance**
Where to start / hotspots	"Downtown by I-35 keeps testing the worst…if you were to test or deploy somewhere I would start there"	Operate effectively in areas with high use Target hotspots first.	4
Source and size	"Most of what we are finding looks like tire/asphalt wear…less bottles, more fine fragments" "Fibers are tricky, how will you tell plastic fibers from natual ones quickly?"	Device should capture very small fragments such as tire wear particles Include a method to differentiate plastic fibers from natural debris	5 4
Cleanup process	"If you stir the bed or floor you'll just remix the problem... capture in the water column, don't resuspend sediments" "If your cleanup basket … fills and sits for days the wind will blow half of it back out"	Device should collect plastics in the water column without disturbing bottom sediments. Device should allow timely servicing before overflow. Device should have overflow protection to prevent re-release of captured debris.	3 3
Evidence and monitoring	"You'll have to compare before and after's at the same spots"	The system's performance should be measurable through repeat sampling at fixed sites. Device deployment should support pre/post-cleanup data collection.	4

Appendix B
Customer Needs Worksheets

Figure B.2

Project/Product Name: Clean Lake Customer: Public Lake Users (11-15 people) Contact Information: N/A random Type of User: General public		Interviewer(s): Christopher Rodriquez, Derek Morales Date: 10/1 Currently Uses: N/A	
Topic	**Customer Statement**	**Interpreted Need**	**Importance**
Visible litter	"There's a lot of trash along the shore…kinda ruins the view. If you fix one thing, clean that up." "Right after rain, there's always more junk floating by the bridges."	The shoreline should appear free of visible plastic and trash. The system should capture debris flushed in by stormwater surges.	5 3
Safety/pets and wildlife	"I don't let my dog near the water…heard about nasty stuff. Also worried about turtles." "Whatever you install, make sure animals can swim around it."	Reduce visible plastic pollution that may harm pets or wildlife. Device should allow safe passage for wildlife and not obstruct movement.	3 4
Awareness	"I didn't know about microplastics…signs or something that show what's being cleaned would help." "Put a tag or something that says 'plastic cleaner' so people don't mess with it."	Provide clear on-site communication (simple signage with what's removed and progress). Device should be clearly labeled to indicate its purpose and discourage tampering.	1 4
Acceptance/Visual	"A giant machine would be ugly…small or temporary setups are fine if they actually clean."	Maintain a low visual profile and small footprint in public areas. Allow for temporary or modular installations that can be moved as needed.	2

Appendix C

Customer Requirements to Address

	Customer Requirement	Weight
I.	**Visible Plastics**	
	A. Shorelines appear free of plastics	3
	B. Near-surface water looks clear of plastics	4
	C. Hotspots do not accumulate visible plastics	5
II.	**Microplastics and Sources**	
	A. Water contains minimal microplastics	5
	B. System captures small floating and suspended plastics before they settle	4
	C. Device collects debris without disturbing bottom sediments	3
III.	**Wildlife and Pets**	
	A. Lake conditions do not endanger pets due to plastics	4
	B. Device does not trap or injure wildlife	5
	C. Device allows safe passage for fish, turtles, and birds	3
IV.	**Experience and Perception**	
	A. People feel comfortable recreating on water without seeing plastic	4
	B. Device labeling clearly indicates its purpose to the public	3
	C. Device has a low profile and minimal noise in public areas	3
V.	**Awareness and Transparency**	
	A. Public can easily see or access information on cleanup progress	3
	B. Device includes simple on-site communication or labeling	2
	C. Plastic status and cleanup results are publicly verifiable	2
VI.	**Persistence and Practicality**	
	A. Captured plastics remain contained until collection	5
	B. System can be deployed modularly at inflows and moved as hotspots shift	3
	C. Maintenance and servicing are simple for city crews or volunteers	4
VII	**Event Resistance**	
	A. Performance holds during storms and high flows	5
	B. Captured plastics stay contained under extreme conditions	4
	C. Safe fail and rapid recovery after extreme events	3

Appendix D

Task List

Figure D.1

#	TASK	ASSIGNED TO	PROGRESS	START	END
	September				
1.1	Faculty Advisor Meeting	All	100%	9/18/25	9/19/25
1.2	Team Contract	All	100%	9/18/25	9/29/25
1.3	Assign Tasks & Roles	All	100%	9/18/25	9/29/25
1.4	Establish meeting times	All	100%	9/18/25	9/29/25
1.3	Draft Interview Questions	Alexander, Christopher	100%	9/28/25	10/3/25
	October				
2.1	Field Interviews	All	100%	9/29/25	10/3/25
2.1.1	Interview Stakeholders: UT	All	100%	9/29/25	10/3/25
2.1.2	Interview Stakeholders: Austin	Derek, Christopher	100%	9/29/25	10/3/25
2.1.3	Interview Customers: LBL Pedestrians	Christopher Derek	100%	9/29/25	10/3/25
2.1.4	Organize Customer Needs	Ethan, Derek	100%	9/29/25	10/3/25
2.2	GANTT/Task List	Alexander, Christopher, Ethan	100%	9/30/25	10/7/25
2.3	Proposal Presentation	All	100%	10/2/25	10/7/25
2.3.1	Structure and Assign Proposal tasks	Ethan	100%	10/2/25	10/7/25
2.4	House of Quality	All	100%	10/3/25	10/13/25
2.4.1	Structure and Document HOQ	Ethan	100%	10/3/25	10/13/25
2.4.2	Analyze and measure HOQ	Ethan	100%	10/3/25	10/13/25
2.5	Proposal Report	All	100%	10/7/25	10/13/25
2.5.1	Introduction & Conclusion	Sarah	100%	10/7/25	10/13/25
2.5.2	Background Research	Ethan	100%	10/7/25	10/13/25
2.5.3	Customer Needs	Ethan, Derek, Alex, Sarah	100%	10/7/25	10/13/25
2.5.4	HOQ	Ethan, Sarah	100%	10/7/25	10/13/25
2.5.5	Problem Statement	Sarah	100%	10/7/25	10/13/25
2.5.6	Gantt & Task List	Alexander, Christophter	100%	10/7/25	10/13/25
2.5.7	Engineering requirements	Derek	100%	10/7/25	10/13/25
2.5.8	Writing and Structure	All	100%	10/7/25	10/13/25
2.6	Proposal Peer Evaluation	All	100%	10/12/25	10/20/25

Appendix D
Task List

Figure D.2

2.7	PDR Presentation	All	100%	10/19/25	11/4/25
2.7.1	Function Tree	Sarah	100%	10/19/25	10/23/25
2.7.2	Idea Generation Techniques	All	100%	10/21/25	10/28/25
2.7.3	Search Prior Work	Ethan	100%	10/19/25	10/30/25
2.7.4	Morphological Matrix	Derek	100%	10/21/25	10/28/25
2.7.5	Sketches of 3-5 "Final" Concept Variants	All	100%	10/30/25	11/4/25
2.7.6	Update Gantt Chart and Task lists	Alex, Christopher	100%	10/12/25	11/4/25
2.8	Notebook Submission #2	All	100%	9/15/25	10/20/25
	November				
3.1	PDR Report	All	100%	10/27/25	11/12/25
3.1.1	Pugh Chart	All	100%	11/10/25	11/12/25
3.1.2	Back-of-the-Envelope Calculations	Derek, Christopher	100%	11/11/25	11/12/25
3.1.3	Leading Concept Selection + Justification	All	100%	11/11/25	11/12/25
3.1.4	Formatting	Alex	100%	11/12/25	11/12/25
3.2	PDR Peer Evaluation	All	100%	11/12/25	11/17/25
3.3	Prototype Check-in	All	100%	11/16/25	11/20/25
3.3.1	CAD Designs	Christopher, Derek	100%	11/12/25	11/18/25
3.3.2	CAD Drawings & Formatting	All	100%	11/17/25	11/18/25
3.4	Notebook Submission #3	All	100%	10/20/25	11/17/25

Appendix D

Task List

Figure D.3

	December				
4.1	Final Presentation Submission	All	100%	11/17/25	12/2/25
4.1.1	Background and Motivation	Ethan	100%	11/17/25	12/2/25
4.1.2	Customer Needs and Specifications	Alex	100%	11/17/25	12/2/25
4.1.3	Functional Decomposition	Sarah	100%	11/17/25	12/2/25
4.1.4	Concept Generation and Selection	Derek	100%	11/17/25	12/2/25
4.1.5	Final Concept and Prototyping	Chris, Ethan	100%	11/17/25	12/2/25
4.1.6	Future Work	Chris	100%	11/17/25	12/2/25
4.1.7	Organization and Editing	All	100%	11/17/25	12/2/25
4.2	Final Prototype Showcase	All	100%	12/1/25	12/2/25
4.3	Comprehensive Design Review Report	All	100%	12/1/25	12/8/25
4.3.1	Failure Risk Analysis	Alex	100%	12/2/25	12/8/25
4.3.2	Design for X	Alex	100%	12/2/25	12/8/25
4.3.3	Prototyping	Ethan	100%	11/17/25	12/8/25
4.3.4	Design Updates	Chris	100%	11/17/25	12/8/25
4.3.5	Final Design	All	100%	11/28/25	12/8/25
4.3.6	Update Gantt, PDR, misc.	All	100%	12/2/25	12/8/25
4.3.7	CAD Drawings	Derek	100%	12/2/25	12/8/25
4.3.7	Formatting	Sarah	100%	12/2/25	12/8/25
4.3.8	Organization and Editing	All	100%	12/2/25	12/8/25
4.4	CDR Peer Evaluation	All	100%	12/7/25	12/8/25
3.5	Notebook Submission #4	All	100%	11/10/25	12/8/25

Appendix E

Engineering Specifications

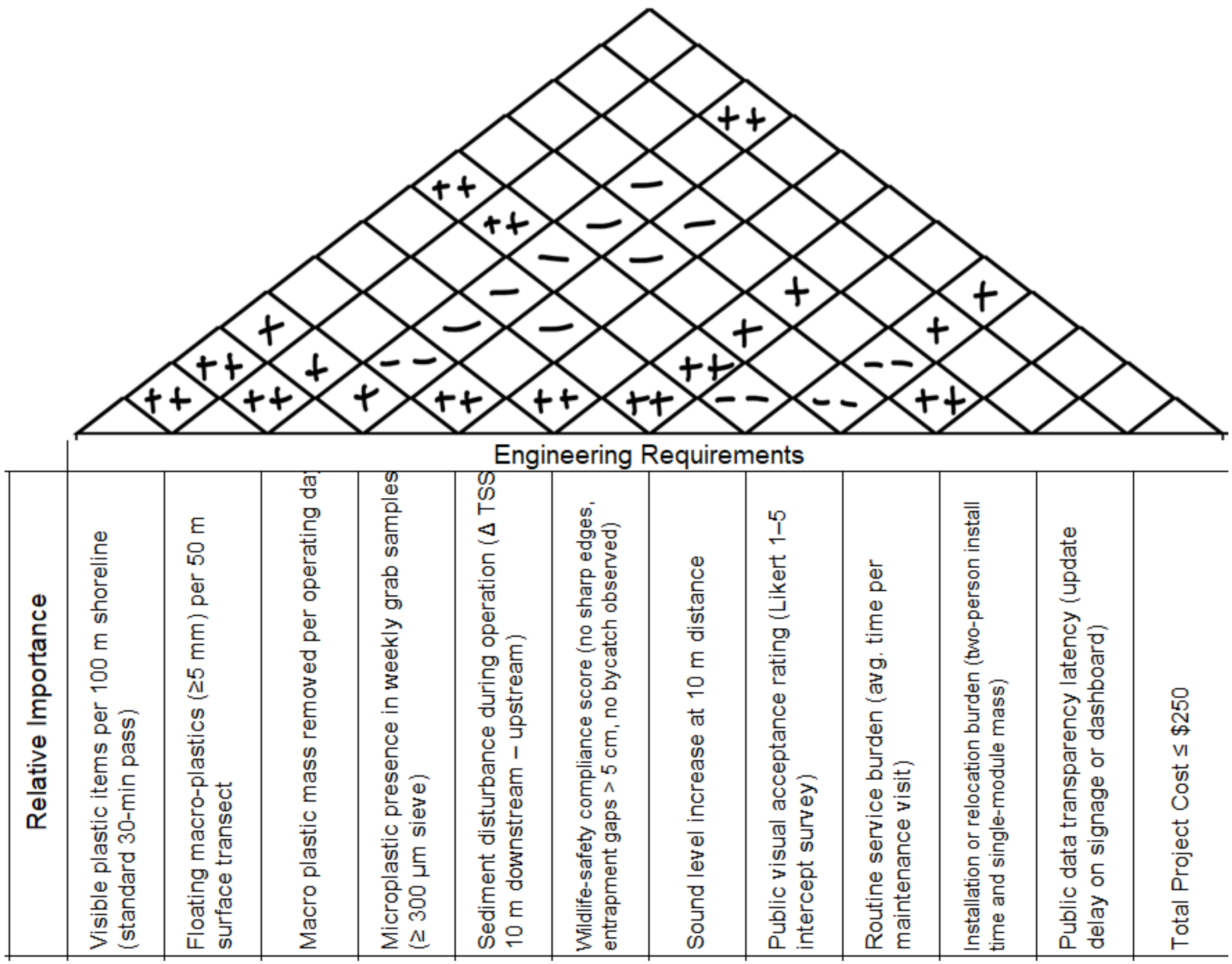
Figure E

Dates	Imp.	Specification	Metric	Target Value	Verification Method	Responsibility	Source / Justification
26-Nov	W	Routine service burden (avg. time per maintenance visit)	Minutes / visit	≤ 20 min	Time study during maintenance	Team	Customer Needs
26-Nov	D	Installation / relocation burden	Two-person install time (h)	≤ 2 h	Setup trial	Team	Customer Needs
26-Nov	D	Single Module Mass	Mass per module	≤ 23 kg module	Weight test	Team	Customer Needs; NIOSH Lifting Equation
26-Nov	D	Project Budget	Project Budget	≤ $250	Review of BoM	Team	Customer Needs / Project course guidelines
26-Nov	D	Visible plastic items per 100 m shoreline (standard 30-min pass)	Count	≤ 2 items / 100 meter	Field survey + video documentation	Team	Customer Needs
26-Nov	D	Floating macro-plastics (≥ 5 mm) per 50 m surface transect	Count	≤ 3 items / 50 meter	Transect sampling + visual inspection	Team	Customer Needs
26-Nov	D	Macro plastic mass removed per operating day	kg / day	≥ 1 kg/day	Field trial + weigh-scale validation	Team	(United Nations International Telecommunication Union, 2020)
26-Nov	D	Microplastic presence in weekly grab samples (≥ 300 µm sieve)	% of samples with detectable plastics	≤ 20 %	Lab filtration + microscopy	Team	Customer Needs; US EPA sediment/turbidity criteria snapshot
26-Nov	D	Retention of captured plastics under agitation	% retained after 2 min wake test	≥ 95 %	Simulated 2 minute wake test	Team	Customer Needs; ASTM F1523 – Selection of Booms
26-Nov	W	Sediment disturbance during operation(Δ TSS 10 m downstream–upstream)	mg/L TSS	≤ +5 mg/L	Turbidity probe testing	Team	Customer Needs
26-Nov	D	Wildlife-safety compliance score	Pass/Fail	Pass	Safety audit + visual inspection	Team	Customer Needs
26-Nov	W	Sound level increase at 10 m distance	dB above Ambient	≤ 5 dB	Sound meter test	Team	Customer Needs; Austin Outdoor Amplified Sound
26-Nov	D	Public visual acceptance rating	Likert 1–5 survey	≥ 4	Public intercept survey	Team	Customer Needs
26-Nov	D	Public data transparency latency	Hours delay	≤ 24 h	Dashboard update log	Team	Customer Needs

Appendix F

House of Quality

Figure F.1



Appendix F

House of Quality

Figure F.2

		Relative Importance	Visible plastic items per 100 m shoreline (standard 30-min pass)	Floating macro-plastics (≥5 mm) per 50 m surface transect	Macro plastic mass removed per operating day	Microplastic presence in weekly grab samples (≥ 300 µm sieve)	Sediment disturbance during operation (Δ TSS 10 m downstream – upstream)	Wildlife-safety compliance score (no sharp edges, entrapment gaps > 5 cm, no bycatch observed)	Sound level increase at 10 m distance	Public visual acceptance rating (Likert 1–5 intercept survey)	Routine service burden (avg. time per maintenance visit)	Installation or relocation burden (two-person install time and single-module mass)	Public data transparency latency (update delay on signage or dashboard)	Total Project Cost ≤ $250	Now: **Competitor A:** Mr. Trash Wheel **Competitor B:** StormX Netting Trash Trap **Competitor C:** SeaBin Our Desired Product*				
			Engineering Requirements																
Direction of Improvement		X	↓	↓	↑	↓	↓	↑	↓	↑	↓	↓	↓	↑	←1				5→
Visible plastics	Shorelines appear free of plastics	3	9	3	3	0	0	0	0	9	1	1	0	1		C	B		A *
Visible plastics	Near-surface water looks clear of plastics	4	3	9	3	3	0	0	0	9	0	0	0	1			BC		A *
Visible plastics	Hotspots (e.g. I-35) do not accumulate visible plastics	4	3	9	9	0	0	0	0	3	3	3	0	1		C		B	A *
Micropastics & sources	Water contains minimal microplastics	5	0	1	3	9	1	0	0	0	0	0	1	0	A	B	C	*	
Micropastics & sources	System captures small floating and suspended plastics before they settle	5	1	3	9	9	3	0	0	0	0	1	0	1			ABC		*
Micropastics & sources	Device collects debris without disturbing bottom sediments	5	0	0	3	3	9	0	0	0	0	0	0	0			BC	A	*

Appendix F

House of Quality

Figure F.3

Customer Needs	Mi	Device collects debris without disturbing bottom sediments	5	0	0	3	3	9	0	0	0	0	0	0	0		BC	A	*
	Wildlife/Pets	Lake conditions do not endanger pets due to plastics	4	3	3	3	3	1	3	0	1	0	0	0	1		BC		A *
		Device does not trap or injure wildlife	4	0	0	0	0	0	9	1	1	0	0	0	1		C	AB	*
		Device allows safe passage for fish, turtles, and birds	5	0	0	0	0	0	9	0	1	0	0	0	0		AC	B	*
	Experience & Perception	People feel comfortable recreating on water without seeing plastic	4	3	9	3	1	0	1	1	9	0	0	0	1		BC		A *
		Device labeling clearly indicates its purpose to the public	3	0	0	0	0	0	0	0	3	0	0	9	0	B	C	A	*
		Device has a low profile and minimal noise in public areas	2	0	0	0	0	0	0	9	9	0	0	0	0		A	C	B *
	Awareness & Transparency	Public can easily see or access information on cleanup progress	3	0	0	0	0	0	0	0	1	0	0	9	0	B	C		A *
		Device includes simple on-site communication or labeling	2	0	0	0	0	0	0	0	3	0	0	9	0	B	C	A	*
		Plastics status is publicly verifiable	3	0	0	0	0	0	0	0	0	0	0	9	0	B	C		A *
	Persistence & Practicality	Affordable Solution	5	3	3	9	1	1	1	1	1	1	1	1	9		C	B	A *
		System can be deployed at inflows and moved as hotspots shift	4	0	1	1	0	0	0	0	0	1	9	0	0	A	B	C	*
		Maintenance and servicing are simple for city crews/volunteers	4	0	0	0	0	0	0	0	0	9	1	0	0		A	BC	*
	Event Resistance	Peformance holds during storms	3	3	3	3	1	0	0	0	0	0	0	0	9	C		B	A *
		Captured plastics stay contained under extremes	4	0	0	3	0	0	0	0	0	0	0	0	9		C		AB *
		Safe fail + rapid recovery after events	4	0	0	0	0	0	0	0	0	1	3	0	9		C	AB	*

Appendix F
House of Quality

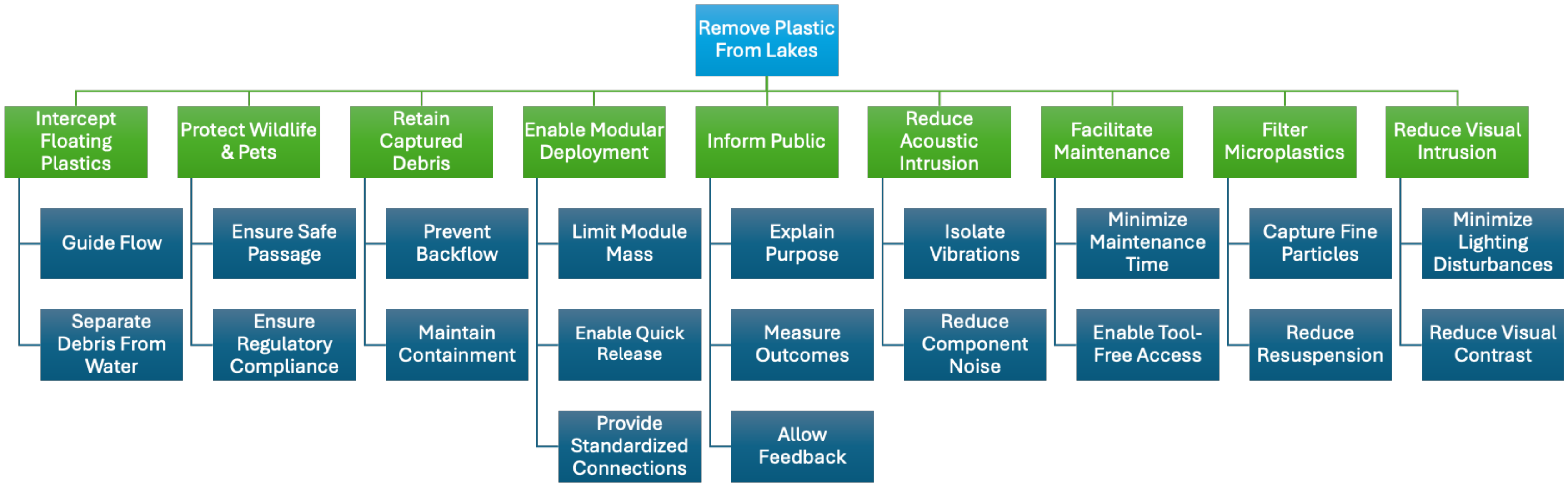
Figure F.4

Units	X	count/ 100m	count / 50m	kg / day	% pos	mg / L	P/F	dBA above amb	score 1-5	min	min / kg	hrs	% ret
Target Value	X	≤ 2 items	≤ 1 item	≥ 1 kg/day	≤ 20 %	≤ +5 mg/L	Pass	≤ +3 dBA	≥ 4.0	≤ 20 min	≤ 30 min install, ≤ 25 kg per module	≤ 24 h	≥ 95 %
Competitor A Value	X	5	3	5000	90%	5	4	55	5	60	240 min; 2000kg	0-1 days	98%
Competitor B Value	X	15	9	200	90%	10	4	0	3	45	180 min; 500kg	none	95%
Competitor C Value	X	20	13	3	75%	10	3	50	3	15	60 min; 40kg	5 days	85%
Absolute Importance	X	104	177	226	141	74	102	31	165	64	77	109	172
Relative Importance	X	7%	13%	16%	10%	5%	7%	2%	12%	5%	5%	8%	12%
Ranked Importance	X	6	2	1	5	10	8	12	4	11	9	6	3

Appendix G

Function Tree

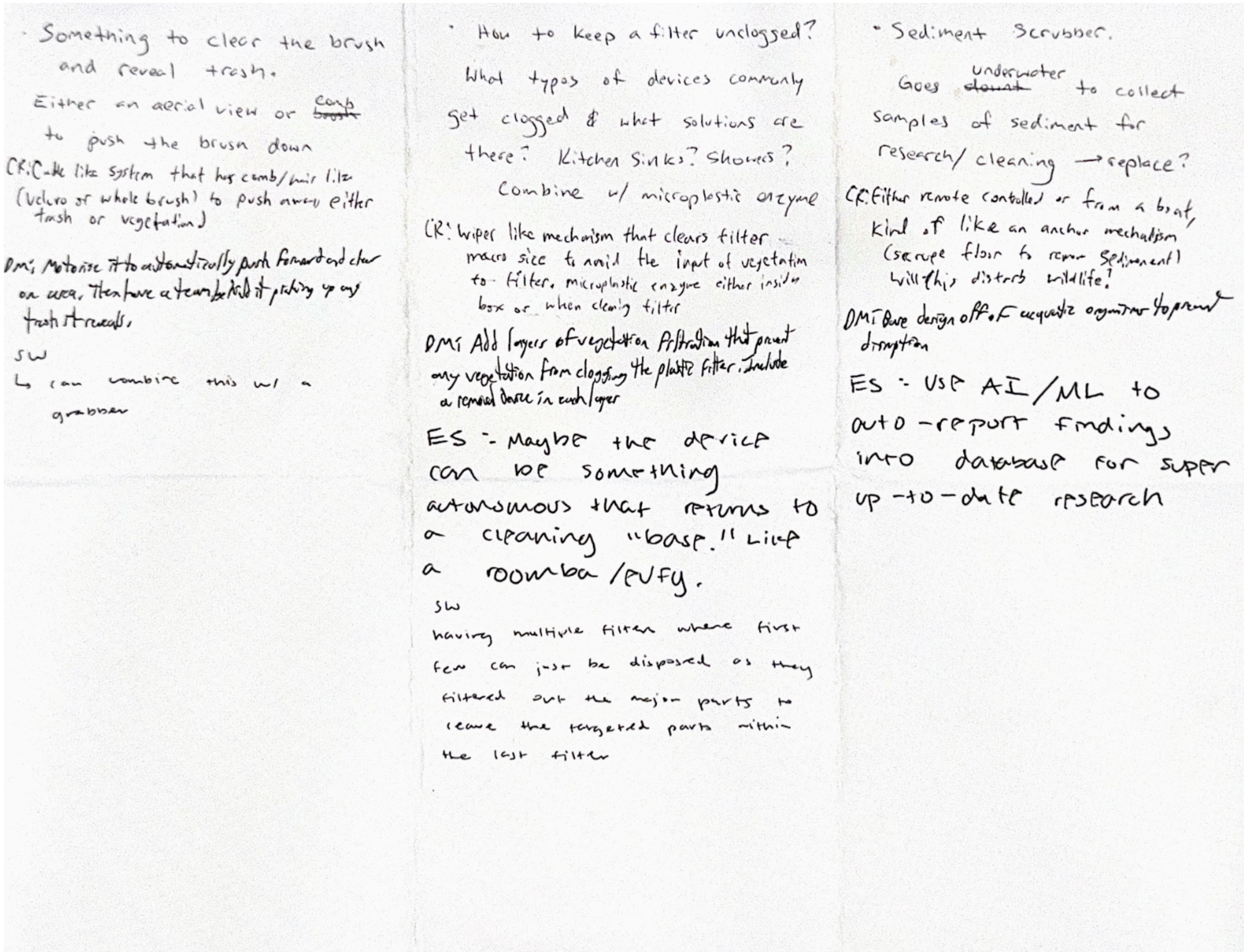
Figure G



Appendix H

Concept Generation Methods

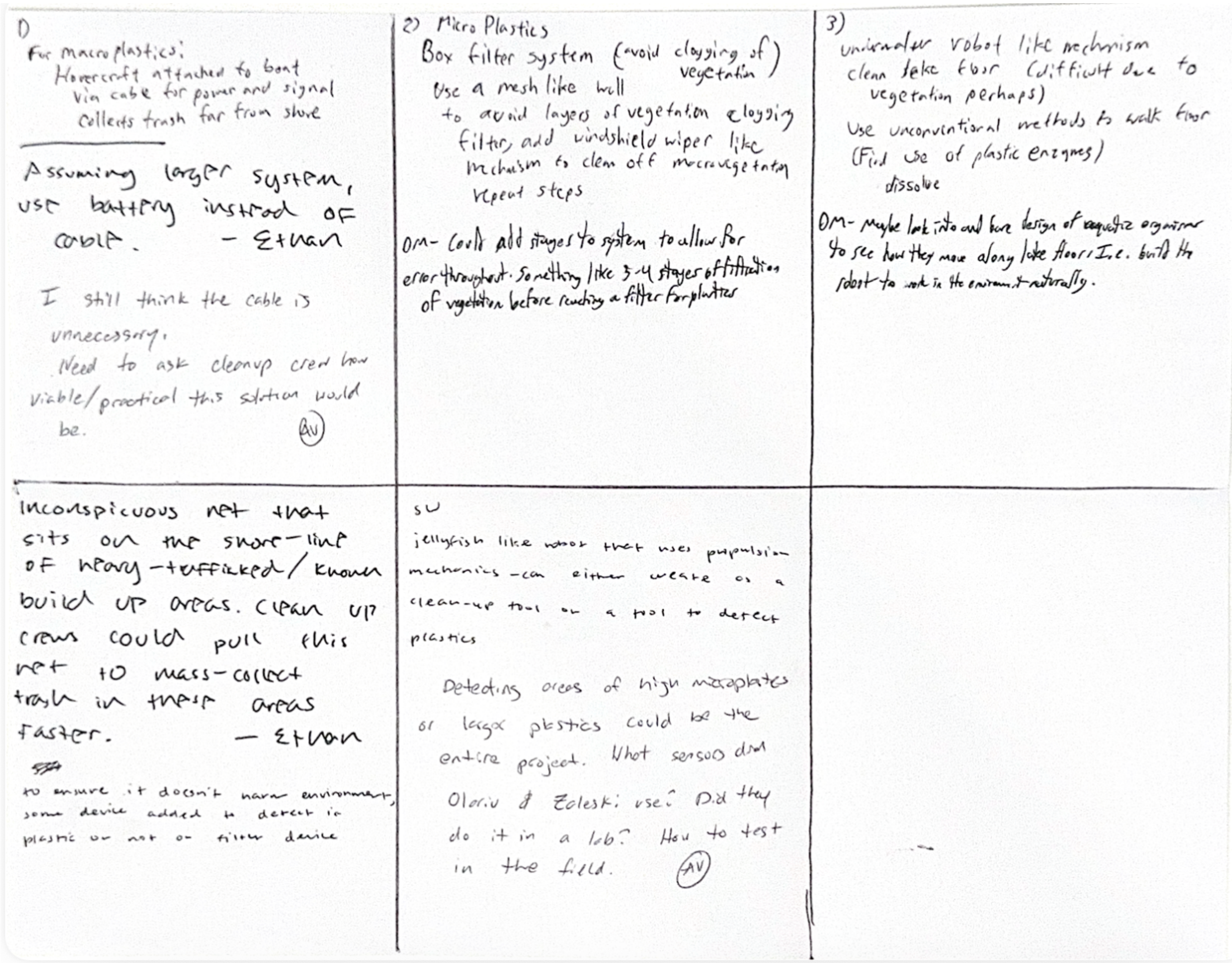
Figure H.1



Appendix H

Concept Generation Methods

Figure H.2



1)
For macroplastics:
Hovercraft attached to boat
via cable for power and signal
Collects trash far from shore

Assuming larger system, use battery instead of cable. – Ethan

I still think the cable is unnecessary.
Need to ask cleanup crew how viable/practical this solution would be. (AV)

2) Micro Plastics
Box filter system (avoid clogging of vegetation)
Use a mesh like wall
to avoid layers of vegetation clogging
filter, add windshield wiper like
mechanism to clean off macrovegetation
repeat steps

OM – Could add stages to system to allow for error throughout. Something like 3-4 stages of filtration of vegetation before reaching a filter for plastics

3)
underwater robot like mechanism
clean lake floor (difficult due to
vegetation perhaps)
Use unconventional methods to walk floor
(Find use of plastic enzymes)
dissolve

OM – Maybe look into and base design of aquatic organisms to see how they move along lake floor, I.e. build the robot to work in the environment naturally.

Inconspicuous net that sits on the shore-line of heavy-trafficked/known build up areas. Clean up crews could pull this net to mass-collect trash in these areas faster. – Ethan

to ensure it doesn't harm environment, some device added to detect if plastic or not or filter device

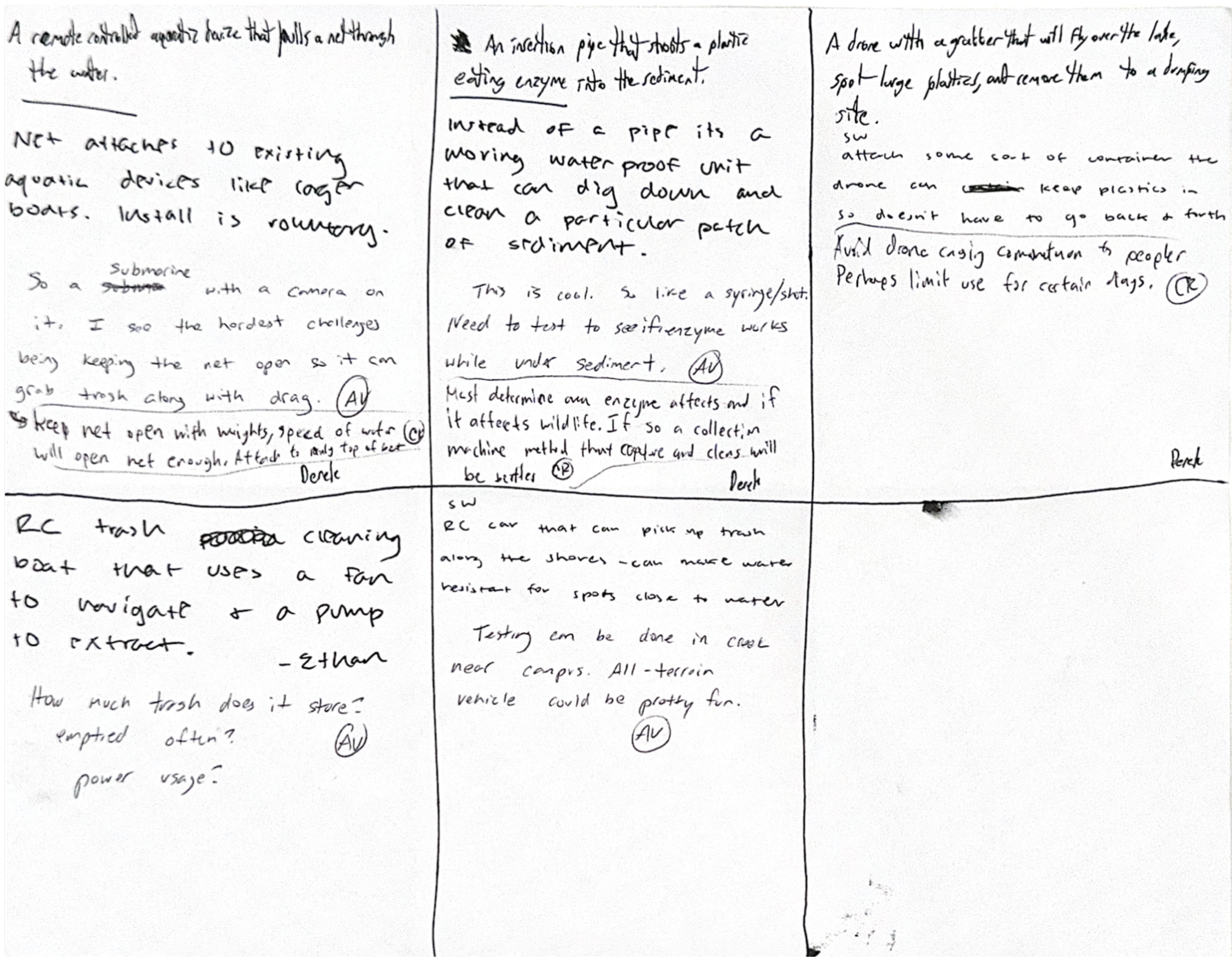
SU
jellyfish like robot that uses propulsion mechanics – can either create or a clean-up tool or a tool to detect plastics

Detecting areas of high microplastics or large plastics could be the entire project. What sensors did Olariu & Zoleski use? Did they do it in a lab? How to test in the field. (AV)

Appendix H

Concept Generation Methods

Figure H.3



A remote controlled aquatic device that pulls a net through the water.

Net attaches to existing aquatic devices like cager boats. Install is rountory.

So a submarine with a camera on it. I see the hardest challenges being keeping the net open so it can grab trash along with drag. (AV)

Keep net open with weights, speed of water will open net enough. Attach to only top of net (CR)

Derek

An insertion pipe that shoots a plastic eating enzyme into the sediment.

Instead of a pipe its a moving water proof unit that can dig down and clean a particular patch of sediment.

This is cool. So like a syringe/shot. Need to test to see if enzyme works while under sediment. (AV)

Must determine own enzyme affects and if it affects wildlife. If so a collection machine method that capture and cleans will be settles (CR)

Derek

A drone with a grabber that will fly over the lake, spot large plastics, and remove them to a dumping site.

SW

attach some sort of container the drone can keep plastics in so doesn't have to go back & forth

Avoid drone causing commotion to people. Perhaps limit use for certain days. (CR)

Derek

RC trash cleaning boat that uses a fan to navigate & a pump to extract.

- Ethan

How much trash does it store? emptied often? power usage? (AV)

SW

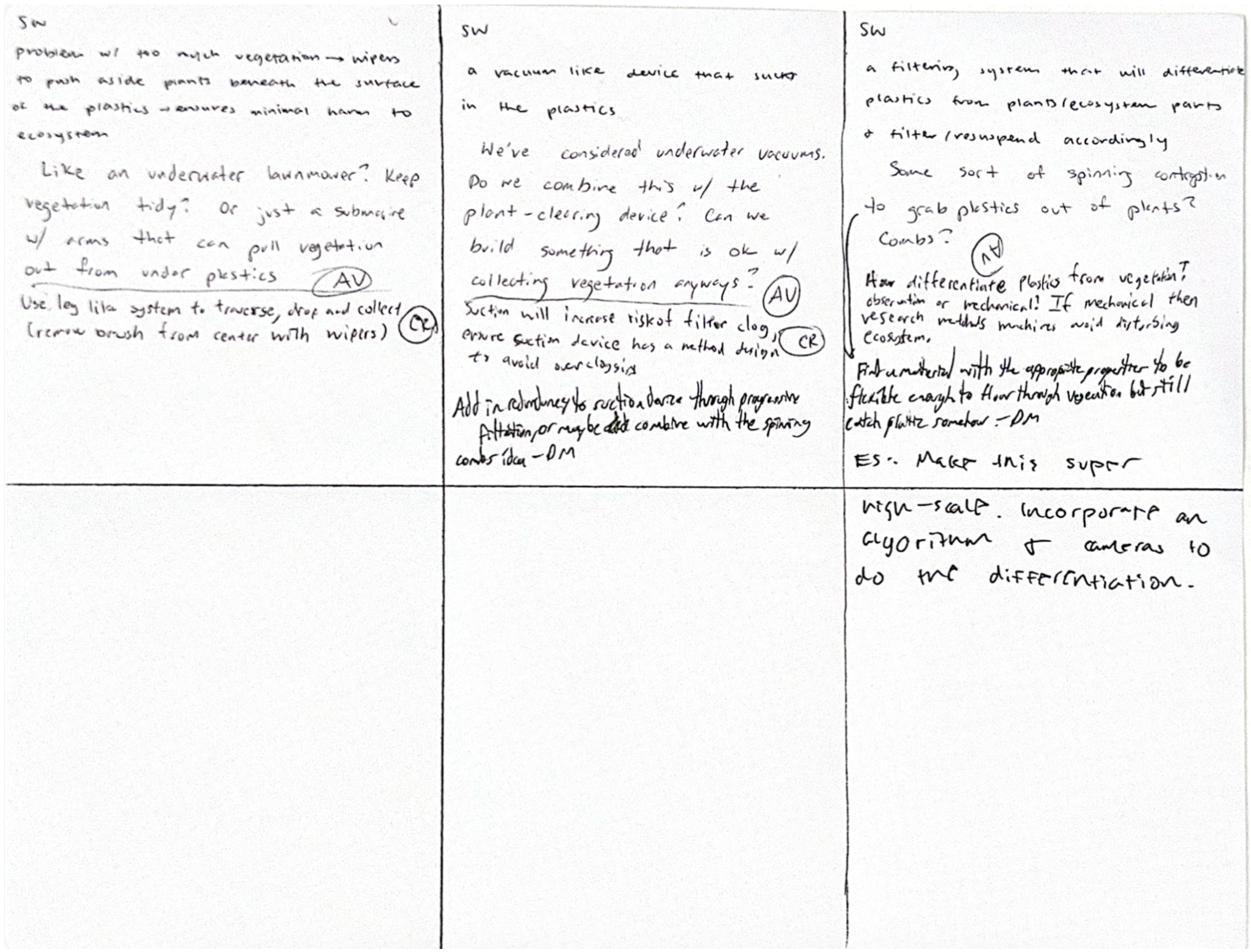
RC car that can pick up trash along the shores - can make water resistant for spots close to water

Testing can be done in creek near campus. All-terrain vehicle could be pretty fun. (AV)

Appendix H

Concept Generation Methods

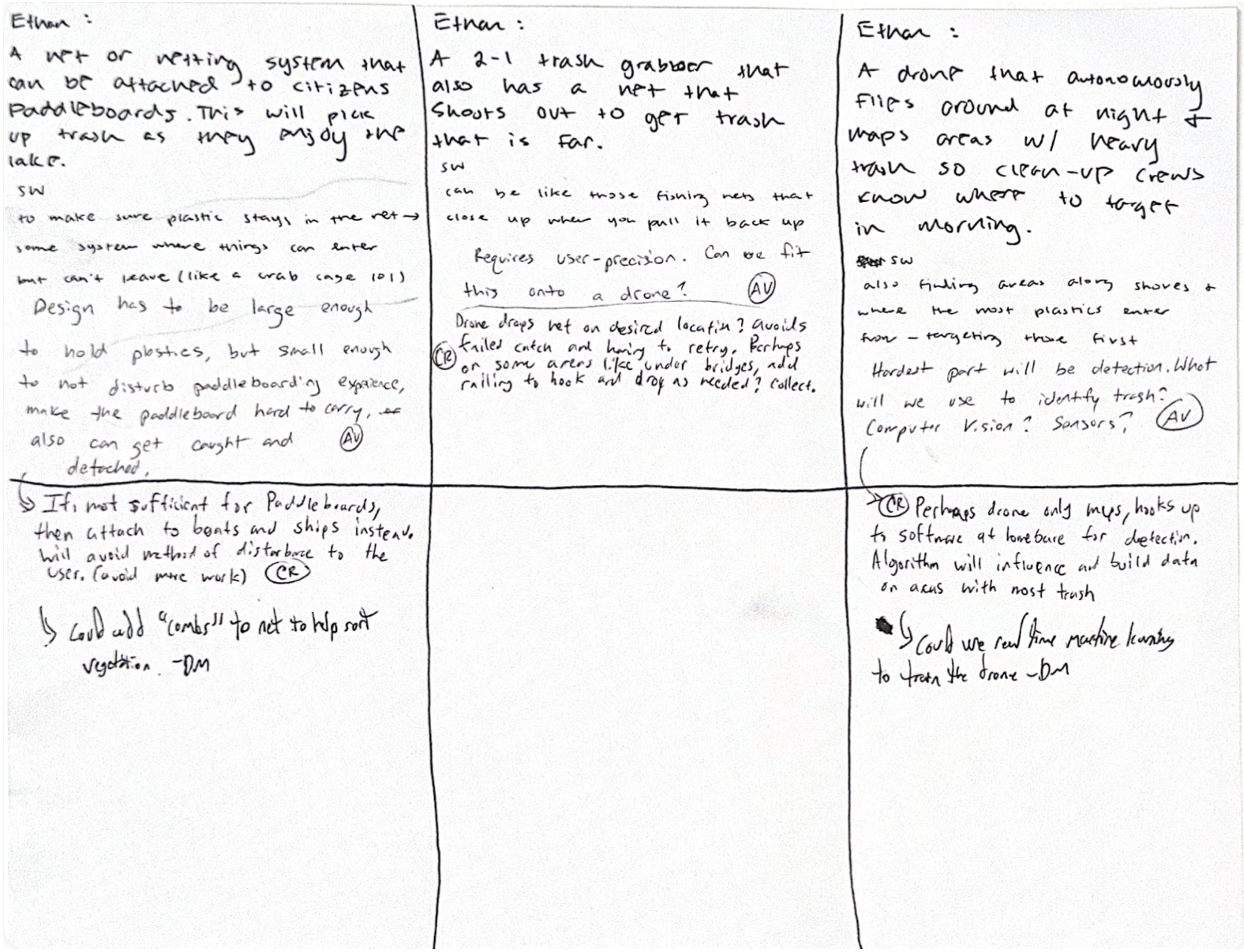
Figure H.4



Appendix H

Concept Generation Methods

Figure H.5



Ethan:
A net or netting system that can be attached to citizens paddleboards. This will pick up trash as they enjoy the lake.
SW
to make sure plastic stays in the net → some system where things can enter but can't leave (like a crab cage 101)
Design has to be large enough to hold plastics, but small enough to not disturb paddleboarding experience, make the paddleboard hard to carry, or also can get caught and detached. (AV)
↳ If not sufficient for paddleboards, then attach to boats and ships instead. Will avoid method of disturbance to the user. (avoid more work) (CR)
↳ Could add "combs" to net to help sort vegetation. -DM

Ethan:
A 2-1 trash grabber that also has a net that shoots out to get trash that is far.
SW
can be like those fishing nets that close up when you pull it back up
Requires user-precision. Can we fit this onto a drone? (AV)
(CR) Drone drops net on desired location? Avoids failed catch and having to retry. Perhaps on some areas like under bridges, add railing to hook and drop as needed? Collect.

Ethan:
A drone that autonomously flies around at night & maps areas w/ heavy trash so clean-up crews know where to target in morning.
SW
also finding areas along shores & where the most plastics enter from – targeting those first
Hardest part will be detection. What will we use to identify trash? Computer Vision? Sensors? (AV)
↳ (CR) Perhaps drone only maps, hooks up to software at home base for detection. Algorithm will influence and build data on areas with most trash
↳ Could we real time machine learning to train the drone -DM

Appendix H
Concept Generation Methods

Table H.1, H.2, H.3

Subfunction 1: Intercept Floating Macroplastics

Analogy Source	Mechanism/Insight Drawn
Fishing Nets	Use mesh barriers that pass water but trap large debris
Baleen Whales	Use fine spacing to filter large particles while letting water through
Airport Windsock	Passive funneling using natural flow to guide debris inward
River Beavers	Use natural flow deflection and branching to capture objects
Leaf Rake	Design comb-like surface or tines to catch and gather plastic

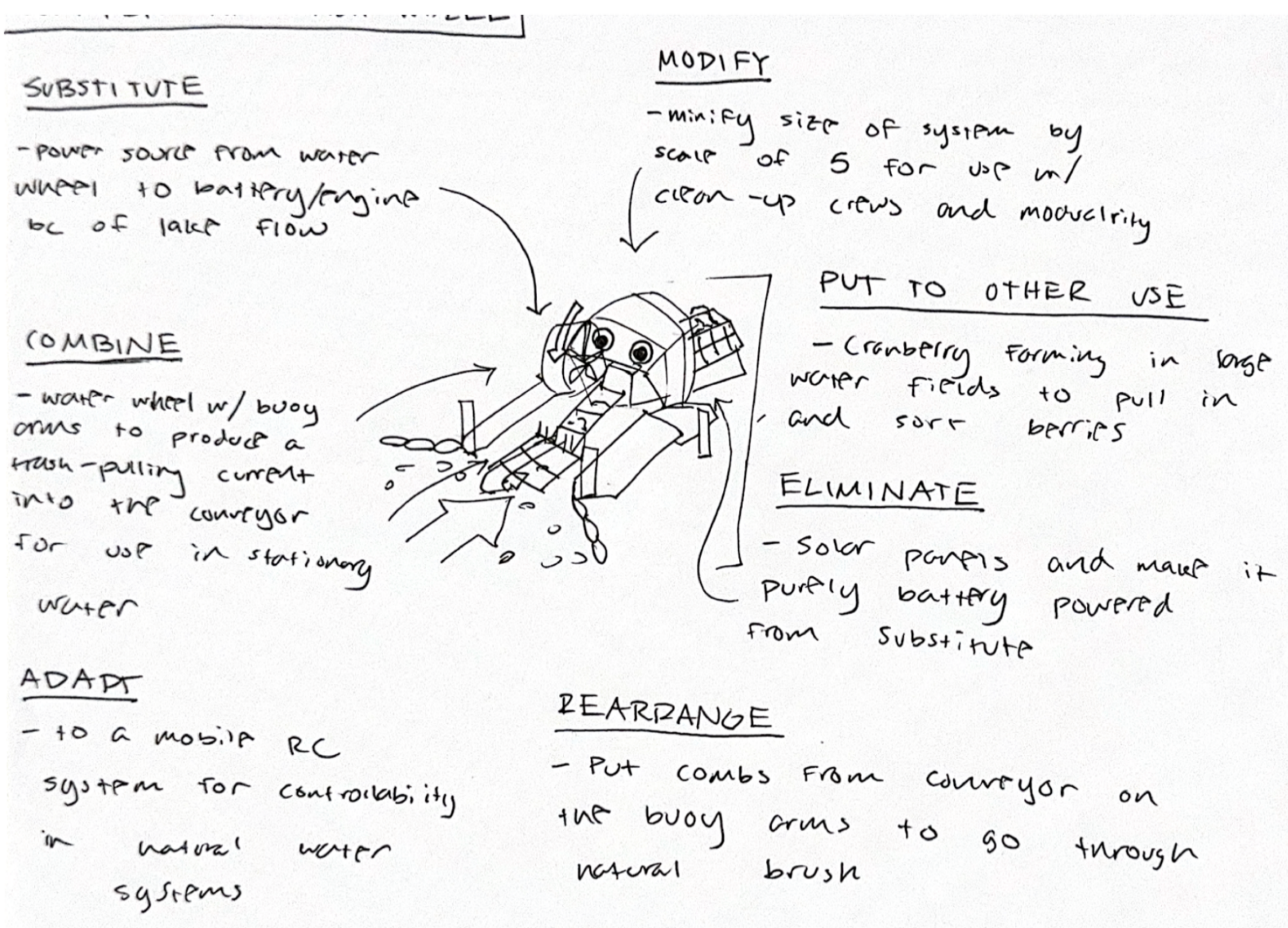
Subfunction 2: Retain Captured Debris (One-Way Retention + Secure Containment)

Analogy Source	Mechanism/Insight Drawn
Check Valves	Allow material to pass in one direction, prevent backflow
Lobster Trap	Entrap objects once they enter, hard to exit without reverse path
Velcro Closure	Simple, durable sealing mechanism for retention mesh bags
Grocery Bagger Loop	Self-closing flaps triggered by object motion
Trash Compactor	Periodically condenses contents to store more in fixed volume

Subfunction 3: Enable Safe Passage for Wildlife

Analogy Source	Mechanism/Insight Drawn
Pet Doors	Directional, species-specific access mechanisms
Bird Netting	Large mesh size avoids small wildlife entrapment
Aquarium Baffles	Flow-guiding barriers that control circulation and prevent harm
Highway Wildlife Overpasses	Design around animal behavior to offer alternate safe routes
Swimming Pool Skimmers	Surface-level collection avoids deeper zones where wildlife move

Figure H.6


MODIFY
- minify size of system by scale of 5 for use w/ clean-up crews and modularity
SUBSTITUTE
- power source from water wheel to battery/engine bc of lake flow
PUT TO OTHER USE
- Cranberry farming in large water fields to pull in and sort berries
COMBINE
- water wheel w/ buoy arms to produce a trash-pulling current into the conveyor for use in stationary water
ELIMINATE
- Solar panels and make it purely battery powered from substitute
ADAPT
- to a mobile RC system for controllability in natural water systems
REARRANGE
- Put combs from conveyor on the buoy arms to go through natural brush

Appendix I

Morphological Matrix

Figure I

Guide Flow of Plastic	Arms	Funnel	Vacuum	Fans	Paddle	Water Sock
Seperate Debris from Water	Comb	Claw Grabber	Filter	Net	Mesh	
Prevent Bycatch	Motion sensors	Wipers	Comb	Camera	Computer Vision	Acoustic Deterrents
Enable Safe Passage	Air Fans	Fish Ladders	Fish Screens	Gentle Current	Drone	
Ensure Regulatory Compliance	Government Grant	Public Permits	Environmental Impact Report			
Prevent Backflow	Lobster Trap	Arms	Grabbers	Dump Box	Check Valves	
Secure Containment	Servo Actuated	Velcro	Grocery Bagger	Latching Lid		
Limit Module Size	Floating Net	Trash Compactor	Minify Size	Evaporation		
Quick Release/Redeploy	Waterproof Material	Mobile RC System	Attach to Boats	Modular Clips	Anchor Release	
Standardized Connections	Standard Parts	3D Printed	Common Fasteners	Modular Interface		
Explain Purpose	Presentation	Academic Paper	Posted Signs	Website	QR Code	
Measure Outcomes	Research Studies	Sensors	AI/ML Autoreport	Water Quality Tests		
Enable Access & Feedback	Check in with Experts	Suggestion Box	Feedback Email	Public Survey		
Isolate Vibrations	Springs	Rubber Lining	Damping Material	Flexible Couplings		
Minimize Visual Disruption from Lightin	No Lights	Red Lights	Shielded Lights	Submerged Lights		
Reduce Visual Contrast	Camo	Biological Design	Natural Materials	Submerged Components		
Enable Tool-Free Access	Snap-fit Lid	Thumb Screws	Hinged Panels	Latches		
Minimize Maintanence Time	Easy-access	Autonomous Cleaning Base	Self Clearing Filter	Corrosion Resistant Material		

Appendix J

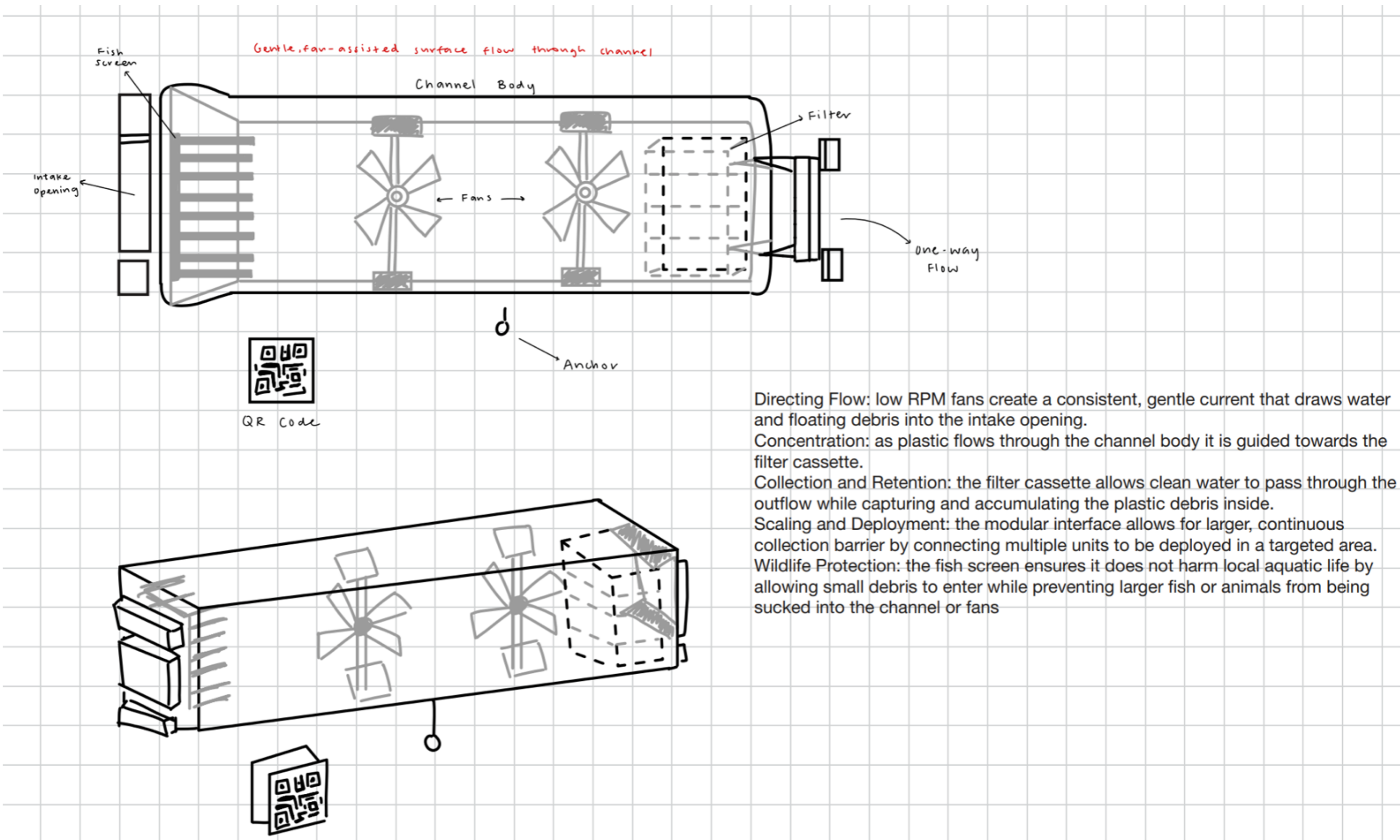
Concept Sketches

Figure J.1.1

Guide Flow of Plastic	Arms	Funnel	Vacuum	Fans	Paddle	Water Sock
Seperate Debris from Water	Comb	Claw Grabber	Filter	Net	Mesh	
Prevent Bycatch	Motion sensors	Wipers	Comb	Camera	Computer Vision	Acoustic Deterrents
Enable Safe Passage	Air Fans	Fish Ladders	Fish Screens	Gentle Current	Drone	
Ensure Regulatory Compliance	Government Grant	Public Permits	Environmental Impact Report			
Prevent Backflow	Lobster Trap	Arms	Grabbers	Dump Box	Check Valves	
Secure Containment	Servo Actuated	Velcro	Grocery Bagger	Latching Lid		
Limit Module Size	Floating Net	Trash Compactor	Minify Size	Evaporation		
Quick Release/Redeploy	Waterproof Material	Mobile RC System	Attach to Boats	Modular Clips	Anchor Release	
Standardized Connections	Standard Parts	3D Printed	Common Fasteners	Modular Interface		
Explain Purpose	Presentation	Academic Paper	Posted Signs	Website	QR Code	
Measure Outcomes	Research Studies	Sensors	AI/ML Autoreport	Water Quality Tests		
Enable Access & Feedback	Check in with Experts	Suggestion Box	Feedback Email	Public Survey		
Isolate Vibrations	Springs	Rubber Lining	Damping Material	Flexible Couplings		
Minimize Visual Disruption from Lightin	No Lights	Red Lights	Shielded Lights	Submerged Lights		
Reduce Visual Contrast	Camo	Biological Design	Natural Materials	Submerged Components		
Enable Tool-Free Access	Snap-fit Lid	Thumb Screws	Hinged Panels	Latches		
Minimize Maintanence Time	Easy-access	Autonomous Cleaning Base	Self Clearing Filter	Corrosion Resistant Material		

Appendix J
Concept Sketches

Figure J.1.2



Directing Flow: low RPM fans create a consistent, gentle current that draws water and floating debris into the intake opening.
Concentration: as plastic flows through the channel body it is guided towards the filter cassette.
Collection and Retention: the filter cassette allows clean water to pass through the outflow while capturing and accumulating the plastic debris inside.
Scaling and Deployment: the modular interface allows for larger, continuous collection barrier by connecting multiple units to be deployed in a targeted area.
Wildlife Protection: the fish screen ensures it does not harm local aquatic life by allowing small debris to enter while preventing larger fish or animals from being sucked into the channel or fans

Appendix J

Concept Sketches

Figure J.2.1

Guide Flow of Plastic	Arms	Funnel	Vacuum	Fans	Paddle	Water Sock
Seperate Debris from Water	Comb	Claw Grabber	Filter	Net	Mesh	
Prevent Bycatch	Motion sensors	Wipers	Comb	Camera	Computer Vision	Acoustic Deterrents
Enable Safe Passage	Air Fans	Fish Ladders	Fish Screens	Gentle Current	Drone	
Ensure Regulatory Compliance	Government Grant	Public Permits	Environmental Impact Report			
Prevent Backflow	Lobster Trap	Arms	Grabbers	Dump Box	Check Valves	
Secure Containment	Servo Actuated	Velcro	Grocery Bagger	Latching Lid		
Limit Module Size	Floating Net	Trash Compactor	Minify Size	Evaporation		
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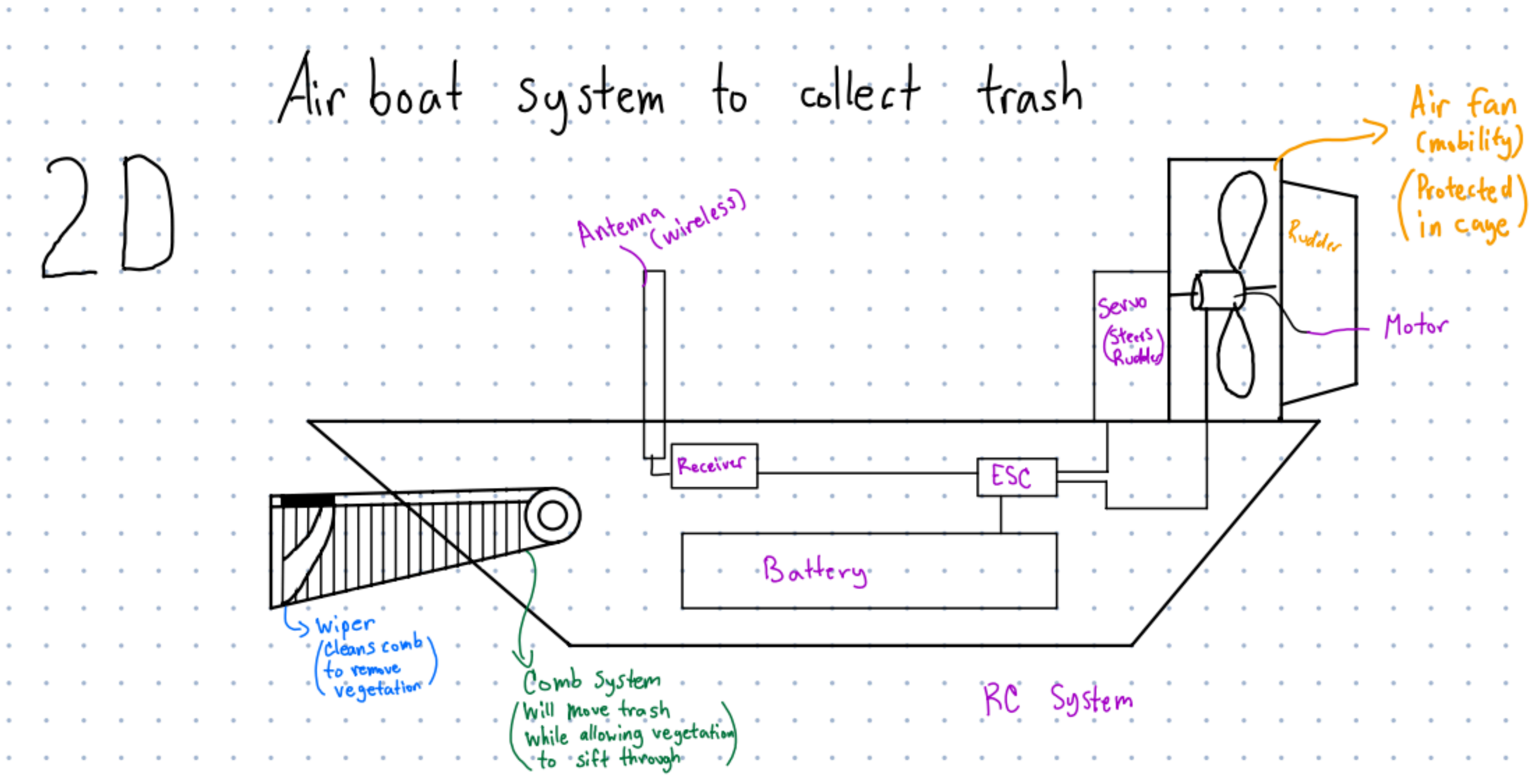
Standardized Connections	Standard Parts	3D Printed	Common Fasteners	Modular Interface		
Explain Purpose	Presentation	Academic Paper	Posted Signs	Website	QR Code	
Measure Outcomes	Research Studies	Sensors	AI/ML Autoreport	Water Quality Tests		
Enable Access & Feedback	Check in with Experts	Suggestion Box	Feedback Email	Public Survey		
Isolate Vibrations	Springs	Rubber Lining	Damping Material	Flexible Couplings		
Minimize Visual Disruption from Lightin	No Lights	Red Lights	Shielded Lights	Submerged Lights		
Reduce Visual Contrast	Camo	Biological Design	Natural Materials	Submerged Components		
Enable Tool-Free Access	Snap-fit Lid	Thumb Screws	Hinged Panels	Latches		
Minimize Maintanence Time	Easy-access	Autonomous Cleaning Base	Self Clearing Filter	Corrosion Resistant Material		

Appendix J

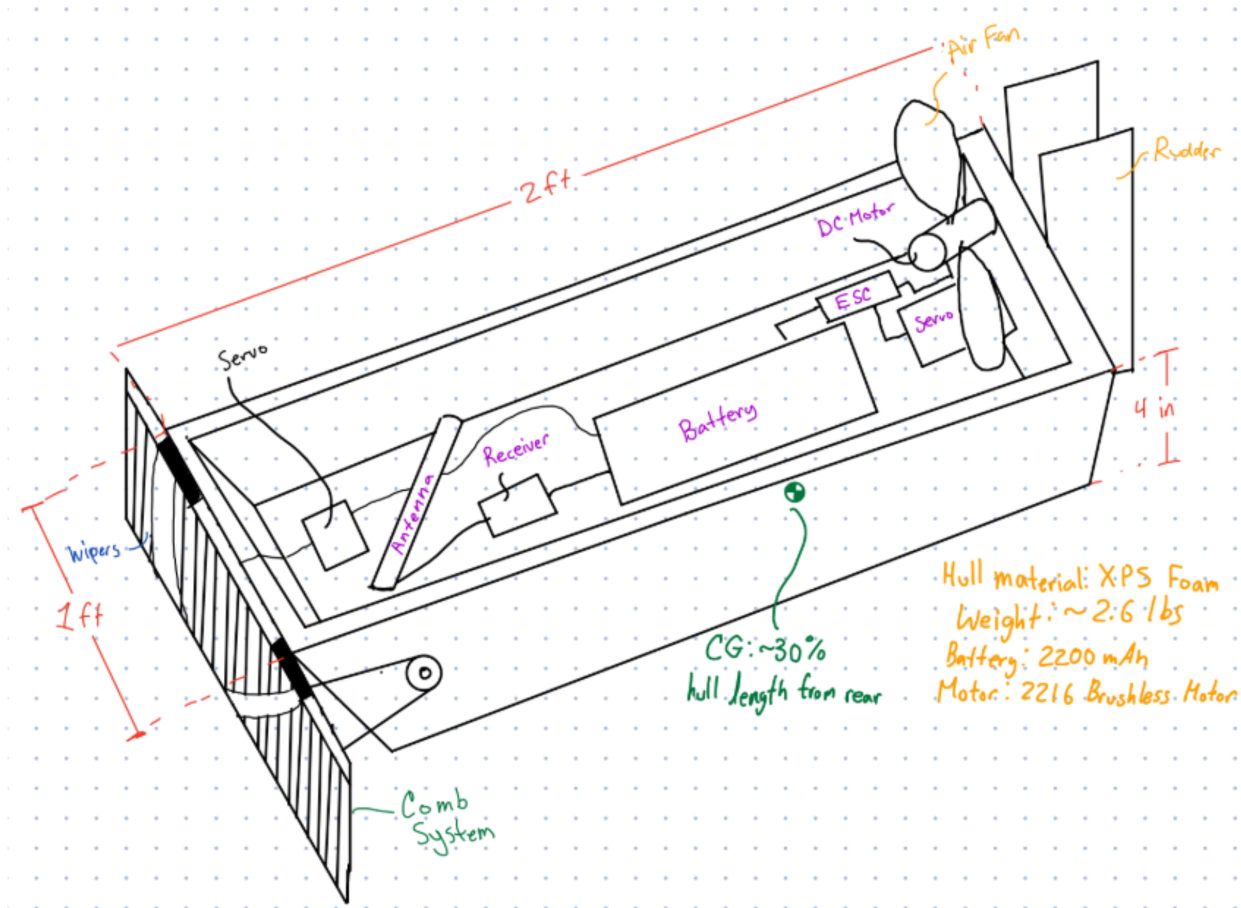
Concept Sketches

Figure J.2.2



Appendix J
Concept Sketches

Figure J.2.3



Appendix J

Concept Sketches

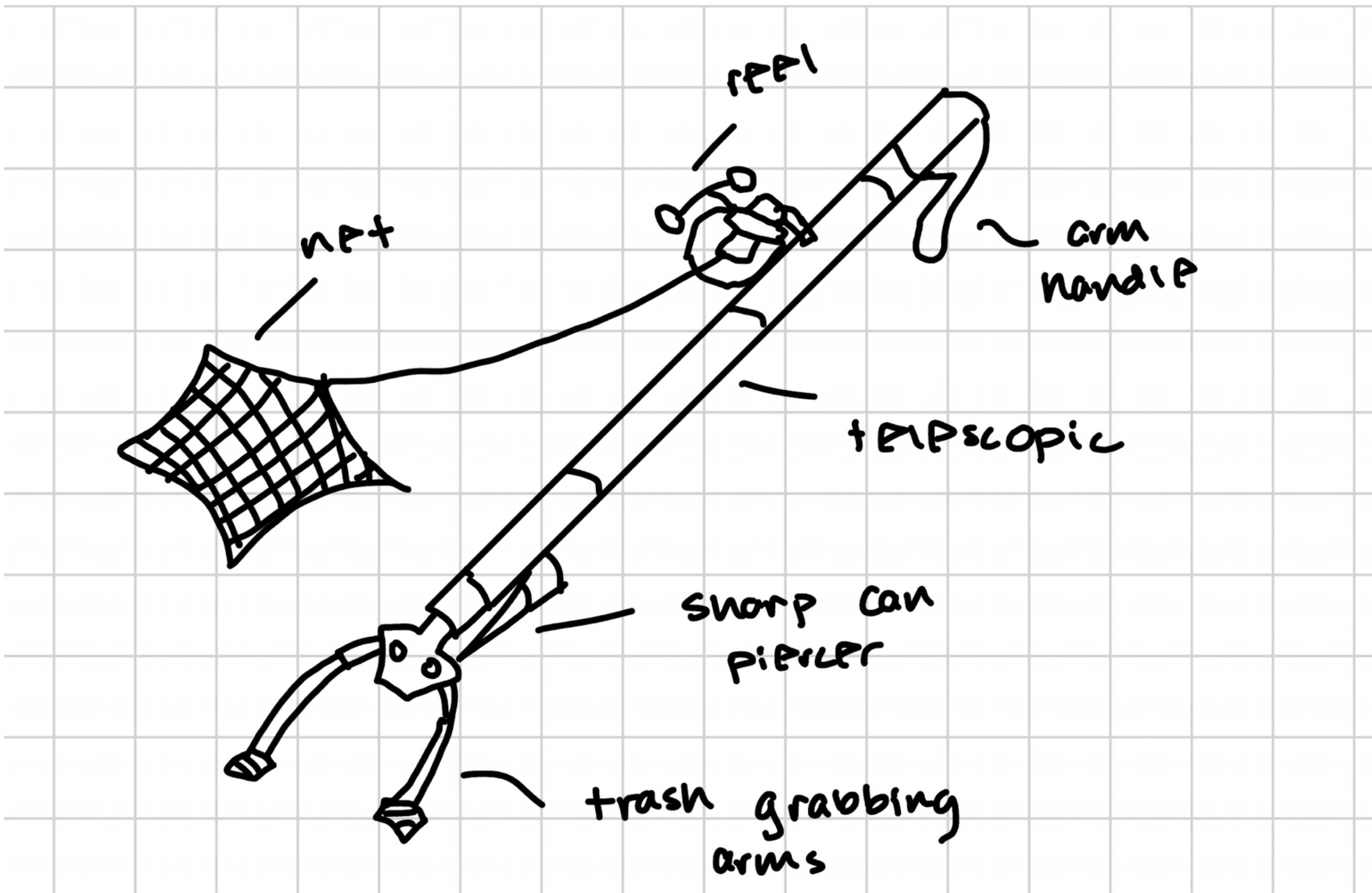
Figure J.3.1

Guide Flow of Plastic	Arms	Funnel	Vacuum	Fans	Paddle	Water Sock
Seperate Debris from Water	Comb	Claw Grabber	Filter	Net	Mesh	
Prevent Bycatch	Motion sensors	Wipers	Comb	Camera	Computer Vision	Acoustic Deterrents
Enable Safe Passage	Air Fans	Fish Ladders	Fish Screens	Gentle Current	Drone	
Ensure Regulatory Compliance	Government Grant	Public Permits	Environmental Impact Report			
Prevent Backflow	Lobster Trap	Arms	Grabbers	Dump Box	Check Valves	
Secure Containment	Servo Actuated	Velcro	Grocery Bagger	Latching Lid		
Limit Module Size	Floating Net	Trash Compactor	Minify Size	Evaporation		
Quick Release/Redeploy	Waterproof Material	Mobile RC System	Attach to Boats	Modular Clips	Anchor Release	
Standardized Connections	Standard Parts	3D Printed	Common Fasteners	Modular Interface		
Explain Purpose	Presentation	Academic Paper	Posted Signs	Website	QR Code	
Measure Outcomes	Research Studies	Sensors	AI/ML Autoreport	Water Quality Tests		
Enable Access & Feedback	Check in with Experts	Suggestion Box	Feedback Email	Public Survey		
Isolate Vibrations	Springs	Rubber Lining	Damping Material	Flexible Couplings		
Minimize Visual Disruption from Lightir	No Lights	Red Lights	Shielded Lights	Submerged Lights		
Reduce Visual Contrast	Camo	Biological Design	Natural Materials	Submerged Components		
Enable Tool-Free Access	Snap-fit Lid	Thumb Screws	Hinged Panels	Latches		
Minimize Maintanence Time	Easy-access	Autonomous Cleaning Base	Self Clearing Filter	Corrosion Resistant Material		

Appendix J

Concept Sketches

Figure J.3.2



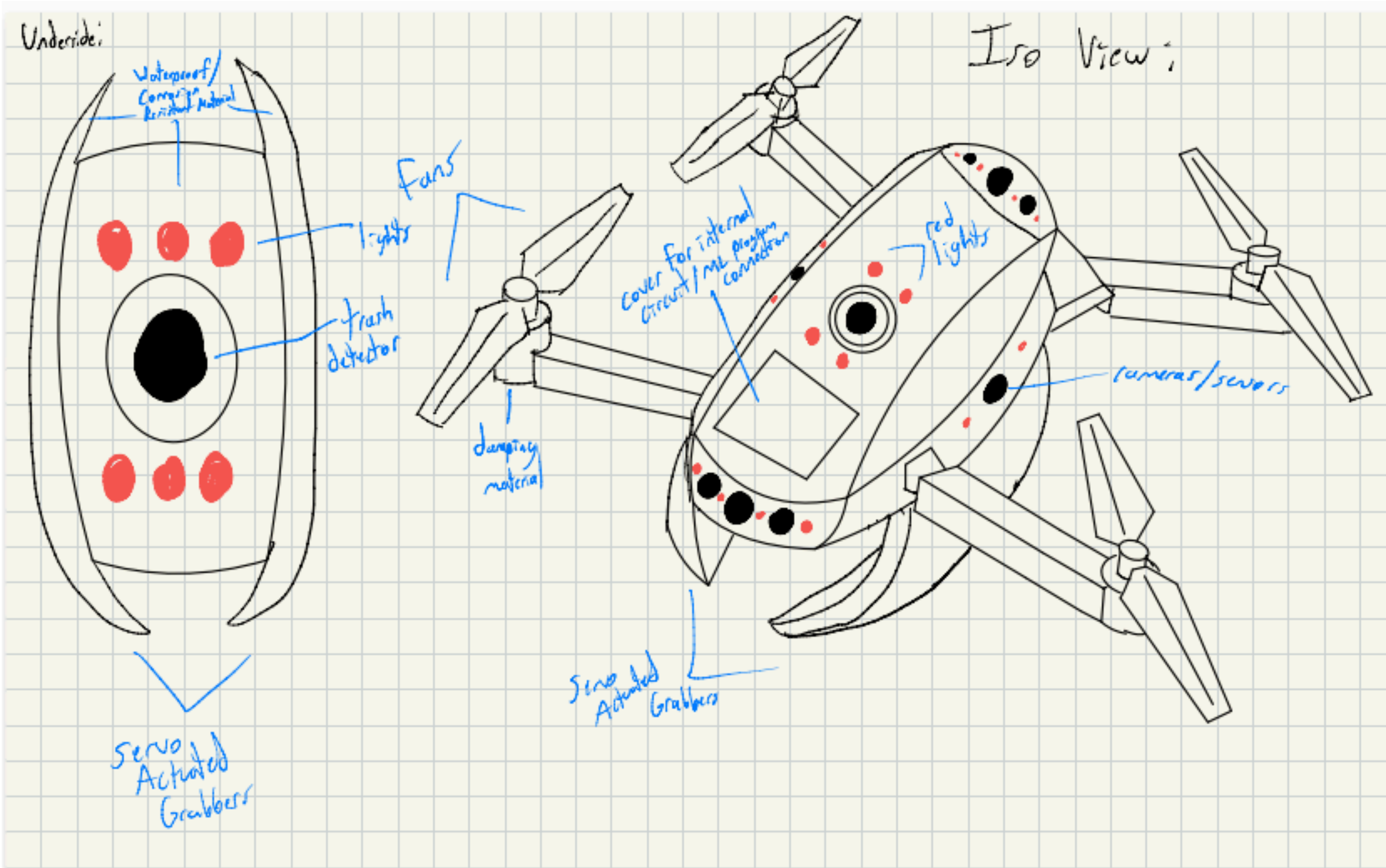
Appendix J

Concept Sketches - Drone

Figure J.4.1

Guide Flow of Plastic	Arms	Funnel	Vacuum	Fans	Paddle	Water Sock
Seperate Debris from Water	Comb	Claw Grabber	Filter	Net	Mesh	
Prevent Bycatch	Motion sensors	Wipers	Comb	Camera	Computer Vision	Acoustic Deterrents
Enable Safe Passage	Air Fans	Fish Ladders	Fish Screens	Gentle Current	Drone	
Ensure Regulatory Compliance	Government Grant	Public Permits	Environmental Impact Report			
Prevent Backflow	Lobster Trap	Arms	Grabbers	Dump Box	Check Valves	
Secure Containment	Servo Actuated	Velcro	Grocery Bagger	Latching Lid		
Limit Module Size	Floating Net	Trash Compactor	Minify Size	Evaporation		
Quick Release/Redeploy	Waterproof Material	Mobile RC System	Attach to Boats	Modular Clips	Anchor Release	
Standardized Connections	Standard Parts	3D Printed	Common Fasteners	Modular Interface		
Explain Purpose	Presentation	Academic Paper	Posted Signs	Website	QR Code	
Measure Outcomes	Research Studies	Sensors	AI/ML Autoreport	Water Quality Tests		
Enable Access & Feedback	Check in with Experts	Suggestion Box	Feedback Email	Public Survey		
Isolate Vibrations	Springs	Rubber Lining	Damping Material	Flexible Couplings		
Minimize Visual Disruption from Lightin	No Lights	Red Lights	Shielded Lights	Submerged Lights		
Reduce Visual Contrast	Camo	Biological Design	Natural Materials	Submerged Components		
Enable Tool-Free Access	Snap-fit Lid	Thumb Screws	Hinged Panels	Latches		
Minimize Maintanence Time	Easy-access	Autonomous Cleaning Base	Self Clearing Filter	Corrosion Resistant Material		

Figure J.4.2


Underside:
Waterproof/
lights
trash detector
Servo Actuated Grabbers
Fans
damping material
cover for internal circuit/ML program connection
red lights
Iso View:
cameras/sensors
Servo Actuated Grabbers

Appendix J

Concept Sketches

Figure J.5.1

Guide Flow of Plastic	Arms	Funnel	Vacuum	Fans	Paddle	Water Sock
Seperate Debris from Water	Comb	Claw Grabber	Filter	Net	Mesh	
Prevent Bycatch	Motion sensors	Wipers	Comb	Camera	Computer Vision	Acoustic Deterrents
Enable Safe Passage	Air Fans	Fish Ladders	Fish Screens	Gentle Current	Drone	
Ensure Regulatory Compliance	Government Grant	Public Permits	Environmental Impact Report			
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Secure Containment	Servo Actuated	Velcro	Grocery Bagger	Latching Lid		
Limit Module Size	Floating Net	Trash Compactor	Minify Size	Evaporation		
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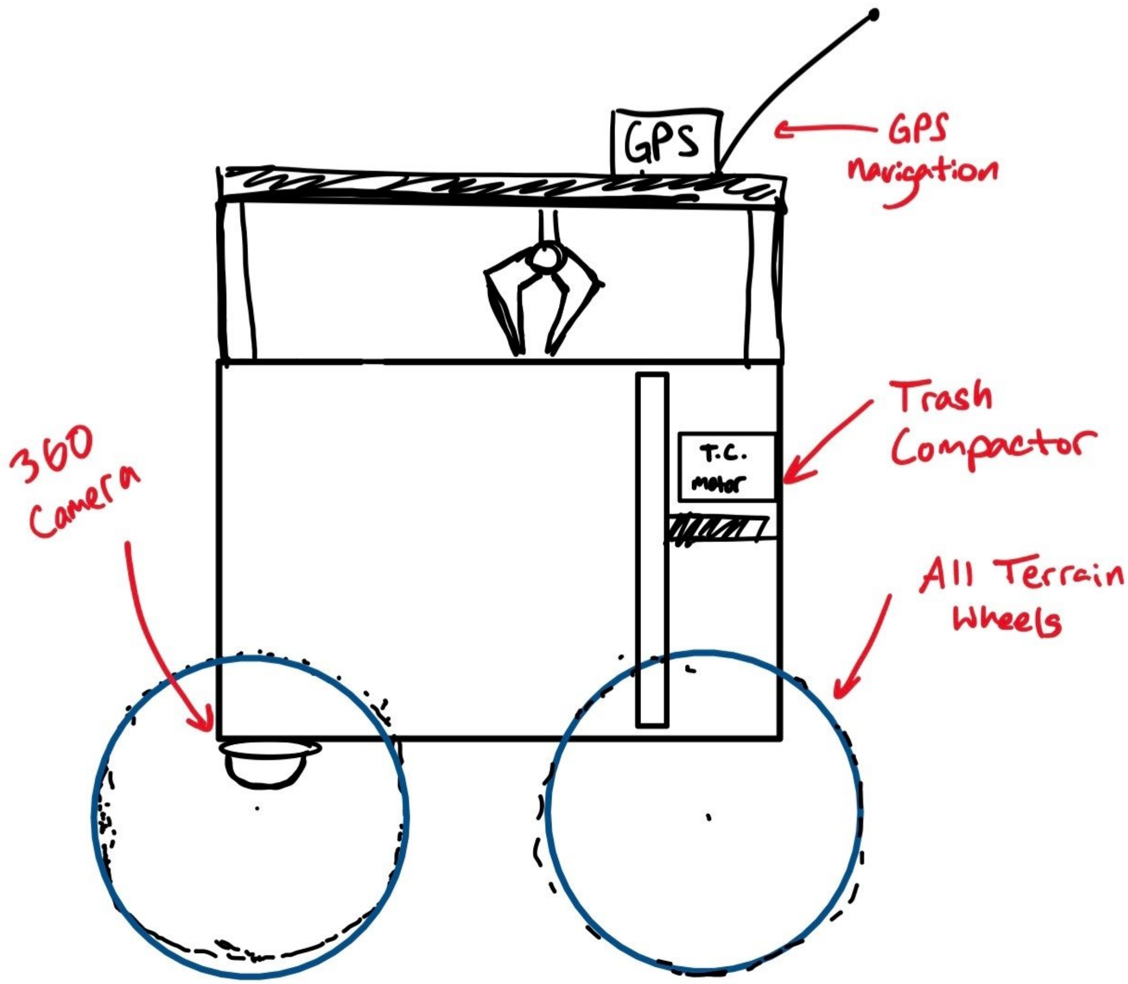
Minimize Visual Disruption from Lightin	No Lights	Red Lights	Shielded Lights	Submerged Lights		
Reduce Visual Contrast	Camo	Biological Design	Natural Materials	Submerged Components		
Enable Tool-Free Access	Snap-fit Lid	Thumb Screws	Hinged Panels	Latches		
Minimize Maintanence Time	Easy-access	Autonomous Cleaning Base	Self Clearing Filter	Corrosion Resistant Material		

Appendix J

Concept Sketches

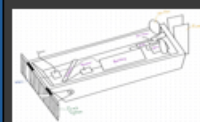
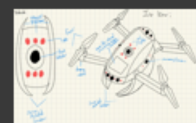
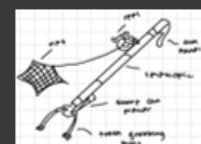
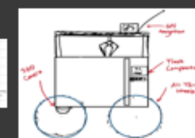
Figure J.5.2



Appendix K

Pugh Charts – Air Boat

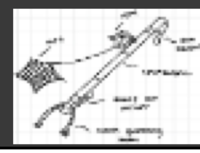
Figure K.1

Only use +, -, or S		Concepts				
		Air Boat (Datum)	Drone	Net Gun	Floating Channel	Creek Crawler
						
Criteria	Plastic Removal Effectiveness	0	-	0	+	0
	Wildlife Safety	0	0	0	0	+
	Public Transparency	0	0	-	0	0
	Collection Capacity	0	-	-	0	0
	Ease of Maintenence	0	-	+	0	0
	Ease of Deployment Relocation	0	+	+	+	0
	Durability and Reliability	0	0	0	0	0
	Noise and Visual Intrusion	0	0	+	0	0
	Cost and Ease of Manufacturing	0	-	+	0	-
	Mobility and Scability	0	+	+	0	0
	Risk of Technical Development	0	0	+	-	0
Totals	Positive Count	0+	2	5	2	1
	Negative Count	0-	4	2	0	1
	Total Sum	0	-2	3	2	0
	Rank	X	4	1	2	3

Appendix K

Pugh Charts - Drone

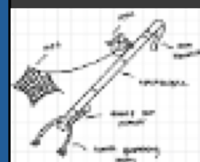
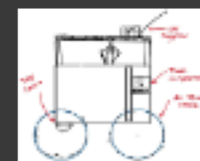
Figure K.2

		Concepts				
		Drone (Datum)	Net Gun	Floating Channel	Creek Crawler	Air Boat
						
Criteria	Plastic Removal Effectiveness	0	0	+	-	+
	Wildlife Safety	0	+	-	+	0
	Public Transparency	0	-	+	+	0
	Collection Capacity	0	-	+	+	+
	Ease of Maintenence	0	+	-	0	+
	Ease of Deployment Relocation	0	+	-	+	+
	Durability and Reliability	0	+	0	+	+
	Noise and Visual Intrusion	0	+	0	0	0
	Cost and Ease of Manufacturing	0	+	+	0	+
	Mobility	0	-	-	-	-
	Risk of Technical Development	0	+	0	0	0
Totals	Positive Count	0+	7	4	5	6
	Negative Count	0-	3	4	2	1
	Total Sum	0	4	0	3	5
	Rank	X	2	4	3	1

Appendix K

Pugh Charts – Net Gun

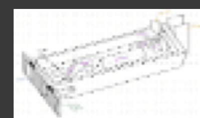
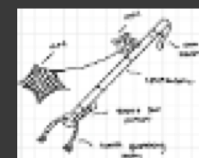
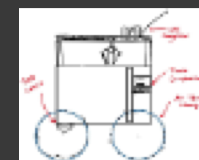
Figure K.3

		Concepts				
		Net Gun (Datum)	Air Boat	Drone	Creek Crawler	Floating Channel
						
Criteria	Plastic Removal Effectiveness	0	+	+	+	+
	Wildlife Safety	0	-	-	-	-
	Public Transparency	0	+	+	+	+
	Collection Capacity	0	+	+	+	+
	Ease of Maintenence	0	-	-	-	-
	Ease of Deployment Relocation	0	-	+	-	-
	Durability and Reliability	0	0	-	-	0
	Noise and Visual Intrusion	0	-	-	-	-
	Cost and Ease of Manufacturing	0	-	-	-	-
	Mobility	0	+	+	+	-
	Risk of Technical Development	0	0	-	-	-
Totals	Positive Count	0+	4	5	4	3
	Negative Count	0-	5	6	7	7
	Total Sum	0	-1	-1	-3	-4
	Rank	x	1	1	3	4

Appendix K

Pugh Charts – Floating Channel

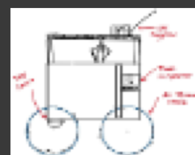
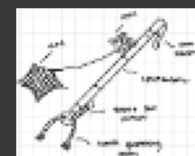
Figure K.4

		Concepts				
		Floating Channel (datum) 	Air Boat 	Drone 	Net Gun 	Creek Crawler 
Criteria	Plastic Removal Effectiveness	0	+	-	+	0
	Wildlife Safety	0	0	-	0	0
	Public Transparency	0	0	0	-	0
	Collection Capacity	0	+	-	0	0
	Ease of Maintenence	0	0	-	+	0
	Ease of Deployment Relocation	0	0	+	+	0
	Durability and Reliability	0	0	0	0	0
	Noise and Visual Intrusion	0	0	0	+	-
	Cost and Ease of Manufacturing	0	0	-	+	-
	Mobility and Scability	0	+	+	+	0
	Risk of Technical Development	0	+	-	+	0
Totals	Positive Count	0+	4	2	7	0
	Negative Count	0-	0	6	1	2
	Total Sum	0	4	-4	6	-2
	Rank	X	2	4	1	3

Appendix K

Pugh Charts – Creek Crawler

Figure K.5

		Concepts				
		Creek Crawler (Datum)	Air Boat	Drone	Net Gun	Floating Channel
						
Criteria	Plastic Removal Effectiveness	0	+	+	-	0
	Wildlife Safety	0	-	-	+	0
	Public Transparency	0	0	0	-	0
	Collection Capacity	0	-	-	-	0
	Ease of Maintenence	0	0	-	+	0
	Ease of Deployment Relocation	0	+	0	0	0
	Durability and Reliability	0	0	-	-	0
	Noise and Visual Intrusion	0	0	0	0	0
	Cost and Ease of Manufacturing	0	0	-	+	+
	Mobility and Scability	0	0	0	0	0
	Risk of Technical Development	0	+	-	+	0
Totals	Positive Count	0+	3	1	4	1
	Negative Count	0-	2	6	4	0
	Total Sum	0	1	-5	0	1
	Rank	X	1	4	3	1

Appendix L

Back of the Envelope Calculations – Air Boat

Figure L.1.1

1. **Baseline Assumptions of Boat:**

Boat: 2 ft length, 1 ft wide, ~6 in height.

Flat bottom hull design.

Weight: ~ 2.6 lbs

Center of Gravity:28-35% of hull length

Density: $p = \frac{m}{V} \quad (\frac{kg}{m^3})$

Buoyancy: $F_{buoyancy} = pVg \quad (N)$

2. **RC System:**

Battery: 2200 mAh

Motor: 300 – 600 W
(specs of power output follow torque speed plot)

$T_o = \frac{r_m}{R_m} v_{in,rated} - [\frac{r_m^2}{R_m} + B_m] w_m$ (N * m)

$Power = Torque(Angular\ Velocity)$ (Hp)

$Power = voltage(current) \quad (W)$

$voltage = current(resistance)$ (V)

3. **Prototype Cost:**

Power System: 2216 Brushless Motor (2200 KV): $35

Battery: 3S LiPo (11.1 V, 2200 mAh): $20

Hull materials: XPS Foam + Polycrylic or Paint: $25

Steering: Standard Servo: $12

Control: 2-Channel Radio & Receiver: $30

Mechanism: DIY wire mesh: $10

Charger: LiPo Balance Charger: $25

Misc: 6-7” Prop, Wire, Glue: $15

Total: ~ $172

Appendix L

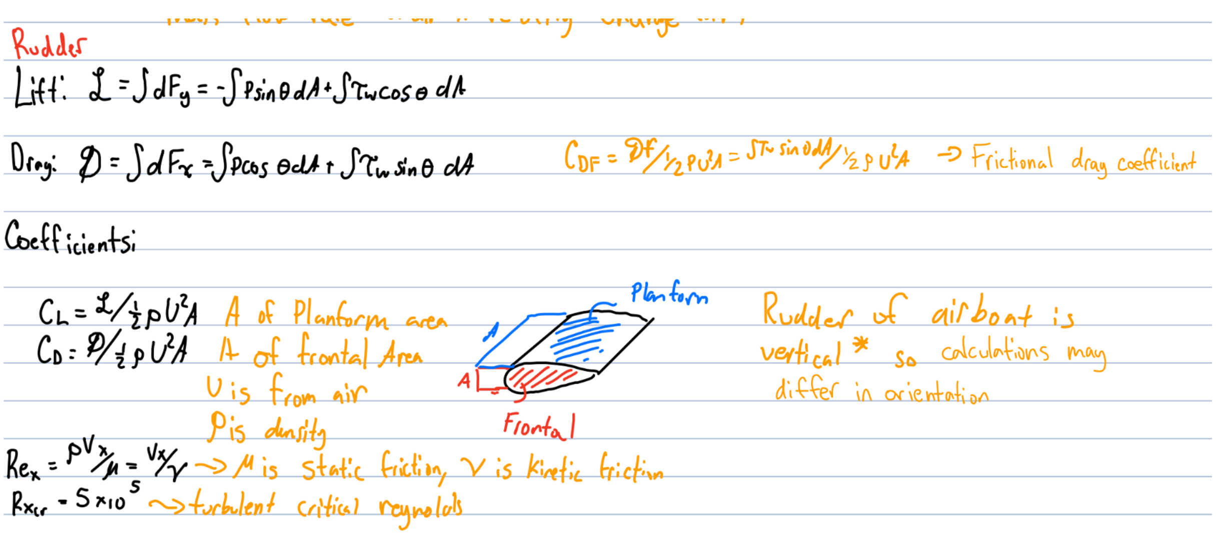
Back of the Envelope Calculations – Air Boat

Figure L.1.2

Component	Specs Needed	Est. Cost
Power System	3548 Brushless Motor (800-1000KV) + 70A-80A ESC	$75
Battery	4S LiPo (14.8V, 5000mAh)	$55
Hull Materials	XPS Foam + Fiberglass & Epoxy	$60
Steering	20kg Metal Gear Servo	$20
Control	Basic 2-Channel Radio & Receiver	$30
Mechanism	DIY PVC/Mesh Scoop	$20
Charger	LiPo Balance Charger	$25
Misc	10-12" Prop, Heavy wire, Glue	$20
TOTAL		~$305

Higher cost prototype BOM

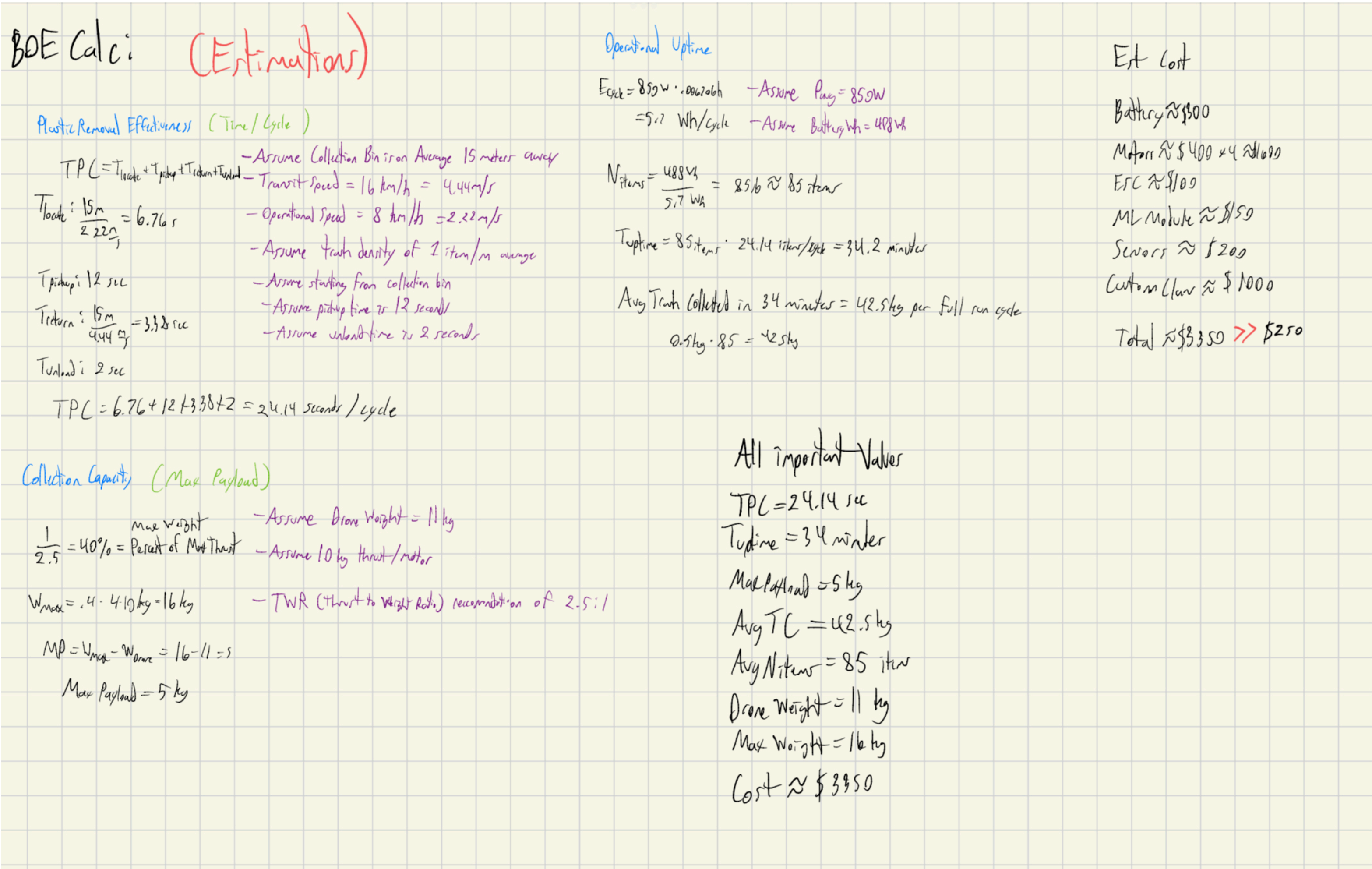
Figure L.1.3



Appendix L

Back of the Envelope Calculations – Drone

Figure L.2



BOE Calc: (Estimations)

Plastic Removal Effectiveness (Time / Cycle)

$TPC = T_{locate} + T_{pickup} + T_{return} + T_{unload}$

- Assume Collection Bin is on Average 15 meters away
- Transit Speed = 16 km/h = 4.44 m/s
- Operational Speed = 8 km/h = 2.22 m/s
- Assume trash density of 1 item/m average
- Assume starting from collection bin
- Assume pickup time is 12 seconds
- Assume unload time is 2 seconds

$T_{locate}: \frac{15m}{2.22 \frac{m}{s}} = 6.76 s$

T_{pickup}: 12 sec

$T_{return}: \frac{15m}{4.44 \frac{m}{s}} = 3.38 sec$

T_{unload}: 2 sec

$TPC = 6.76 + 12 + 3.38 + 2 = 24.14$ seconds / cycle

Collection Capacity (Max Payload)

- Assume Drone Weight = 11 kg
- Assume 10 kg thrust/motor
- TWR (Thrust to Weight Ratio) recommendation of 2.5:1

$\frac{1}{2.5} = 40\% =$ Max Weight / Percent of Max Thrust

$W_{max} = .4 \cdot 4 \cdot 10 kg = 16 kg$

$MP = W_{max} - W_{drone} = 16 - 11 = 5$

Max Payload = 5 kg

Operational Uptime

$E_{cycle} = 850 W \cdot .006706 h$ — Assume $P_{avg} = 850 W$

$= 5.7$ Wh/cycle — Assume Battery Wh = 488 Wh

$N_{items} = \frac{488 Wh}{5.7 Wh} = 85.6 \approx 85$ items

$T_{uptime} = 85_{items} \cdot 24.14$ items/cycle $= 34.2$ minutes

Avg Trash collected in 34 minutes = 42.5 kg per full run cycle

$0.5 kg \cdot 85 = 42.5 kg$

Est Cost

Battery ≈ $300

Motors ≈ $400 × 4 ≈ $1600

ESC ≈ $100

ML Module ≈ $150

Sensors ≈ $200

Custom Claw ≈ $1000

Total ≈ $3350 >> $250

All Important Values

TPC = 24.14 sec

T_{uptime} = 34 minutes

Max Payload = 5 kg

Avg TC = 42.5 kg

Avg N_{items} = 85 items

Drone Weight = 11 kg

Max Weight = 16 kg

Cost ≈ $3350

Appendix L

Back of the Envelope Calculations – Net Gun

Figure L.3

1. Baseline assumptions

- Telescopic pole (3 sections, extended length $L = 2.5$ m; collapsed 0.8 m). Base tube $D_o = 30$ mm, wall $t = 2$ mm; 6061-T6 Al, $E = 69$ GPa.
- Reel: size "2500", 5:1 gear, spool radius $r_{\text{reel}} = 25$ mm, handle radius $r_{\text{hand}} = 45$ mm.
- Line: braided Ø0.8 mm, tensile ≳ 500 N (50 kgf).
- Net: round hoop Ø0.35 m; while retrieving, effective projected area $A \approx 0.029\ \text{m}^2$(net partially collapsed); $C_d = 1.1$, water density $\rho = 1000\ \text{kg/m}^3$.
- Probe: stainless rod Ø6 mm, length 0.4 m (pinned-pinned for buckling).
- "Typical debris" payload ≈ 2 kg when netted (bottles, cups, weeds).

2.1 Pole bending at full extension

End load $F = mg = 2\ \text{kg} \cdot 9.81 \approx 19.6$ N.
Cantilever moment at base $M = FL = 19.6 \cdot 2.5 = 49.0$ Nm.
For a thin tube: $I = \frac{\pi}{64}(D_o^4 - D_i^4)$, $D_i = D_o - 2t = 26$ mm
$I \approx 1.16 \times 10^{-8}\ \text{m}^4$; $c = D_o/2 = 0.015$ m

- Bending stress: $\sigma = \frac{Mc}{I} \approx \frac{49.0 \cdot 0.015}{1.16 \times 10^{-8}} \approx$ 42 MPa
  (good vs. ~250 MPa yield; SF≈6)
- Tip deflection: $\delta = \frac{FL^3}{3EI} \approx \frac{19.6 \cdot 2.5^3}{3 \cdot 69 \times 10^9 \cdot 1.16 \times 10^{-8}} \approx 85$ mm

Implication**:** 2 kg at 2.5 m is comfortable.
Design SWL**:** 2.0 kg with ≥1.5× ultimate margin ≈ 3 kg.

2.2 Probe buckling

Euler $P_{\text{cr}} = \frac{\pi^2 EI}{(KL)^2}$, $E_{SS} \approx 193$ GPa, $K = 1$.
$I = \frac{\pi d^4}{64}$with $d = 6$ mm, $L = 0.4$ m→ $P_{\text{cr}} \approx$ 760 N(~77 kgf).
Plenty for puncturing cans/soft trash.

3.1 Net retrieval drag ($v = 0.5$ m/s)

$F_D = \frac{1}{2}\rho C_d A v^2 = 0.5 \cdot 1000 \cdot 1.1 \cdot 0.029 \cdot 0.5^2 \approx 4.0$ N.
Even with weeds, assume total line tension target limit $T_{\text{set}} \approx 150$ N

3.2 Hand force on reel at drag limit

Spool torque $\tau_{\text{reel}} = T_{\text{set}} r_{\text{reel}} = 150 \cdot 0.025 = 3.75$ Nm
Hand force $F_{\text{hand}} = \frac{\tau_{\text{reel}}}{G\, r_{\text{hand}}} = \frac{3.75}{5 \cdot 0.045} \approx$ 16.7 N (~1.7 kgf).
Comfortable for sustained cranking. Drag limit protects the pole & line.

4. Grabber linkage force

Peak human grip ≈ 200 N at handle; 3:1 linkage → tip ≈ 600 N.
Plenty to pinch bottles or pry stuck items; add over-center latch to hold without sustained grip.

5. Weight & ergonomics

- Telescopic tubes (30×2, 26×1.5, 22×1.5; 0.9 m each) → ~0.94 kg
- Reel (~0.25 kg) + hoop/net (~0.20 kg) + grabber/probe (~0.20 kg) + grips/hardware (~0.15 kg)
  Total ≈ 1.7–1.8 kg (4.0 lb). Balanced center-of-mass near grip by placing reel under the hand.

6. Range, cycle time, throughput

- Reach (close-in): arm (~0.6 m) + pole (2.5 m) → ~3.1 m radius.
- Cast range (net): conservative 5–8 m (short-lead cast with 20–30 g sinker).
- Cycle time: cast (4s) + settle (2s) + retrieve (12s) + dump (2s) ≈ 20 s per item if fishing single objects.
- Throughput: 3 items/min best-case; plan = 1–2 items/min (60–120/hour) in realistic mixed debris.

7. Prototype BOM (off-the-shelf)

- Telescopic aluminum pole (30/26/22 mm): $35
- Spinning reel (size 2500) with drag: $30
- Braided line Ø0.8 mm, 50 m: $12
- Folding landing net (Ø35 cm): $25
- Stainless 3-jaw grabber head: $18
- Probe tip (6 mm SS rod + hardened tip): $6
- 3D-printed adapters & clamps: free
- Rubber grip + wrist lanyard: $9
- SS fasteners & quick pins: $8
- Epoxy/Loctite/tape wraps: free

Prototype total ≈ $143

Appendix L

Back of the Envelope Calculations – Floating Channel

Figure L.4

1. **Intake Hydraulics**
   - Target approach velocity: cap for wildlife safety ($V_a < 0.15$ m/s)
   - Required Intake Area: $A_{intake} = Q/V_a$
   - Module Flow rate: $Q = \sum A_{fan,i} * V_{fan,i}$
2. **Fan Sizing and Power**
   - Hydraulic Power: $P_h = \Delta p_{total} * Q$
   - Electrical Power: $P_e = P_h/n_{sys}$
3. **Intake Screen Design**
   - Bar Spacing Check: choose spacings that blocks target wildlife and large debris
   - Velocity through Bars: $V_b = Q/A_{open}$ with $A_{open} = b*s*H$
   - Screen Drag Force: $F_s \approx \Delta p_{rack} * A_{proj}$
4. **Retention Against Wake Backflow (one-way flow)**
   - Flap cracking pressure: $p_c > \Delta p_{wake}$
   - Flap torque check: $M = \Delta p*A*r$
5. **Visual Lighting Intrusions**
   - Glare Limit: pick finish; if lighting used, calculate illuminance at shore (lux)
6. **Weight & Handling**
   - Module Mass Target: $m< 25\text{-}30$ kg
   - Moment During Carry: Able for safe carry
7. **Capture Performance Metrics**
   - Macro capture efficiency: % of seeded items captured
   - Micro capture efficiency: $n = 1 - C_{out}/C_{in}$ from sample bottles
   - Retention After Wake: % retained during imposed n waves
8. **Structural Checks**
   - Channel wall stress: plate bending under hydro load $\sigma \sim \Delta p a^2/t^2$
   - Fasteners: $F = \Delta p * A$
   - Anchor/tie-back load: combine steady drag and wave impulse
9. **Prototype BOM**
   - 2 Low-RPM impellers: $100
   - Filter cassette: $50
   - HDPE sheet: $100
   - Fasteners (bolts, washers, rivets): $30
   - Anchor: $30
   - Check-flap materials: $20
   - Wiring, fuse, switch: $30

Prototype Total: $360

Appendix L

Back of the Envelope Calculations – Creek Crawler

Figure L.5

1. **Volume**
   - Overall = 0.8m x 0.6m x 0.6m
   - Internal Trash Bay = 0.5m x 0.4m x 0.4m = $0.1m^3$
2. **Mass**
   - Without payload = 18kg HDPE
   - Loose Payload = 4-8kg
   - Compacted Payload = 12-18 kg
   - Total System mass = 33 kg
3. **Wheels**
   - Radius = 0.15m
   - Wheelbase = 0.55m
   - Torque $\tau = F * r = 66 \; * 0.15 = 10\ N$
   - Tank Drive
4. **Compaction**
   - Target compaction ratio = 3:1
   - Force target = 1250 N
   - Torque target = 6 N*m at screw with 10-12 N*m motor

5. **Electronics**
   - Battery capacity = 24V * 20Ah = 480 Wh
   - Avg power draw (drive + compactor + electronics) = 150-195W
   - Battery runtime = 2.5-3 hours
   - Effective range = 5-6 km at 0.5 m/s

6. **Performance Metrics**
   - Debris Capture Rate: % of visible items picked up per pass
   - Cycle Time per pickup: time from spotting to storing
   - Runtime per Charge: operation time before battery depletion

7. **Forecasted BOM**

- Microcontroller + RC receiver: $35
- Drive motors (2× high-torque gearmotors): $80
- Battery (24 V, 20 Ah LiFePO4): $120
- Compactor motor + linkage: $45
- Chassis + wheels (aluminum + all-terrain wheels): $60
- 360 camera module: $40
- Misc. hardware (fasteners, wiring, mounts): $20
- Estimated Total: ~$300

Appendix M

Failure Mode and Effects Analysis

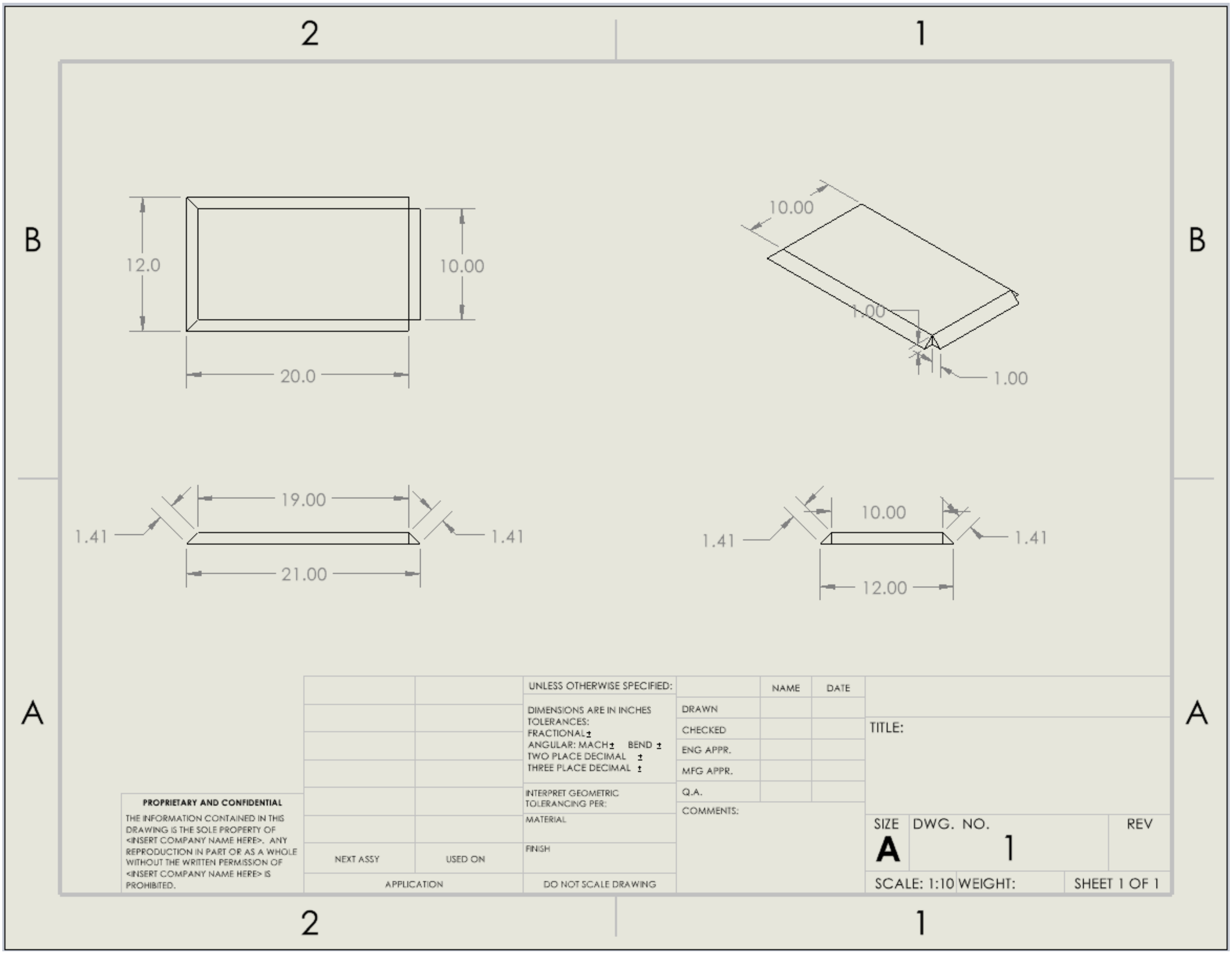
Figure M.1

				Current Situation						*Improved Situation*				
Failure Location	**Failure Mode**	**Failure Effect**	**Failure Cause**	**Current Detection Steps**	**S**	**O**	**D**	**RPN**	**Suggested Remedial Measures**	**Revision**	**S**	**O**	**D**	**RPN**
Floatation	Puncture	Partial/Full Sinking	Collision	Visual Inspection before launch	9	3	6	162	Add HDPE on bottom/bumper					
Floatation	Wear	Loss of buoyancy	Rough Handling	Visual Inspection before launch	9	3	6	162	Add HDPE on bottom/bumper					
Floatation	Flooding	Electronics swamped	Weight/Water Height	Monitor boat trim	8	4	5	160	Raise deck height/thickness					
Comb	Vegetation Jam	Boat stalls	Heavy vegetation	Watch comb for buildup	7	6	6	252	Angled weed-deflector bar	Angled weed-deflector bar	7	3	4	84
Comb	Buckling	Reduced Efficiency	Impacts	Visual Inspection before launch	6	4	6	144	HDPE comb					
Comb	Rotting	Reduced Efficiency	Water	Visual Inspection before launch	6	4	6	144	Laminate Wood/HDPE					
Comb	Trash Slippage	Wasted Effort	No side rails/steering	Experimental Testing	5	5	5	125	Add low perimeter rail/curvature					
Propulsion	Hit by Debris	Loss of thrust	No debris guard	Scanning Environment/Steering	9	2	4	72	Mesh Fan Guard					
Propulsion	Loose Fitting	Loss of control	Insufficient fasteners	Physical Test before launch	6	5	5	150	Lock nuts/Threads					
Electronics	Flooding	Power Loss	Splashing	Check box for leaks/condensatino	9	4	5	180	Electronics enclosure	Electronics enclosure	9	2	3	54
Electronics	Loose Wires	Power Loss	Vibration	Monitor steering responses	7	4	5	140	Locking connectors/clamps					
Electronics	Signal Loss	Loss of control	Range/Battery	Perform range test	8	5	6	240	Receiver failsafe/high antenna	Receiver failsafe/high antenna	8	3	4	96

Appendix N

Engineering Drawings – Hull Bottom

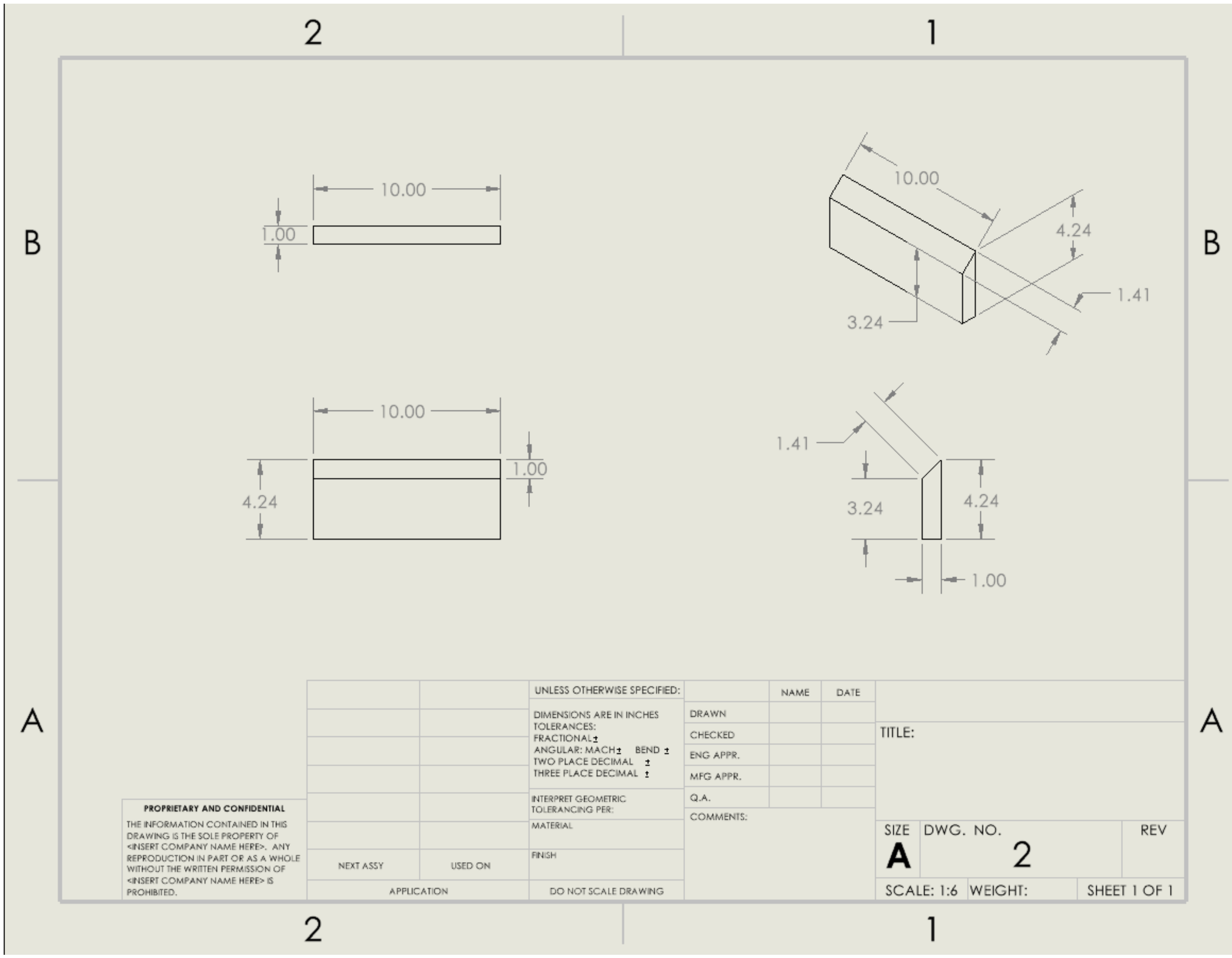
Figure N.1



Appendix N

Engineering Drawings – Hull Front

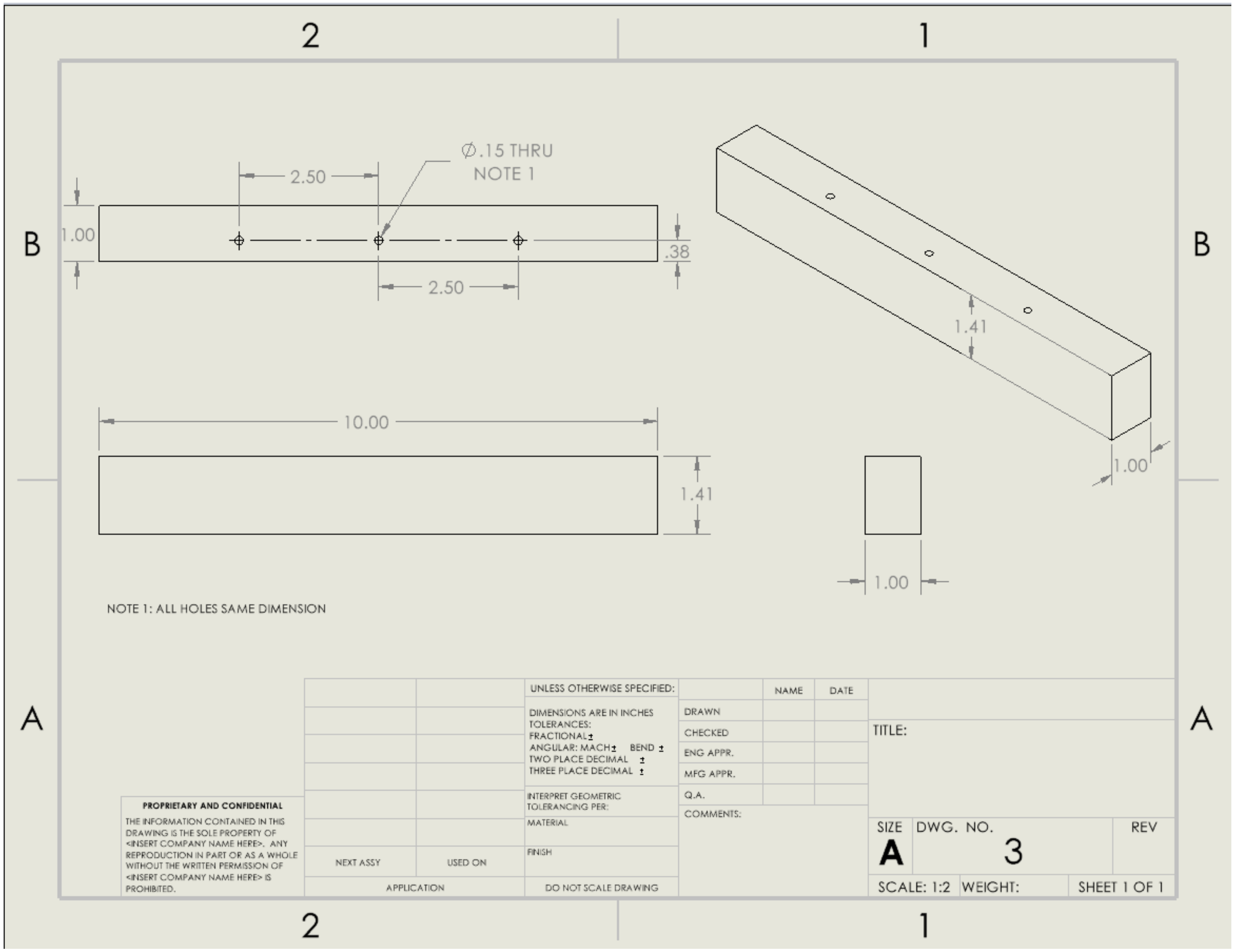
Figure N.2



Appendix N

Engineering Drawings– Hull Wall Left

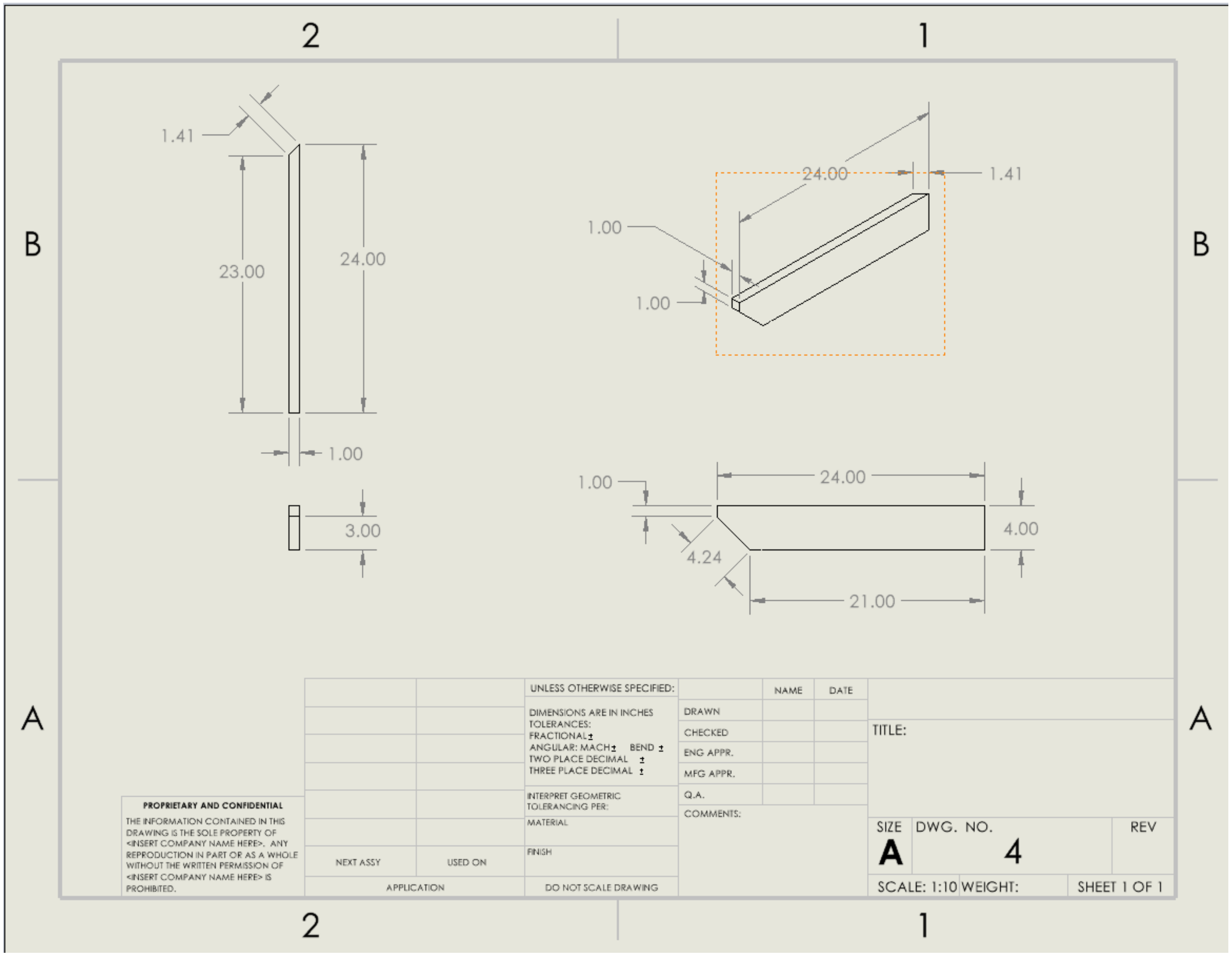
Figure N.3



Appendix N

Engineering Drawings – Hull Back

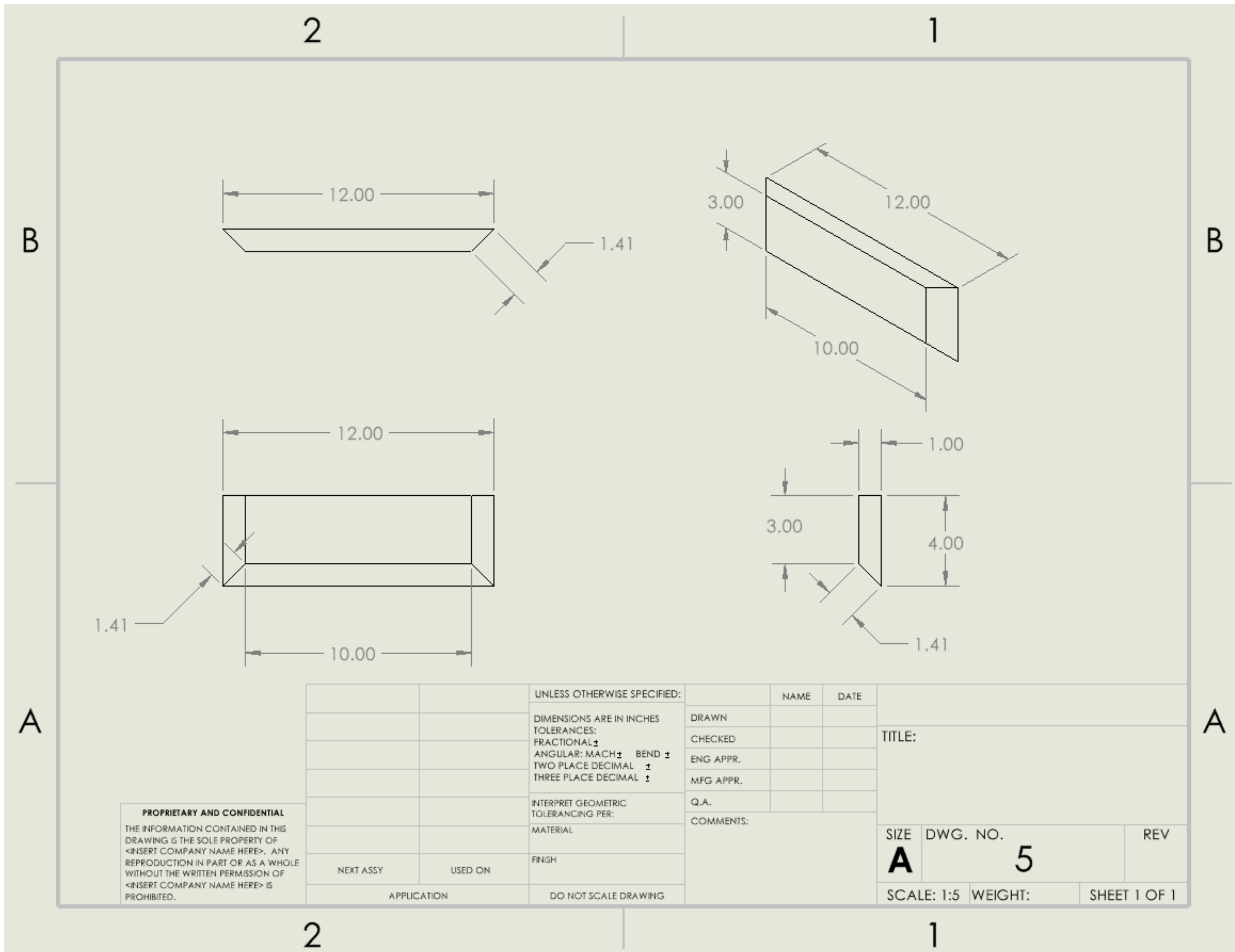
Figure N.4



Appendix N

Engineering Drawings – Hull Front Top

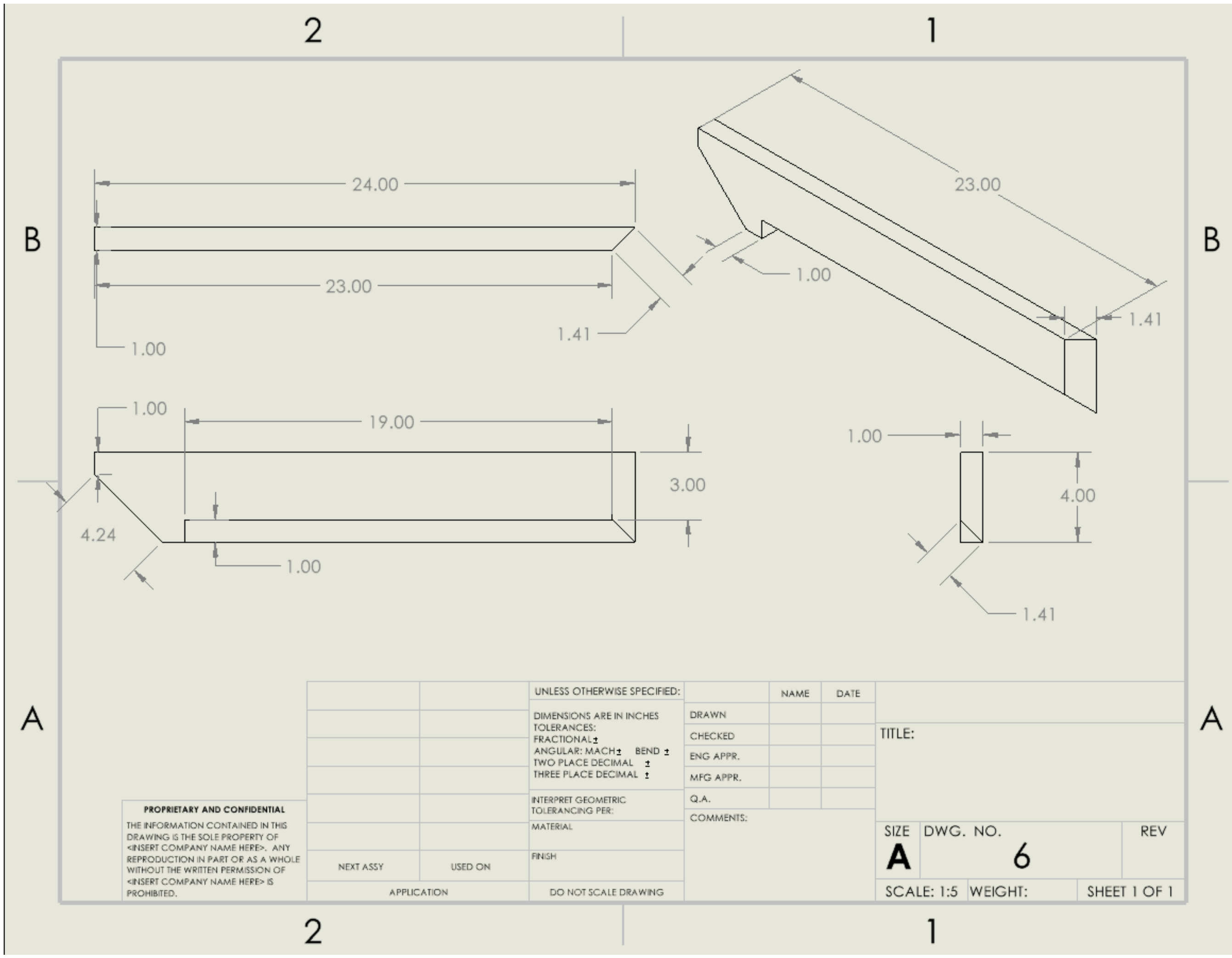
Figure N.5



Appendix N

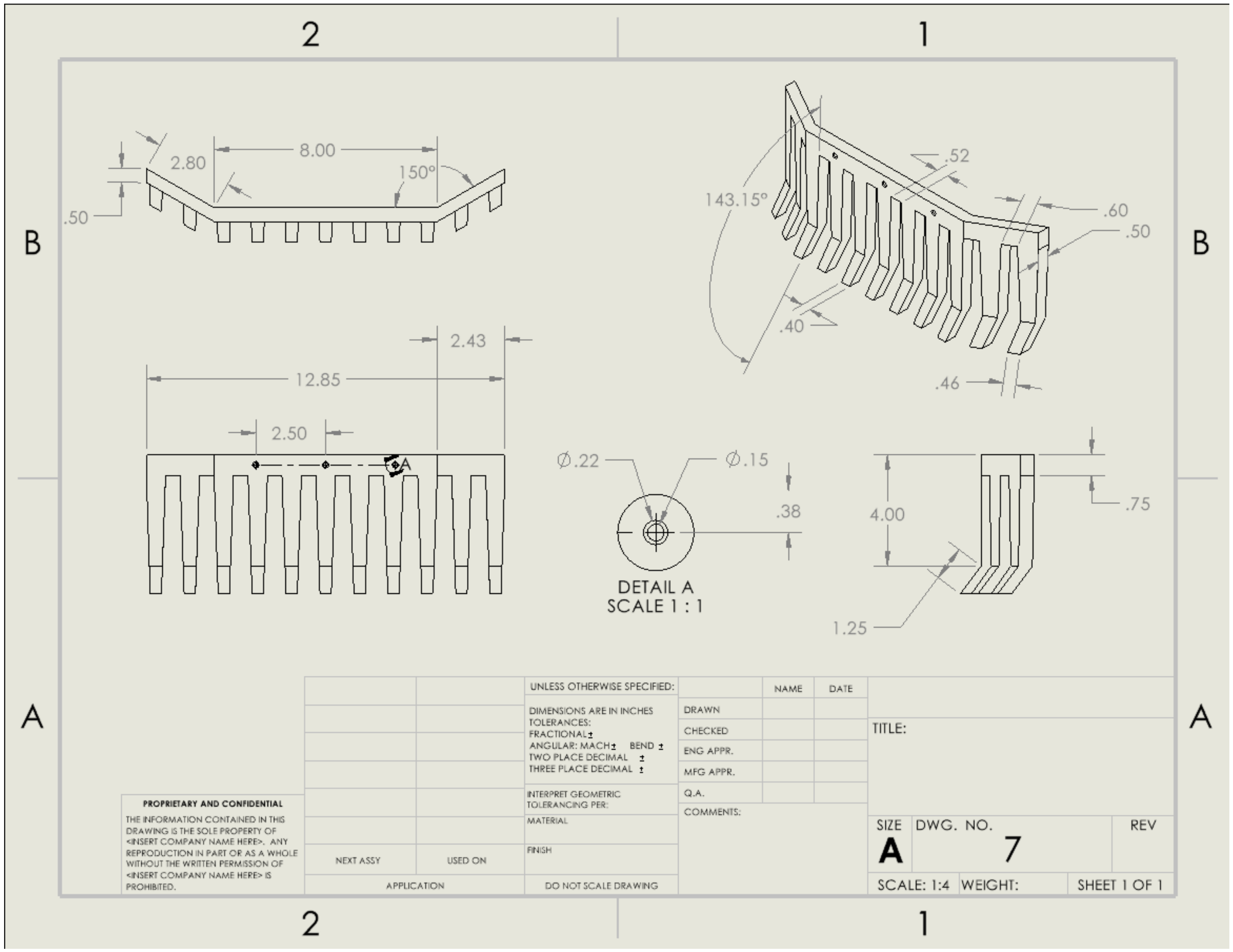
Engineering Drawings – Hull Wall Right

Figure N.6



Appendix N
Engineering Drawings – Rake

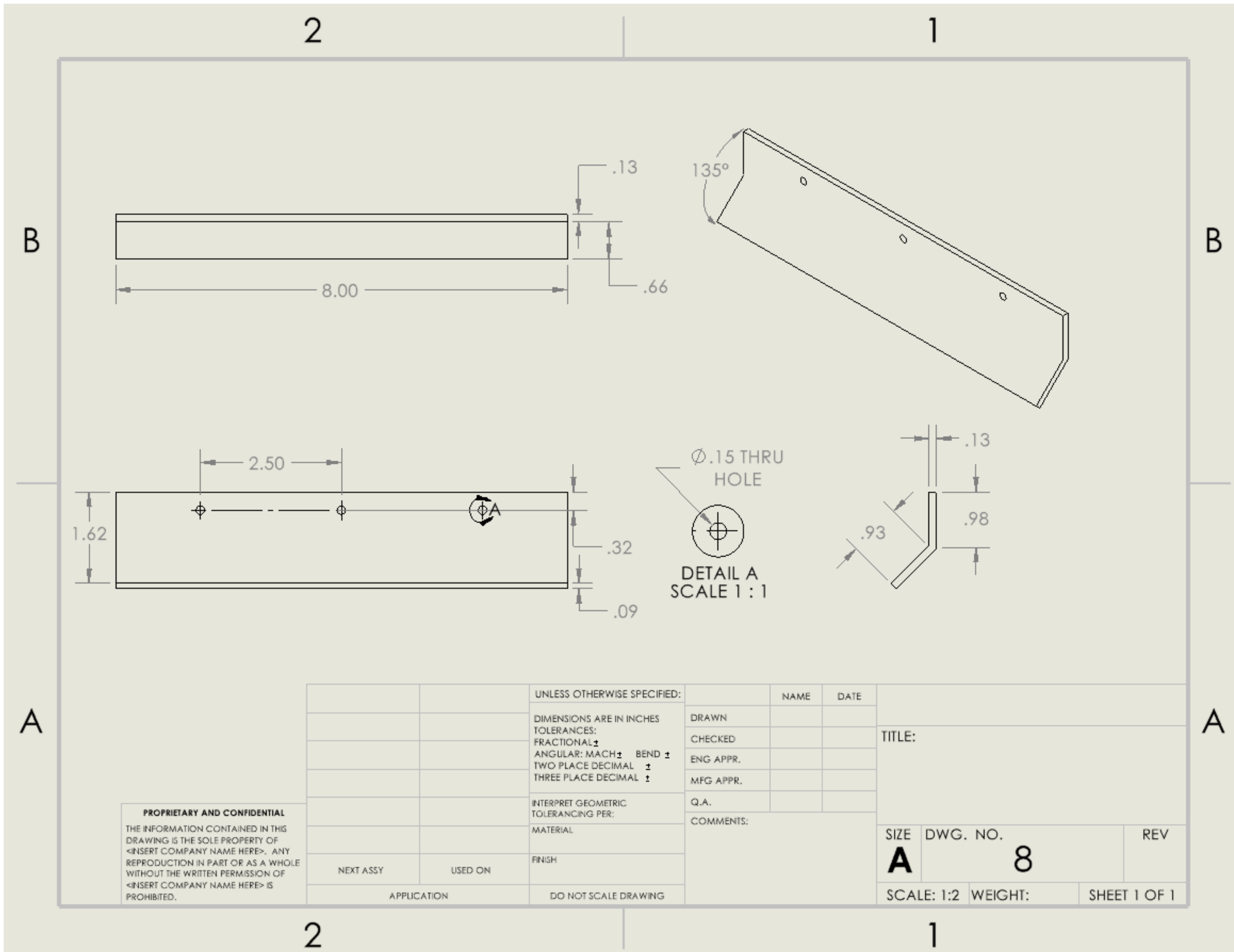
Figure N.7



Appendix N

Engineering Drawings – Hull Plate Out

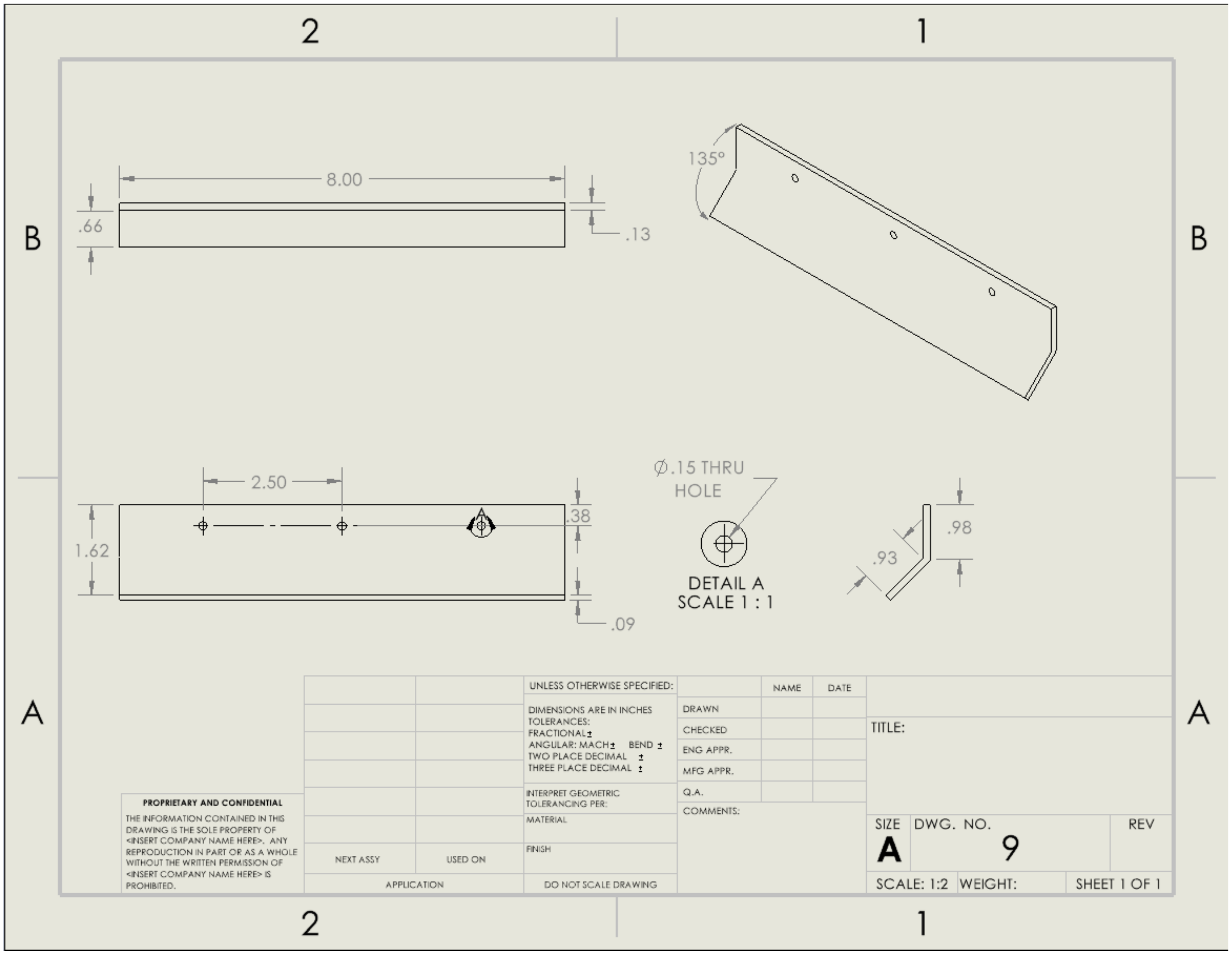
Figure N.8



Appendix N

Engineering Drawings – Hull Plate In

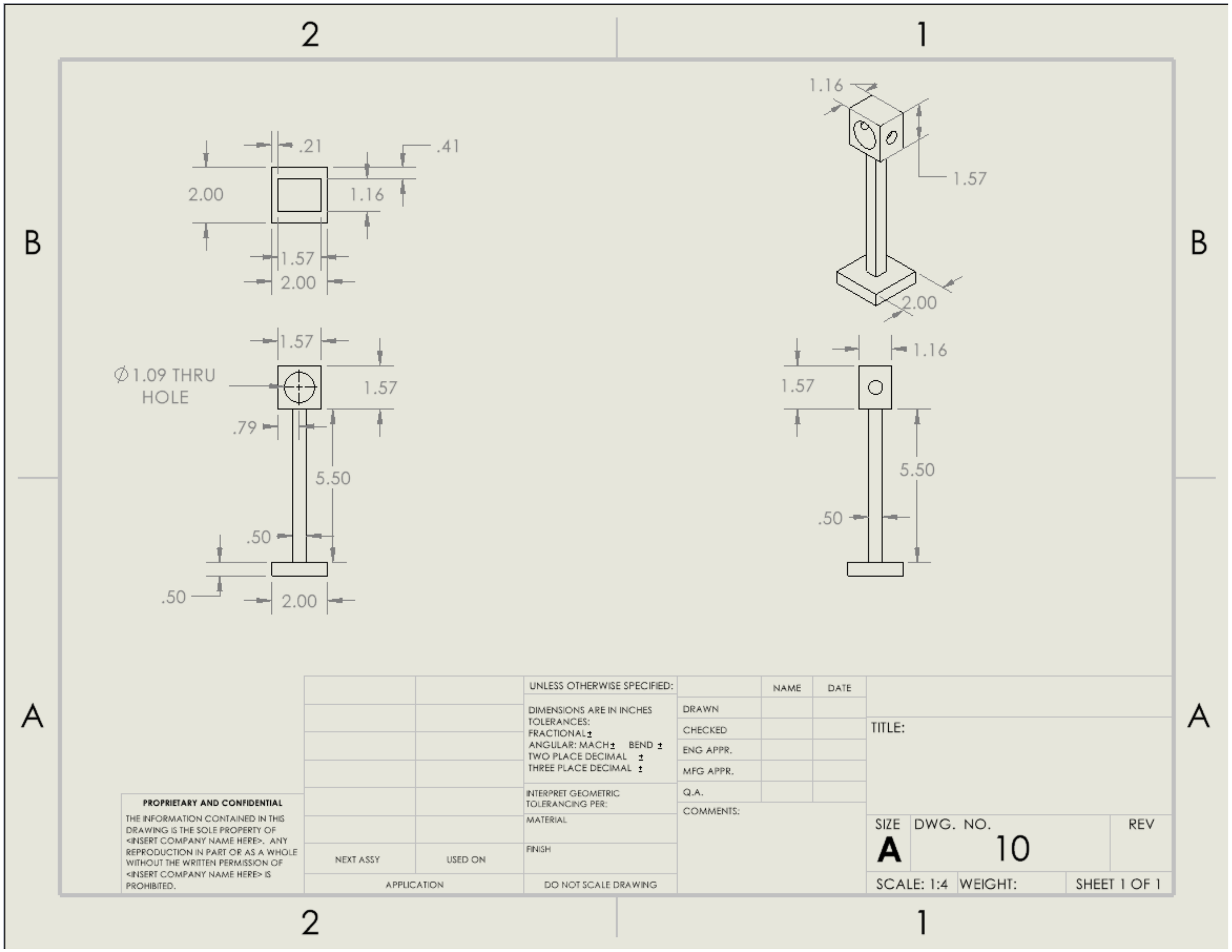
Figure N.9



Appendix N

Engineering Drawings – Motor Mount

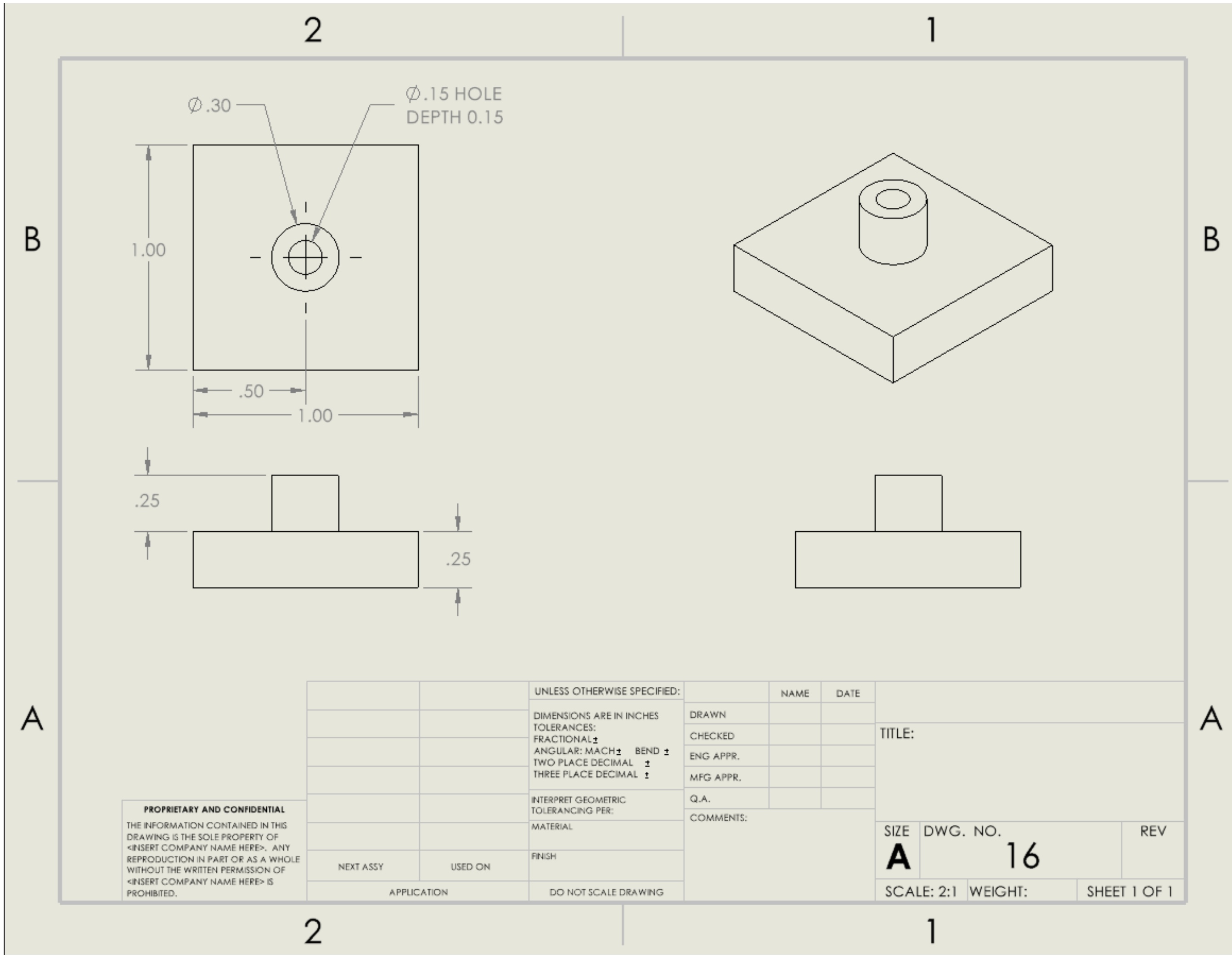
Figure N.10



Appendix N

Engineering Drawings – Antenna Mount

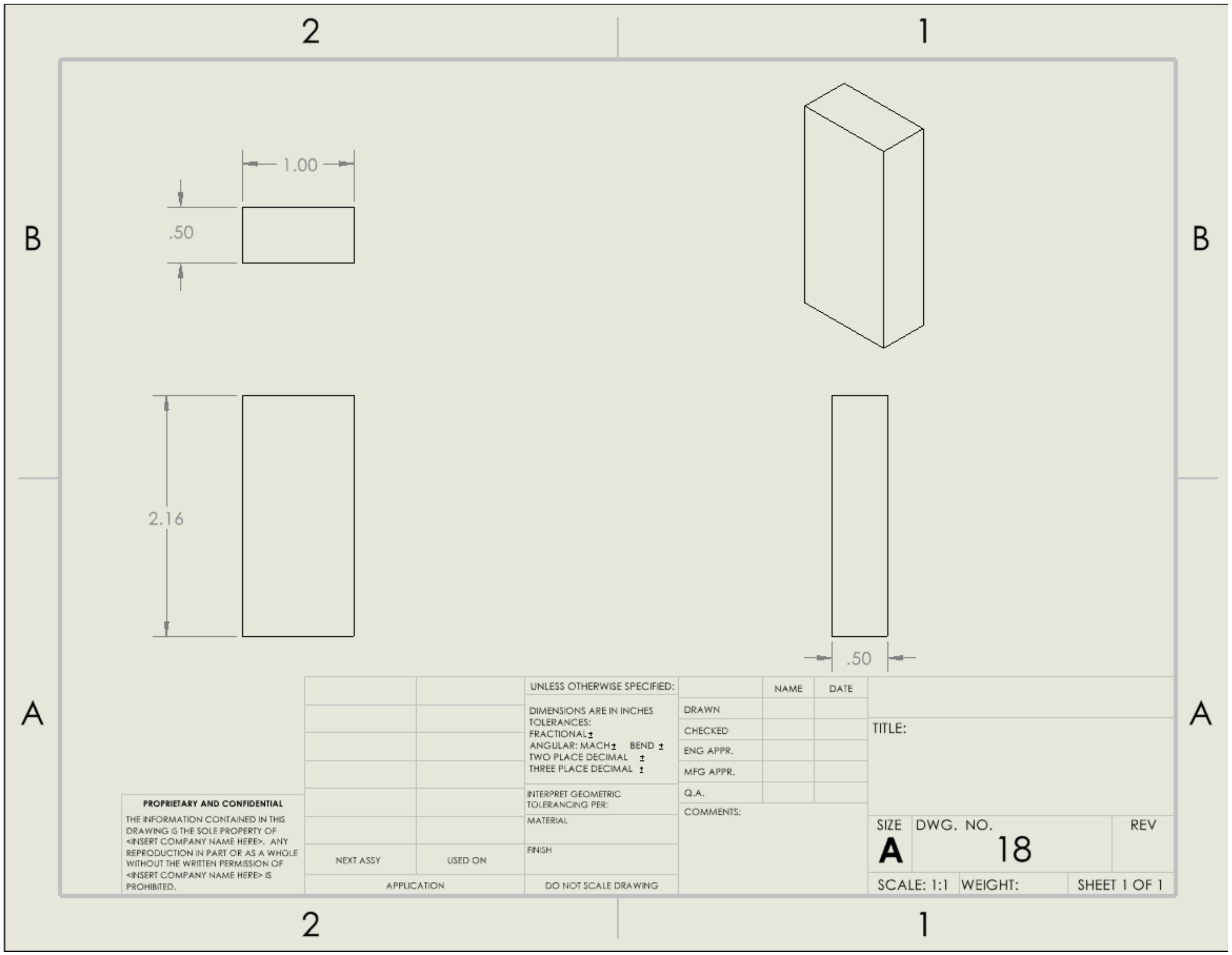
Figure N.11



Appendix N

Engineering Drawings – Servo Holder

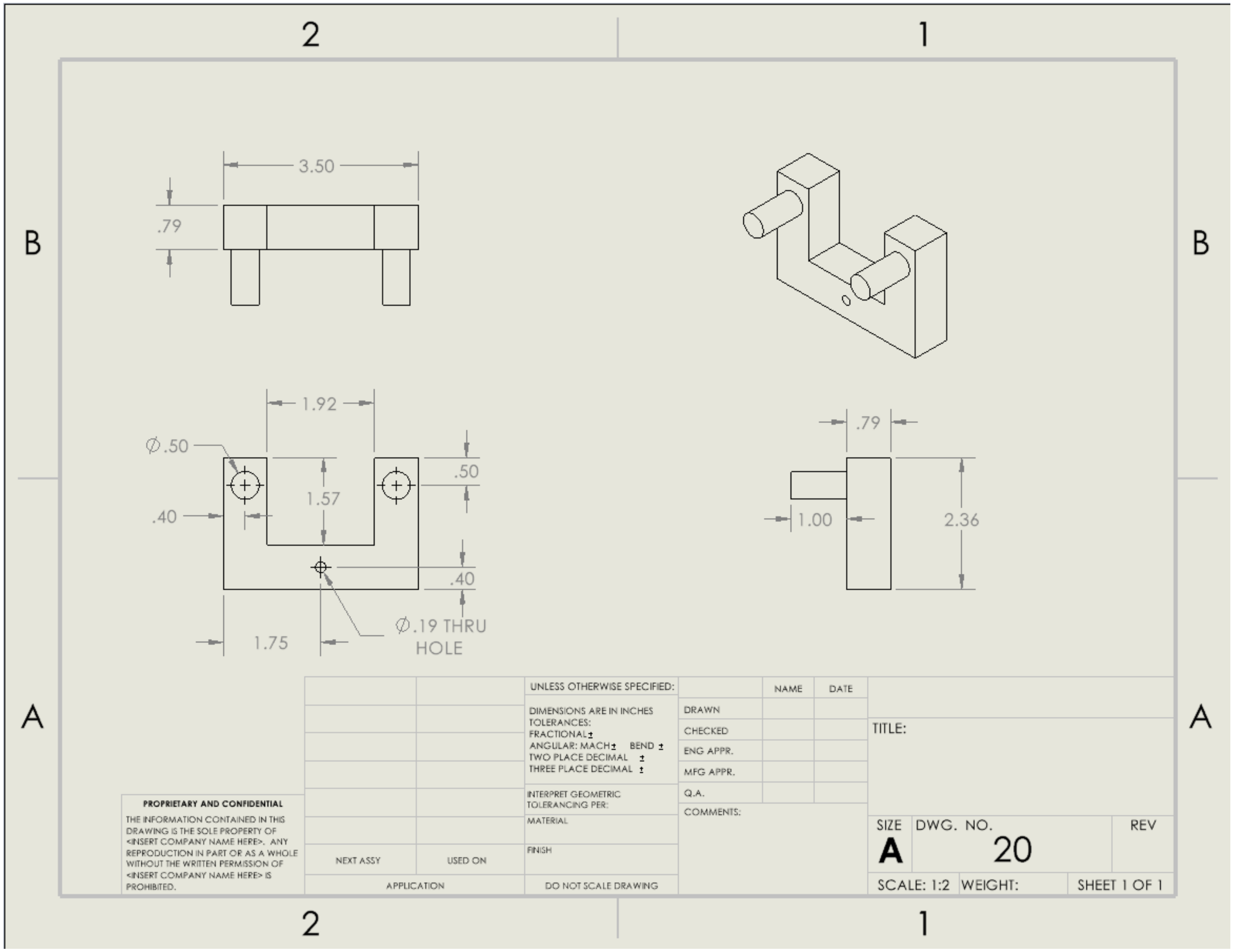
Figure N.12



Appendix N

Engineering Drawings – Servo System

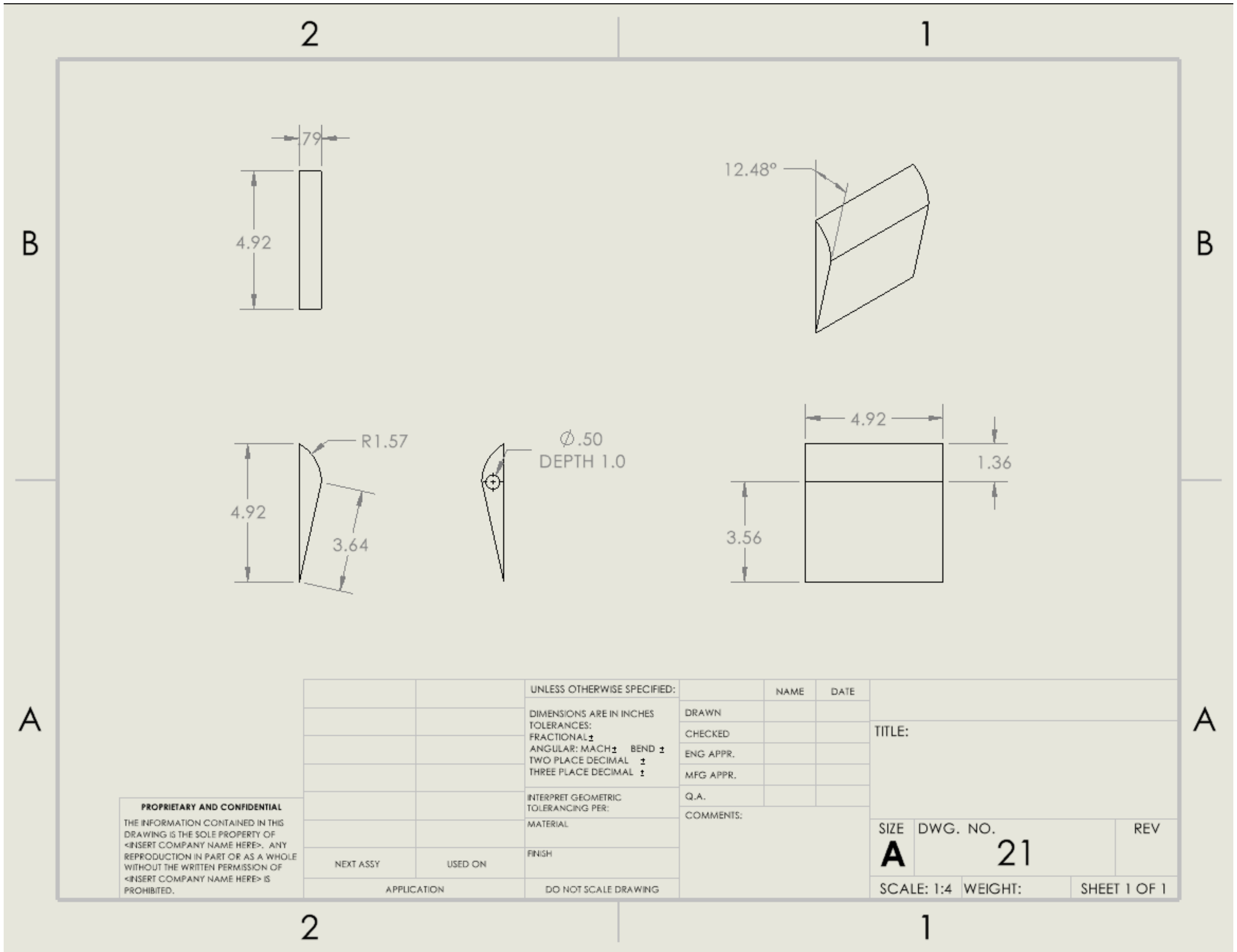
Figure N.13



Appendix N

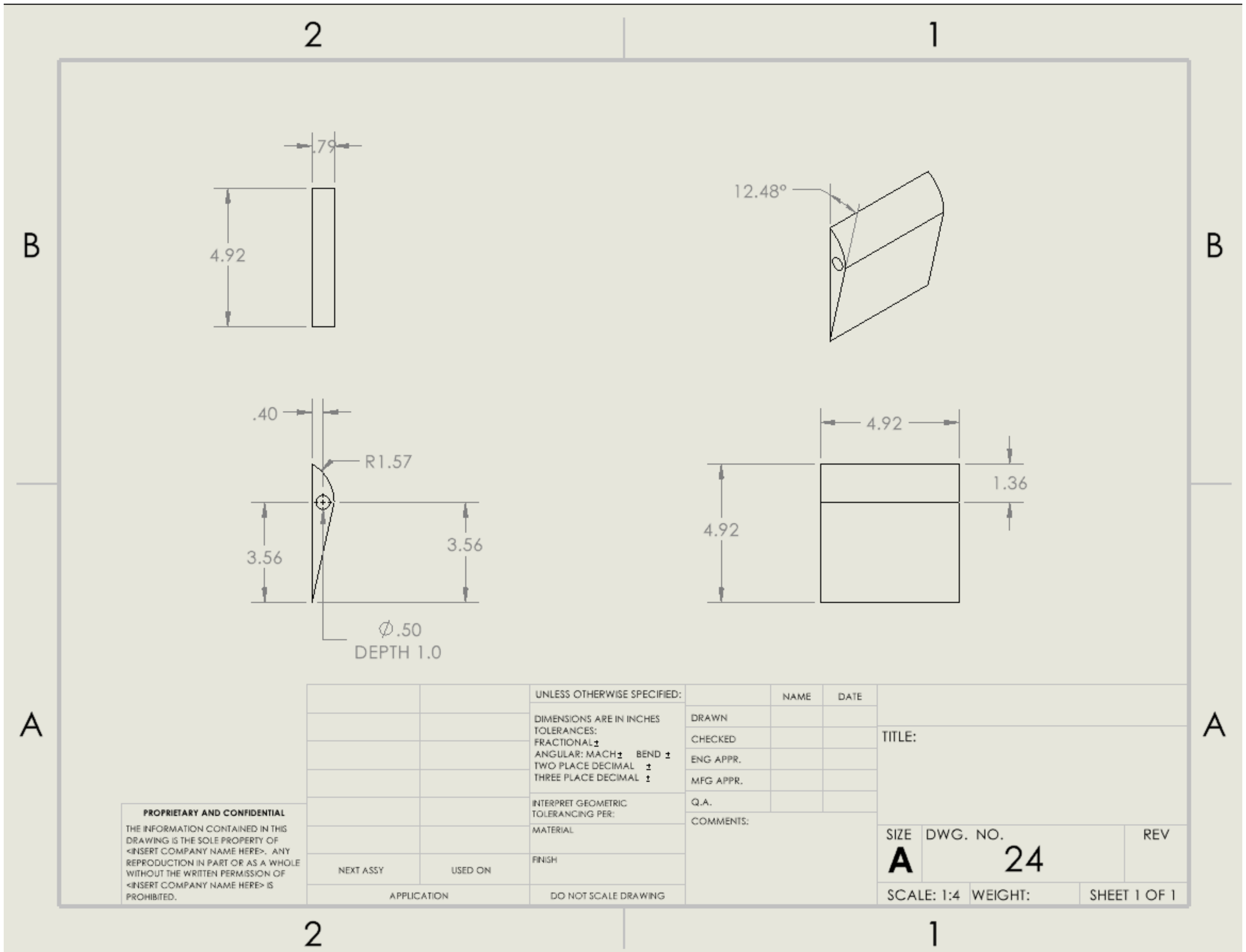
Engineering Drawings– Rudder Right

Figure N.14



Appendix N
Engineering Drawings – Rudder Left

Figure N.15



Appendix O

Assembly Plan

Figure O

Step	Part	Task	Tools	Direction
1	Hull Right	Attach to Hull Base	Epoxy	+y
2	Hull Left	Attach to Hull Base	Epoxy	-y
3	Hull Back	Attach to Hull Base	Epoxy	-x
4	Hull Front Bottom	Attach to Hull Base	Epoxy	+x
5	Hull Front Top	Attach to Hull Front Bottom	Epoxy	+z
6	Inner Mounting Plate	Attach to Hull Front Top	Bolts/Nuts	-x
7	Outer Mounting Plate	Attach to Hull Front Top	Bolts/Nuts	+x
8	Rake	Attach to Outer Mounting Plate	Bolts/Nuts	+x
9	Motor	Attach to Motor Mount	Press Fit	+x
10	Fan	Screw into Motor	Screw	-x
11	Motor Mount	Attach to Hull Base	Epoxy	+z
12	Servo Holder	Attach to Hull Base	Epoxy	+z
13	Servo	Attach to Servo Holder	Adhesive	+z
14	Servo Mount	Attach to Servo	Press Fit/Adhesive	+z
15	Right Rudder	Attach to Servo Mount	Press Fit/Glue	+z
16	Left Rudder	Attach to Servo Mount	Press Fit/Glue	+z
17	ESC	Attach to Hull Base	Glue	+z
18	Antenna Mount	Attach to Hull Base	Glue	+z
19	Antenna	Attach to Antenna Mount	Thread	+z
20	Battery	Attach to Hull Base	Glue	+z
21	Receiver	Attach to Hull Base	Glue	+z

Appendix P

Bill of Materials

Figure P

Item	Part Number	Description	Qty	Cost
1	RC_Airboat_Prototype_Hull_Bottom	XPS Foam Hull	1	$ 3.00
2	RC_Airboat_Prototype_Hull_Front	XPS Foam Hull	1	$ 3.00
3	RC_Airboat_Prototype_Hull_Wall	XPS Foam Hull	1	$ 3.00
4	RC_Airboat_Prototype_Hull_Back	XPS Foam Hull	1	$ 3.00
5	RC_Airboat_Prototype_Hull_Front_Top	XPS Foam Hull	1	$ 3.00
6	RC_Airboat_Prototype_Hull_Wall_R	XPS Foam Hull	1	$ 3.00
7	RAKEv5	Rake / Comb	1	$ 10.00
8	RC_Airboat_Prototype_Hull_Plate	Mounting Plate Out	1	$ 2.00
9	RC_Airboat_Prototype_Hull_PlateIn	Mounting Plate In	1	$ 2.00
10	RC_Airboat_Prototype_Motor_Mount	Motor Mount	1	$ 2.00
11	SUNNYSKY X2216-6 ultra-realistic	Motor	1	$0 (borrowed from ME dept)
12	Fan 15 blades	Fan Blades	1	$0 (borrowed with motor)
13	Part4	Battery	1	$0 (borrowed from ME dept)
14	servo.MG90S	Servo	1	$0 (borrowed from ME dept)
15	spektrum_esc	ESC	1	$0 (borrowed from ME dept)
16	RC_Airboat_Prototype_Antennae_Holder	Antenna Mount	1	$ 1.00
17	spektrum_flight_computer	Receiver / Flight Computer	1	$0 (borrowed from ME dept)
18	RC_Airboat_Prototype_Servo_Holder	Servo Holder	1	$ 1.00
19	RC_Airboat_Prototype_Antennae	Antenna	1	$0 (included with receiver)
20	RC_Airboat_Prototype_Servo_System	Servo Mount	1	$ 1.00
21	RC_Airboat_Prototype_RudderR	Right Rudder	1	$ 2.00
22	92095A489	Button Head Hex Drive Screw	3	$0.20 each (≈$0.60)
23	92095A151	Zinc-Plated Steel Hex Nut	3	$0.10 each (≈$0.30)
24	RC_Airboat_Prototype_Rudder	Left Rudder	1	$ 2.00
Total				$ 41.00