CROCODILE HOVERCRAFT FINAL DESIGN REPORT

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ABSTRACT

This project addresses the environmental and public service challenges that exist for traditional modes of transportation. The hovercraft was designed to operate efficiently over multiple different terrains with no emissions. We were able to minimize weight by using a composite frame, using multiple leaf blowers to optimize lift, and creating a custom skirt structure for the frame design. The prototype successfully met all specifications for speed, maneuverability, and braking. Further improvements could be made to the efficiency of the batteries, adaptability for different terrains, and sustainability and accessibility of the hovercraft.

PROBLEM DEFINITION

Current modes of transportation contribute significantly to environmental pollution and urban congestion. Gas powered vehicles release greenhouse gases that accelerate climate change [1], while traffic inefficiencies increase fuel use and travel time. Also, transportation costs can limit accessibility for those who can't afford it. These issues are critical for both societal and environmental reasons. Reducing pollution is essential for combating climate change and improving air quality and efficient and affordable transportation can enhance mobility, especially for people in congested urban areas. This project aims to explore a sustainable and innovative transportation solution by designing and manufacturing a hovercraft. Hovercrafts can travel over various terrains like ice, land, and shallow water, offering a versatile alternative that reduces dependency on infrastructure like roads. The design is electric, releasing no pollutants during use, and will be made as efficient as possible for longevity of battery life, while keeping costs low through a relatively simple design. The goal of this project is to make this technology viable and accessible for real world applications. Furthermore, beyond the scope of personal transportation, electric hovercrafts may be used for things like emergency response and disaster relief in areas where infrastructure is damaged or inaccessible.

REQUIREMENTS

- At least two drivers per team must participate in the race.
- The vehicle will be evaluated for safety by instructional staff.
- The propulsion mechanism for each team will be the same (different number of leaf blowers allowed).
- The vehicle must be able to maneuver the course.
- Payload for each team will be equalized.

SPECIFICATIONS

Value	Units	Description	Evaluation Method
5	ft	Hovercraft should be able to travel in a straight line within these bounds.	Straight line test with tape measure used to measure point from farthest deviation.
15	mph	Hovercraft should be no faster than this speed.	Tape measure and stopwatch.
5	lbf	Tolerance between payload shall not exceed this bound.	Scale.
15	ft	The vehicle cannot have exceeded this braking distance from top speed.	Tape measure used from point of breaking initiated to point of full stop.

DELIVERABLES

- Operational prototype device ready to race on design day against opposing team.
- Project report with test results.
- CAD Drawing with BOM (refer to Figure 3A).

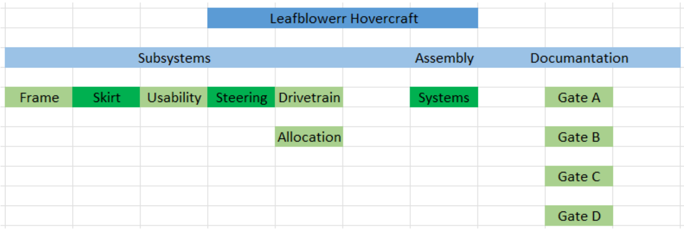


Figure 1. Abridged WBS

CONCEPTS

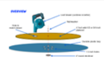
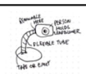
			
	Testing (Baseline)	Sewn Tarp w/ Tight Seal	Pool Noodle
Novel	0	+	-
Ease of Manufacture	0	-	+
Effectiveness	0	+	-
Ease of Use/Safety	0	+	+
Total	0	+2	0

Figure 2. Pugh Matrix for skirt design

The skirt proved to be an integral part of the design and most difficult to get functioning. This will be the focus of concept design. The three main versions were an inner tube (modeled on a small scale as the baseline) a sewn tarp and a pool noodle. The goal is to provide a rigid structure to support the hovercraft, while still being able to conform to the ground to keep a large pressure differential for hovering. The pool noodle was later placed at the bottom of a cylindrical rubber barrier for increased flexibility. Through testing the (modified) final option was picked due to effectiveness and ease of manufacturing. Additionally, the racecourse was changed to a flatter, more uniform surface where skirt compliance is less important than for a general purpose/surface hovercraft. The final design of the entire system is depicted in Figure 1A.

MECHANICAL ANALYSIS

To secure the hovercrafts that we will be using to steer to the frame, we designed leaf blower mounts out of sheet metal. To ensure that the leaf blowers fit onto the mounts, we had to determine the dimensions for the screw holes, along with the tolerance for each dimension. The first time this was done, the tolerances were not calculated correctly, and the mounts were not compatible. After measuring the drill bit and determining that it was 0.017 in. larger than the screw, we redid the calculations and used a tolerance of .020 in. due to the difference in sizing. After the first test, we were able to remake the holes with new more strict tolerances. This led to the mounts fitting and the steering leaf blowers being attached to the frame.

We did not test for any mechanical fatigue issue as we did not expect fatigue to be a mechanical pain point. A big electrical fatigue issue we did have though was the duration of the batteries. Our hovercraft could only float if the leaf blowers blowing downwards were working. Since these downward facing leaf blowers would always be on full power, this was expected to be the biggest fatigue point. To combat this issue, we purchased three spare batteries, to extend the life of the hovercraft.

To attach the 3D printed leaf blower mounts to the frame, we utilized bolts. We wanted to ensure that the bolt was tight enough to withstand the vibration of the craft, while not being overtightened to the point that it causes a fracture in the frame. For this, we conducted the calculation shown below. T is the tightening torque in in-lb, K is the torque coefficient (standard 0.2 for dry steel bolts, F is the desired preload force (200 lbf as a small low-risk preload), while d in the bolt diameter in inches. This calculation yielded us a fastening torque of 10 in-lb, which we used to tighten the bolts.

$$T = K * F * d \quad [1]$$
$$T = 0.2 * 200\ lbf * 0.25 \quad [2]$$

The biggest decision in terms of material selection for this project was deciding what material to make the frame. As the frame was the biggest component of the hovercraft, we wanted to minimize the weight, while not risking the frame breaking due to the force of the payload. To solve this issue, we decided upon a composite structure for the frame, made up of two pieces of 1/8 in. plywood on the outside, and two pieces of 1.5 in. thick foam on the inside. We ran multiple simulations using NX and determined that the composite material will be 193.8 times stiffer than a 0.5 in. piece of plywood, while also being 1.51 times lighter. Similar foam-core plywood sandwich panels in the literature report 30–40 % higher specific stiffness than solid wood laminates [3]. A more detailed analysis with diagrams can be found in the additional files folder within the file titled "TeamCrocodileFrameMaterialTesting."

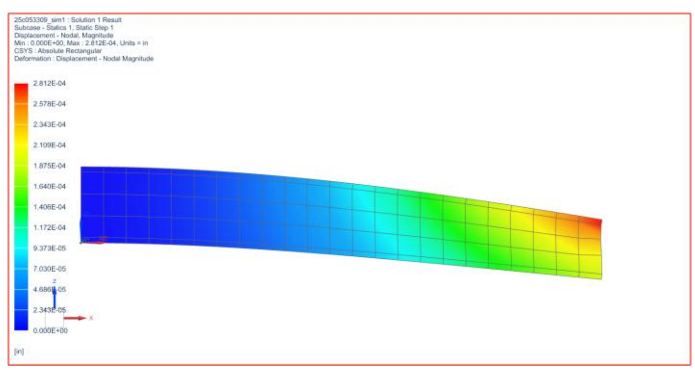


Figure 3. Stress Test of Composite Material Showing Displacement

Our brake system consisted of a wooden rod held by a spring. To decide what spring to buy, we initially calculated the intended placement of the spring, and the length that the spring would have to extend. This led to us purchasing a 4.72 inch spring. For the k value of the spring, we determined that anything below 10 lbf/in would be acceptable and easy to use for the driver. With an expected maximum displacement of two inches, 20 lbf was within the abilities of all team members. This allowed us to ensure that the spring could accurately extend down while not requiring too much force to push.

The hovercraft needs to trap air beneath it to create lift. Bernoulli's Principle and conservation of mass explain how the blower creates the pressure difference needed for lift. The equation relates a rise in velocity under the craft to a drop in static pressure, providing the lift that overcomes weight [2]. Using MATLAB code that can be found in the additional files folder within the file titled "TeamCrocodileComputer-Code.zip", we were able to predict that we would have a hover height of approximately .003. The basis for this value was a back pressure test conducted by the team, where we predicted 103 CFM per hovercraft. This led to us altering our design to utilize three leaf blowers to hover instead of the initially planned two. During final testing, we outperformed our test and measured a hover height of 0.13in, corresponding to a leaf blower CFM of 350. We believe this discrepancy is due to error in the CFM test performed along with measurement error of the hover height as it is fluctuating and not equal around the whole hovercraft.

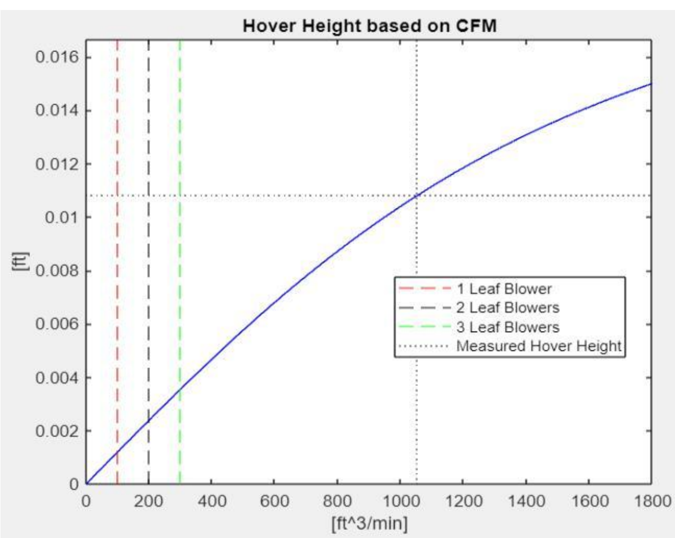


Figure 4. Hover Height Estimates Vs. Actual

MANUFACTURING

Manufacturing will be discussed in sections: frame, skirt, drivetrain and steering.

Frame:

The frame is made of a plywood and foam composite, foam board with 1/8in plywood on either side. The material is designed to be lightweight yet stiff. The layers were glued together using construction adhesive polyurethane then cut to shape using a CNC machine. Large holes were cut on the CNC as well, in the same pass as the whole frame, smaller holes were drilled. The frame was cheap and fast to manufacture.

Skirt:

The bulk of the skirt consists of a rubber mat which was cut lengthwise in half and reattached via rubber cement to thicken (stiffen) the skirt. A slit was cut in a pool noodle, and it was attached to the rubber skirt with rubber cement. Skirt design is discussed in another section; given design this was the ideal way to manufacture the skirt (with available/orderable materials). Parts were 3D printed to connect the frame and skirt. The clips were time consuming to print, but ease of manufacture was high. Adhesive tests were done, and either were destructive to the foam, or did not have the required shear strength to hold the skirt. The connectors slot onto the frame and similarly the skirt into the connector; both were glued with rubber cement and the holes plugged with other 3D printed "blocker" parts, or construction adhesive. If scaled up, the most important change would be finding faster methods to manufacture the connectors.

Drivetrain:

The mounts for the leaf blowers were 3D printed and bolted to the frame. The nozzle for the leaf blower is detachable and 3D printing allowed for replication of the nozzle latch. This provides a secure attachment for the leaf blowers and ease of removal when needed. Similarly to the skirt, 3D printing is effective, but time consuming and other methods should be investigated to save time; possibly molds.

Steering:

Steering comes in two components: thrust and brakes. Two leaf blowers are mounted on the sides of the frame which provide propulsion and whose power can be controlled for steering. The mounts are plasma cut sheet metal bent into a shape mimicking the leaf blower's detachable handle. Sheet metal was chosen for speed of manufacturing and strength at a low thickness. If scaled up the design needs to be changed, due to the shape not all bends can be made with a machine and hand hammering needed to be used. Different geometries would greatly improve large scale manufacturing.

The brakes double as steering. A brake on one side can be applied to pivot and rotate the hovercraft. The breaks are made from dowels suspended by a spring. The spring is attached to hooks on either end, one screwed into the bottom of the dowel, one into the bottom of the frame. PVC pipes were cut and glued into the holes in the frame to provide a smooth, sturdy (compared to the foam) path for the breaks and to closely match the brake's diameter for a better seal between inside the skirt and the atmosphere. The brakes are cheap and easy to manufacture and therefore would need little change if scaled up. To improve performance a rubber casing could be placed over the holes/handles to make a perfect seal.

Hardware Costs	$851.94
Member Time Costs	$32,820
Total Costs	$33,671.94

Member	Alhour	Maxim	Jonathan	Grace
Time	70hr	108.5hr	69.7hr	80hr

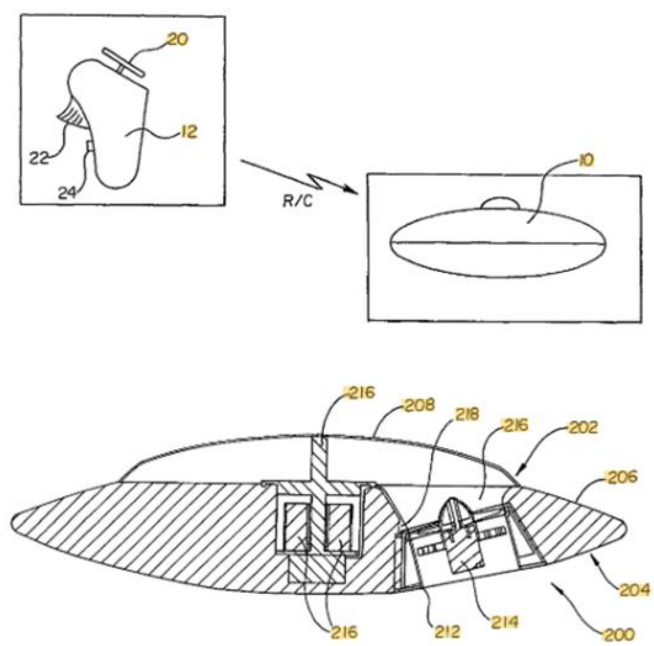
TEST PLAN AND RESULTS

Specification	Test	Pass/Fail
Hovercraft should be able to travel in a straight line within a 5 ft boundary.	Hovercraft was placed at a starting point and driven to a finish point 16 ft away. Deviation from the straight path was visually observed and measured using a tape measure.	Pass – Deviation of approx. 2.4 feet max from path.
Hovercraft should be no faster than 15 mph.	Stopwatch was used to time hovercraft as it traveled 16 ft after reaching top speed. Speed was calculated (speed = distance/time) and converted to mph.	Pass – Top speed calculated to be approx. 5.2 mph.
Tolerance between payload shall not exceed 5 lbf.	Use bathroom scale to weigh both drivers. Add weight to lighter driver until the difference in less than or equal to 5 lbf.	N/A - Payload will be equalized on race day.
The vehicle cannot exceed 15 ft braking distance from top speed.	Tape measure is used to measure distance between point where brakes are applied and stopping point after hovercraft has reached top speed.	Pass - Braking distance approx. 4.0 ft from top speed.

No major changes were made to the requirements and specifications. Testing was conducted in Rettner using the final model pictured in Figure 2A. Three tests per specification were conducted with the mean values noted in the table above. Manual timing and visual detection introduced human error, but conducting the tests indoors reduced environmental errors like airflow and terrain inconsistencies and is consistent with race day conditions. Future improvements could include the use of automated timers and sensors to reduce human error. Since all tests met the specified performance requirements, no system tuning is necessary.

INTELLECTUAL PROPERTY

The design and process of the creation of this hovercraft is not patentable. The general concept of a leaf blower powered hovercraft, manufacturing processes, testing methods, and ideas for individual component improvements were not novel. There are some applications of existing ideas, ex. creation of composites for a strong and light weight frame, but this is not patentable. An example of an existing patent in this field is shown below. Textron Innovations, Aeronext and Wing Aviation are the three most prolific companies in the same major classification area as the patent below. Yiochi Suzuki and Kiyoichi Sugaki are the top two inventors in the field.



US9073532B2 - Homeostatic Flying Hovercraft [4].

SOCIETAL AND ENVIRONMENTAL IMPLICATIONS

The hovercraft addresses several issues related to public health, safety, and welfare. By offering an electric transportation method that does not rely on traditional infrastructure like roads and sidewalks, the hovercraft can improve access to mobility for people in congested urban areas and areas affected by infrastructure failures. Although the project has not been developed to this level, advanced hovercrafts could enable quick deployment and transportation of aid and supplies in emergency or disaster situations where roads are rendered unusable.

From a global and cultural perspective, hovercraft technology may allow for the opportunity to bridge transportation gaps in underdeveloped or remote regions where building traditional roads and infrastructure is too expensive or difficult. This could enhance economic opportunities, access to education, and delivery of essential items (like medicine) in these regions. Ethical considerations related to hovercraft technology can relate to the equal distribution of and access to hovercraft technology. It is necessary to ensure that hovercraft technology is not only accessible to wealthy or urban populations but adapted and priced for widespread use.

Some benefits associated with the technology are zero emissions during operation, reduction in noise pollution compared to combustion engines, and lower maintenance cost due to fewer parts. Some drawbacks include reliance on batteries that are energy intensive to produce and charge and can be environmentally damaging if not disposed of correctly. The production of the hovercraft also involved synthetic materials like polyurethane adhesive and 3D-printed plastics, which are not biodegradable and contribute to long term environmental waste if not managed properly.

Some improvements and optimizations could be made to enhance the environmental sustainability of the project. For example, conventional plastics can be replaced with biodegradable or recycled alternatives for 3D-printed components. The lift and propulsion systems could also be developed to be more energy efficient to extend battery life and reduce overall energy consumption.

RECOMMENDATIONS FOR FUTURE WORK

If additional time and resources were available, the top priorities would be improving battery life and energy efficiency and redesigning the skirt for durability and performance. Battery limitations were the biggest operational constraint. Extending hover time is a critical element to make the hovercraft more practical for real world applications. Running the leaf blower at full power all the time wastes a lot of energy, drains battery, and limits operating time. Smart power features like varying speed control or different operational modes may allow the hovercraft to hover for longer with less heat and wear on the electronics.

The current skirt forms a stiff cylindrical perimeter and, while its design is sufficient for a flat race surface, it limits performance over uneven terrains and reduces overall maneuverability. Given additional time and resources, another improvement would be transitioning from the current rigid skirt to an inflatable flexible skirt design. This would offer different advantages like increased ability to conform to various terrains, improved stability due to shock absorption, and better efficiency due to air leakage being reduced. This may even extend battery life by requiring less leaf blower power to maintain hover height.

ACKNOWLEDGMENTS

We are grateful for the assistance of Professor Muir, as well as Chris Pratt, Jim Alkins, Alex Prideaux, and Sebastian Gomez, whose support and contributions were essential to the successful completion of our project.

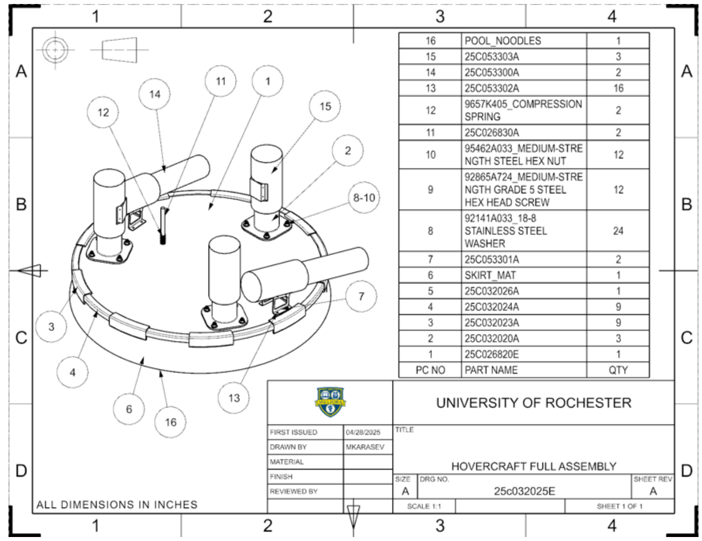
REFERENCES

[1] U.S. Environmental Protection Agency, 2024, “Sources of Greenhouse Gas Emissions,” Greenhouse Gas Emissions Website, Washington, DC. Available at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions. (Accessed 28 Apr 2025).
[2] NASA Glenn Research Center, 2024, “Bernoulli’s Equation,” Beginner’s Guide to Aeronautics, Cleveland, OH. Available at: https://www.grc.nasa.gov/www/k-12/airplane/bern.html. (Accessed 28 Apr 2025).
[3] Labans, E., Kalnins, K., and Bisagni, C., 2019, “Flexural Behavior of Sandwich Panels With Cellular Wood, Plywood Stiffener/Foam, and Thermoplastic Composite Core,” J. Sandwich Struct. Mater., Vol. 21(2), pp. 784-805. doi: 10.1177/1099636217699587. Available at: https://doi.org/10.1177/1099636217699587.
[4] Spirov, P., 2015, “Homeostatic Flying Hovercraft,” U.S. Patent 9,073,532 B2, issued July 7. Available at: https://patents.google.com/patent/US9073532B2. (Accessed 28 Apr 2025).

APPENDIX A

Figure 1A: CAD representation of leaf blower hovercraft with human model.

Figure 2A: Real life representation designed of hovercraft design.



PC NO	PART NAME	QTY
16	POOL_NOODLES	1
15	25C053303A	3
14	25C053300A	2
13	25C053302A	16
12	9657K405_COMPRESSION SPRING	2
11	25C026830A	2
10	95462A033_MEDIUM-STRENGTH STEEL HEX NUT	12
9	92865A724_MEDIUM-STRENGTH GRADE 5 STEEL HEX HEAD SCREW	12
8	92141A033_18-8 STAINLESS STEEL WASHER	24
7	25C053301A	2
6	SKIRT_MAT	1
5	25C032026A	1
4	25C032024A	9
3	25C032023A	9
2	25C032020A	3
1	25C026820E	1

Figure 3A: BOM of full hovercraft assembly.