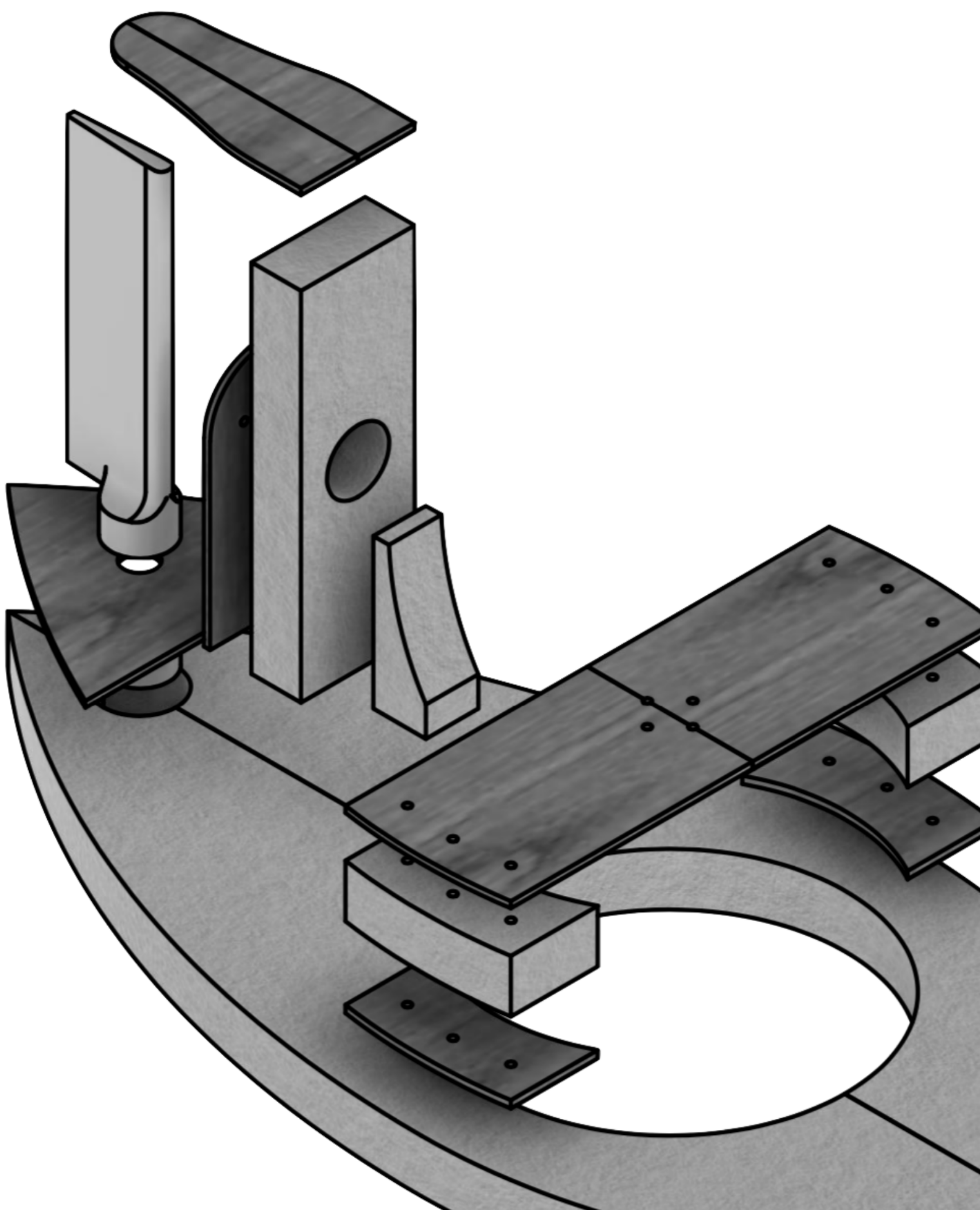
FISH

Hovercraft Inc.

Final Report

Catapult 2019 Session 3



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Final Catapult Report — Team FISH
Hovercraft

FishCraft H3

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Project Summary

Even during early concept sketches of the final hovercraft, the team agreed on a water droplet-shaped exterior, hoping to achieve a more aerodynamic design to maximize the hovercraft's top speed. We wanted to pair this design with a skirt around the base of the hovercraft to minimize friction and drag.

Extensive research about hovercraft mechanics revealed that the water droplet-shaped shape is extremely aerodynamic and has an optimal weight profile. From there we began by designing 3D models of our project in AutoDesk Fusion360. This helped the team visualize the same design, reducing overall confusion later on. The skirt is a piece of plastic or fabric that creates a pressure difference between the high-pressure hull and the low-pressure air around it. Using a wall skirt design on the side of the hovercraft helps contain air in the lower cavity, generating a controlled lifting force.

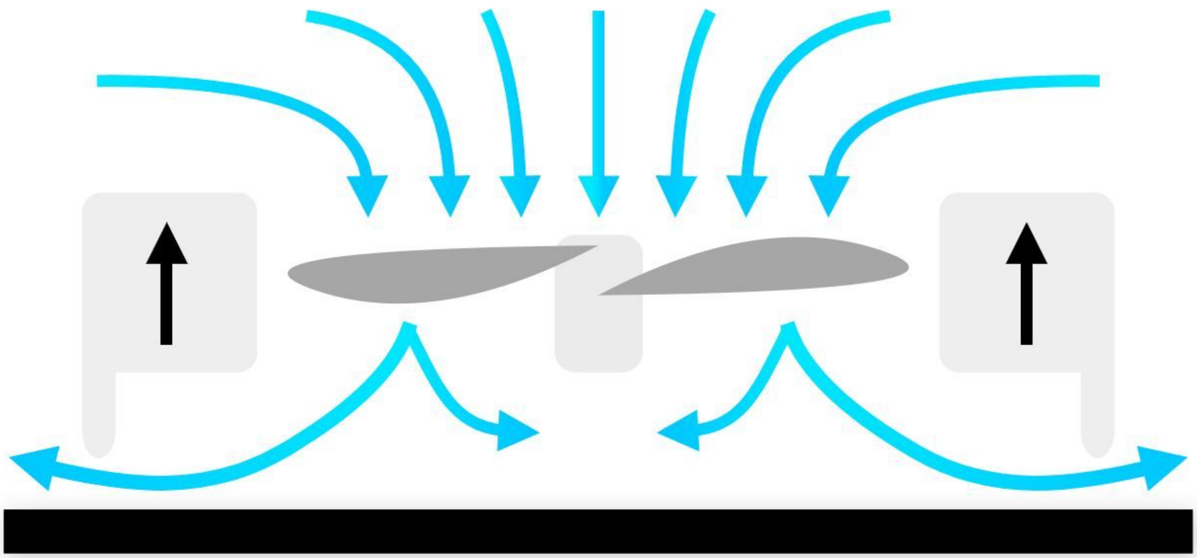
After creating the models we set off to make lightweight 3D printed parts for the rudder and lightweight wooden laser-cut components for the stability of the motors. Keeping the parts as light as possible was a top priority since a heavier hovercraft has more inertia and is more difficult to accelerate.

One major challenge while creating the hovercraft was balance. For some mysterious reason, the hovercraft seemed to favor one side over the other, lifting the craft unevenly and causing unnecessary friction. After numerous iterations on skirt design in hopes of diagnosing exactly what was causing the phenomenon, the team's last resort of simply altering the weight distribution to be heavier on the side that tended to rise effectively solved the issue without any side effects. Though the cause of the uneven lift remains a mystery, the hovercraft is now able to glide across flat surfaces with essentially zero friction.

All in all, the team took a concept design from sketches to a working prototype, overcoming numerous engineering obstacles such as faulty design choices and unexpected phenomenon. Although the current build of the hovercraft cannot quite beat the local record of 94 feet in 3.7 seconds, we hope to soon achieve this through more optimal airflow control.

Introduction

Early stages of project planning focused on the motive and purpose of the team's ultimate product. We soon realized that we required additional technical knowledge on the exact behavior of hovercrafts. From the research papers of official organizations such as NASA, we gathered that hovercrafts are amphibious vehicles capable of traveling over land, water, mud, ice and more. They function by channeling large volumes of air downward into an air-cushion using blowers, or large fans. This heap of accelerated air raises the air pressure of a cavity beneath the hovercraft to a higher pressure than the surrounding atmosphere, causing air to escape through the bottom of the cavity and thereby lifting the hovercraft off the surface ever so slightly. For stability reasons, the air is typically blown through slots or holes around the outside of a disk- or oval-shaped platform (HOVERCRAFT DEV Ltd, 2019).



History of Hovercrafts

The first practical design for hovercraft derived from a British invention in the 1950s to 1960s. Sir Christopher Cockerell developed one of the first working versions of the hovercraft (BBC.co.uk, 2018), which made use of a ring of air for maintaining the cushion to develop a successful skirt. The name "Hovercraft" itself was a trademark owned by Saunders-Roe (later British Hovercraft Corporation (BHC), then Westland). In current times, they're used throughout the world as specialized transports in disaster relief, cargo shipment, as well as military and passenger service (NASA/JPL Edu, 2019). Some instances hovercrafts were re-designed to become torpedo boats and were even armed with torpedoes for testing, however, the idea was scrapped and the engines were returned to the air force. Very large versions have been used to transport hundreds of people and vehicles across the English Channel.

Primary Objective

After evaluating our decision matrix based on these insights, we decided on what we considered the most optimal design choices to achieve our goal: to design and construct a hovercraft that can traverse a 94 feet basketball court in less than 3.7 seconds.

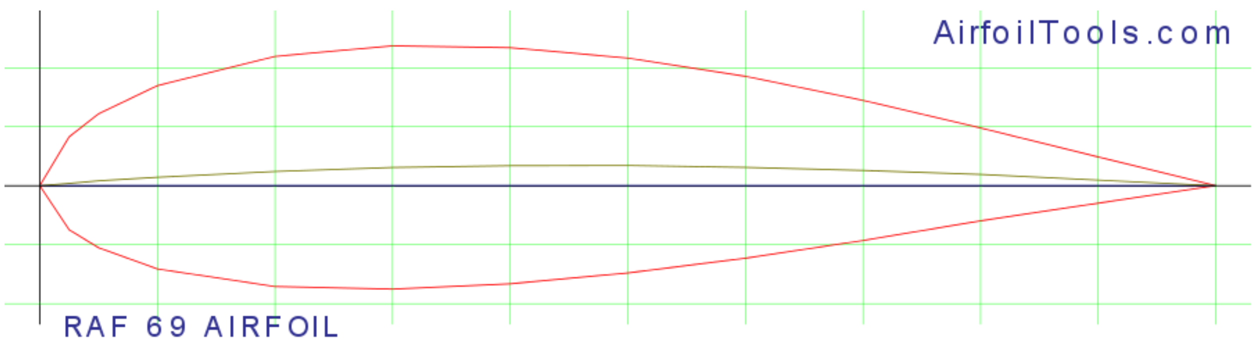
Skirt Shape			
	Circle	**Oval**	**AirFoil**
Air distribution	Best (2)	Best (2)	Worst (0)
Weight distribution	Worst (0)	Medium (1)	Best (2)
Total mass	Best (2)	Medium (1)	Worst (0)
Fish resemblance	Worst (0)	Medium (1)	Best (2)
Total points	4	5	4

Insights and Optimization

Early on, the team decided to pursue the goal of designing the fastest possible hovercraft. This process began with in-depth research on which factors most affect performance in speed. But, we had to consider at a more basic level what goal to tackle — acceleration, speed, or both. The team decided to challenge the previous local record holder of traversing a basketball court (94 feet) in 3.7 seconds. This meant that we needed to optimize acceleration, then top speed. From there, we constructed various decision matrices to decide the most optimal design. We evaluated the matrices based on several insights. On the most basic level, Newton's second law of motion states that an object's net force is proportional to the mass of the object multiplied by its resulting acceleration. Therefore, since the blowers exert the same force regardless of the mass of the hovercraft, a vehicle with lower mass would experience a greater acceleration than a vehicle with a greater mass. In addition, certain shapes are more aerodynamic than others. An object that can cleanly split and then reattach air as it cuts through leaves little turbulence in its wake, therefore, loses less kinetic energy to drag. This means that the object would experience a greater acceleration since its net force is greater. Equally as important is the stability and balance of the craft itself. A hovercraft that accelerates with such a jerk that the base is driven into the surface would introduce unnecessary friction, defeating the purpose of the hovercraft. In order to achieve the most effective linear acceleration, the craft must be able to deliver a constant horizontal force without causing the hovercraft to tip and scrape the surface.
Below is a decision matrix on the ideal shape of the flexible skirt.

Design Process

After defining our ultimate goal, building the fastest hovercraft possible while also maintaining a stable and refined construction, we began the process of designing a hovercraft that adheres to our decision matrices. As determined by our decision matrices, the shape that most effectively minimizes wind resistance is required for the fastest top speed. The teardrop-shaped airfoil is an extremely aerodynamic shape that is said to give the same drag as a small wire only a small fraction of its size.



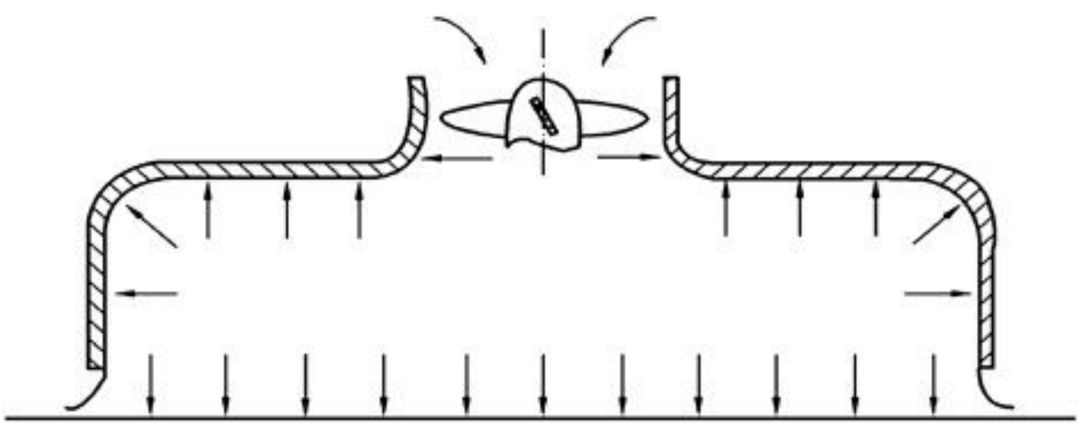
Once we had the shape we started the process of mocking up each layer in hand drawings. The hovercraft design consists of multiple layers of different materials. Each layer is critical to the support and structure of the hovercraft.

After completing concept drawings for each layer of the hovercraft we converted the sketches to CAD drawings. We used Autodesk's cross-platform CAD tool Fusion360 to generate real-sized models of each layer. This tool allowed us first to work on both Mac and Windows and run simulations. We designed a complete 3D model of our hovercraft without the electronics included in the kit. Using Fusion 360 allowed the team to easily export the 3D printed parts as STL files and the laser-cut parts as DWG files.

Construction

Once all of the parts were completed, including laser parts, 3D printed parts and the styrofoam that was cut using a hot wire, we began assembling them. Most of the hovercraft went together without difficulty, however attaching an inflated skirt proved extremely difficult to do with precision, because it was one of the only things that we make by hand. Not to mention that constructing an inflatable skirt out of flat material meant that small creases were constantly made in order to make the oval shape.

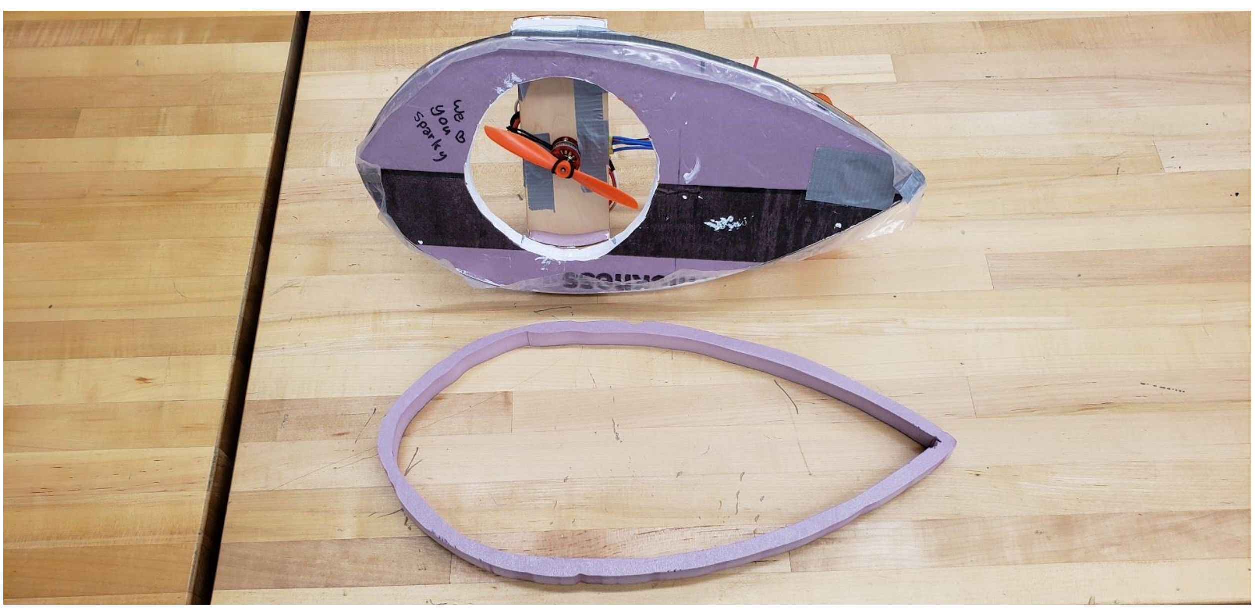
Unfortunately, because of the tiny holes we poked for air to fill the skirt, the skirt had trouble filling up and the hovercraft failed to rise. Even when the hovercraft did manage to float, the team realized that this base was far too uneven, and we decided to completely scratch the idea of an inflatable skirt for a more simple wall skirt. The intention was to allow the skirt to wrap more tightly around the base, allowing for less air loss and thus an easier time achieving lift. Here is a simplified diagram of this design:



At the same time, the opening beneath the propellor was widened so that more air could flow into the lower cavity.

Challenges

While this design allowed us to produce plenty of lift, it uncovered an unforeseen problem with the nature of our design. When active, the hovercraft leaned heavily toward one side while the other side was lifted with ease. Based on qualitative measurements, the team felt that it was likely not an issue with the weight distribution of the components resting on the hovercraft, and instead of a problem with the air dynamics of the interior of the skirt. To test this theory, we constructed a thicker and sturdier wall-type skirt made of pink foam to be certain that the cause of the leaning was improper air distribution.



As expected, the hovercraft continued to lean towards one side and float freely on the other. This left the team with one mystifying question: how can a hovercraft that is seemingly perfectly balanced produce unbalanced lift?

The team turned to doing more research on successful designs, and it was after witnessing a competitor group's successful skirt design that the team developed a theory on why the hovercraft was producing uneven lift. We hypothesized that the lift propellor was forcing too much air out, widening the opening for air to escape on the side with too much lift. To address this, the team decided to alter the design of the skirt to one that spans the entirety of the base to restrict more of the air. Then, holes in the skirt could be made to evenly leak air in a controlled manner, resembling the surface of an air-hockey table.

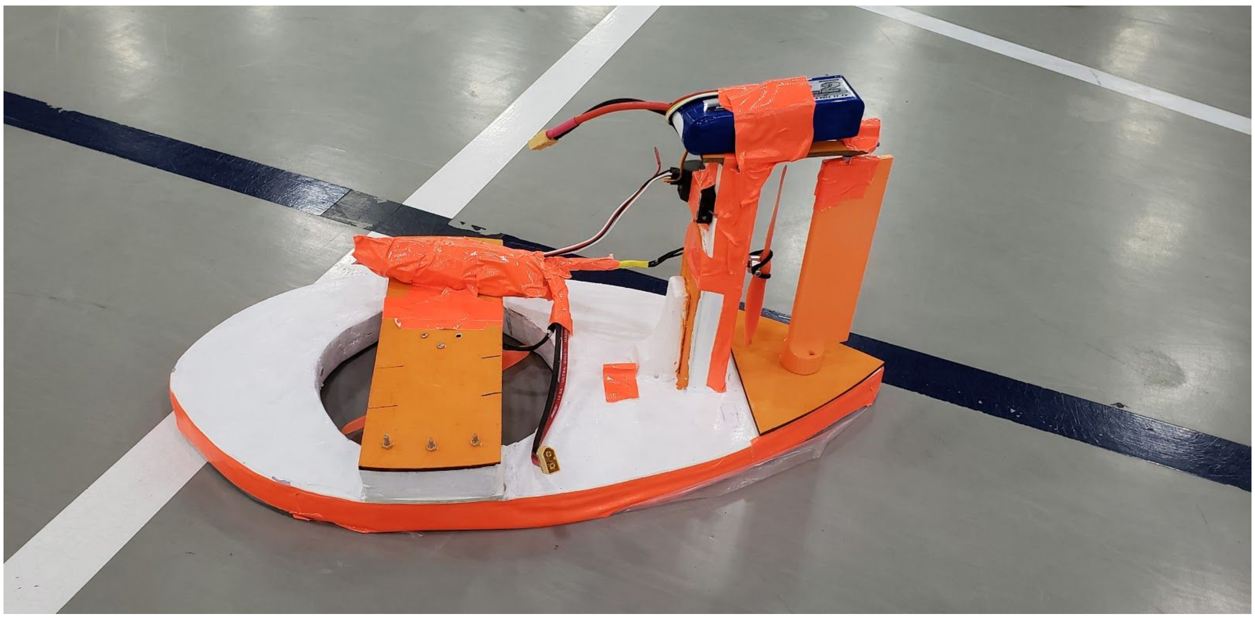
Unfortunately, this method once again did not solve the problem of the hovercraft's uneven tilt. In fact, the hovercraft moved even slower due to too much restriction of air causing friction with the surface. We decided to revert to the wall skirt which would be completely open beneath the hovercraft, and instead made the skirt ¾ inches in width. In addition, we reorganized the electronic components so that heavy battery sat above the side with a tendency to rise, hoping to mitigate the excess lift and give the other side a change to rise as well.

The redistribution of weight drastically affected the performance of the hovercraft. The hovercraft was finally able to lift uniformly above the ground, almost completely negating friction. Doing so made the hovercraft reach a top speed of much higher than before, which was a huge leap towards achieving the team's goal.

Continuing the pattern of unexpected problems, a new problem arose after fixing the balance. Because of conservation of angular momentum, the torque exerted by the motor to spin the propellor clockwise caused the entire hovercraft to spin clockwise. This led to a significant gyroscopic precession, making the hovercraft incredibly difficult to handle. Unfortunately, this issue was never fully addressed, and it persists even in the most recent build.

Final Results

The official test track for hovercrafts consisted of two courses. One was a straight line sprint to measure the speed of the hovercraft, and the other was a figure eight course to assess the maneuverability of the hovercraft. After several inconsistent trials in both courses, the hovercraft finished the sprint in roughly 8 seconds but could not consistently finish the figure eight. This is mostly because of the constant spinning of the hovercraft which interfered heavily with turning. Although we didn’t meet our goal of 3.7 seconds, we learned other valuable lessons such as good hovercraft design, team cohesion and work distribution, and characteristics of industrial-grade hovercrafts.



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