CAPSTONE: MULTI-DRONE

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Background

The Multi-Drone is a remote-operated quadcopter capable of both flying and submerging underwater. The engineering design process was used to bring the concept of a multi-drone to the final product shown today.

The Multi-Drone has four propellers that rotate on the pitch axis and utilize a PID controller. It also includes a buoy which allows the drone to receive its signal underwater.

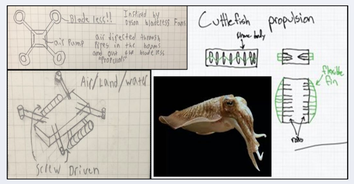


Objective

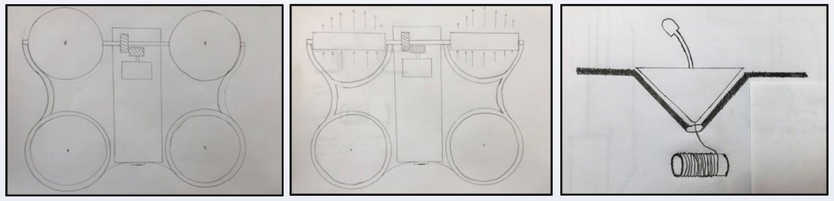
The objective of this project was to create a drone for general use. To acquire these customer needs, this team interviewed an industry expert and collected survey data to help produce design requirements. These design requirements allowed us to quantify needs and helped rank the design concepts we produced.

Impt.	Metric	Units	Value
1	Waterproof Rating	IPX Rating	IPX8
2	Maximum Total Mass	kg	<3
3	Maximum Cost per Completed Unit	US $	<2000
4	Maximum Size (Fits in a Backpack)	cm	≤40 X 30 X 13
5	Average Flight Time	min	>20
6	Average Time for New User to Perform Basic Operations	min	<30
7	Impact Resistance From Dead Fall	m	6
8	Maximum Time to Transition From Water to Air (or Vice Versa)	sec	<30
9	Minimum % of Successful Flights (Reliability)	%	>80
10	Live-Stream Video Latency	ms	40
11	Visibility in Clear Water	m	30
12	Minimum Signal Transmission Distance	km	>1
13	Maximum Noise	dB	<80
14	Aerial Top Speed	m/s	13
14	Aquatic Top Speed	m/s	0.5
15	Average Repair Cost	$	<20
16	GPS Tracking Radius (Positional Accuracy)	m	15
17	Minimum Quality Video	PPI	>1080

Concept Generation and Selection



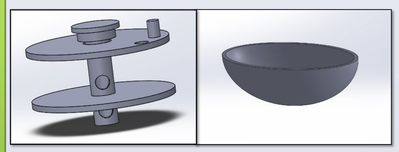
Many unique solutions and concepts were generated.



The chosen concept featured a traditional quadcopter style drone with a rotating shaft to allow the propellers to provide directional thrust underwater. The rotating shaft was attached to a gear system and servo to allow for full 360 degrees of rotation. A buoy is used to transfer signals while the drone is underwater. The design was selected using a scoring matrix

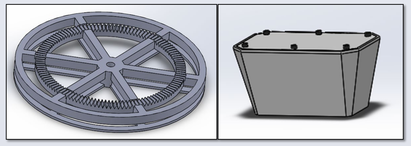
Design and Analysis

Reel & Buoy System Iterations



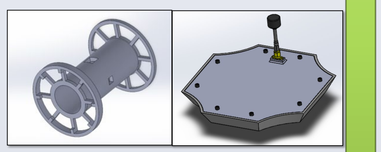
1st iteration:

- Reel uses Coil spring to mechanically keep tension
- Buoy is oval – most stable shape



2nd iteration:

- Reel is gear driven by a servo with a complex tether path
- Buoy design is more functional

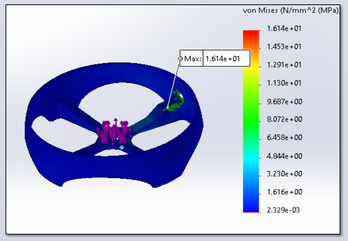


3rd iteration:

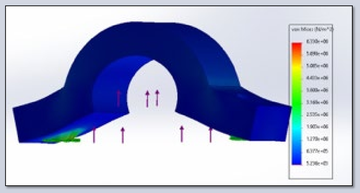
- Reel is directly driven by a servo with a direct tether path
- Both designs are a better use of space

Analysis & Simulations

FEA was used to test the strength of the motor mounts, the shaft, and the saddle. After multiple iterations, the final designs are strong enough to lift the Multi-Drone.



Motor Mount FEA



Saddle FEA

Physical Testing

Impact testing was performed to test the strength of the material. The Multi-Drone was dropped from multiple heights and started to crack at 5 ft. Modifications were made to help brace the impact.

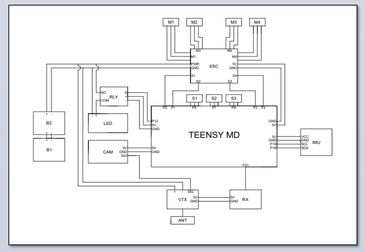
The drone was also tested to ensure it was sufficiently waterproof. These waterproof tests helped reveal problematic areas that were altered for the final design.



Physical Drop Test

Electronics

The electronics included a flight controller that was programmed with 3 modes; quadcopter flight mode, transition mode (air to water & water to air), and underwater mode. An independent PID controller was used for each mode. These modes were tested using a test stand that mimicked the motion of the Multi-Drone.



Electronics Schematic

Alpha Prototype

An alpha prototype was printed and assembled, and many issues were encountered including gear meshing difficulties, excess flex in motor mount to shaft connection, inadequate clearance for brass inserts and bolts, and insufficient waterproofing for battery doors. These issues were solved in the final design.



Final Design

The final Multi-Drone design consists of a standard quadcopter style while in the air. In the water, the propellors can synchronously rotate to control the direction of propulsion, and a reel-buoy system is used to receive signal from the controller while under the water.

The final design applies many waterproofing methods. O-rings were used to seal any openings and waterproof spray was utilized to prevent water from seeping into the 3D printed material.

The team used the engineering process to successfully design and build a drone capable of both in-air flight and operation in-water. This drone is manually piloted, with the assistance of PID control for stabilization.

To complete this drone, many problems and challenges were encountered. Several design iterations were performed to obtain the final functioning product.



Future Works

This Multi-Drone project will continue as another capstone next year. We recommend several design improvements including waterproof connectors to limit openings, locating the axle at the bottom instead of the top, metal gears for the axles, and using larger props to increase lift force.

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