MAE 4344- Senior Design Capstone

Group 2b- Dolphin Blowhole Simulator

Team Lead: Kevin Quinn

Team Members: Daniel Wigley, Jason Fey

Introduction / Background / Problem Statement:

The use of drones have been proposed for the collection of biological samples in marine mammals, specifically marine biologists need to obtain samples of dolphin "blow" from their blowhole discharge in the wild. These non-invasive techniques are needed to assess biological health such as reproductive and adrenal functions. While the techniques have been demonstrated on whales, dolphins have proven more difficult to obtain samples from due to their speed and apprehensiveness to typical quadcopter drone. Thus, quiet fixed wing vehicles are proposed. In order to assess the feasibility to capture a sample, a blowhole simulator is needed that mimics the intermittent outflow characteristics of the blowhole jet, including flow rate, jet velocity, height, and spread.

Detailed list of project requirements / deliverables:

From the problem statement a list of deliverables and project goals were created for completion by the end of the semester. The first deliverable was providing a working simulator. This simulator would need to simulate a dolphins blow as closely as possible according to the following empirical measurements: flow rate, exit velocity, height of blow, and width of blow. The simulator needed to have lateral movement capabilities that could mimic those of a dolphin in the wild. Finally, engineering design calculations for the simulator design and results from the simulator testing were to be delivered with the final product.

Plan of attack / Approach to Solving the Problem - Summary:

Before the first design iteration could be made for the deliverables in the problem statement, initial research needed to be conducted in order to find out what empirical data we would need to meet. Initial research was done by each team member in order to find the blow height, width, flow rate, and exit velocity. This data proved to be difficult to find and professional corroboration was sought out to confirm the data we had found. Researchers and Marine Biologist from Purdue and UC Davis were contacted in order to confirm the empirical data we had found on the blow characteristics as well as to get extra background information on the dolphin blow process in general. Specific measurements on blow hole diameters and shape were collected by marine biologist in the field from Hawaii, Bermuda, and Oahu. Once this initial research was done, the parameters for our first design were made and the first iteration for the blow hole simulator was made. This first iteration proved to be undesirable for its high pressure system and limited shot capabilities. The next step in the plan of attack was for each team member to individually research a new design that would implement a low pressure system with multi-shot capabilities. This design matrix then underwent a pro/con evaluation for review by each team member and our funders. From this design matrix, our final design was chosen. This final design was to be a pneumatic piston system that would push air through an open pipe with an exit “blowhole” at the end of it. A water system would be integrated mechatronically with the pneumatic system in order to time the water delivery with the air delivery, thus mimicking a “blow” by a dolphin. After the design was finalized on paper, a parts list was assembled and parts bought. Then the simulator was assembled and testing of the simulator was done by the team.

Detailed Description of Work / Key Decisions made - with reasons:

Initial research showed that the design needed to be capable of high exit velocity and high flow rate achieved over a small time interval. This flow and speed would be accompanied by a pressure drop that would also need to be constant as the blow was "exhaled". The team compared five different designs in order to determine which design would best meet the desired criteria.

Design Option #1 & #2

The first two designs were similar to what is shown to the right. This design utilized high pressure in order to achieve the large flow rates and exit velocities that the dolphin exhibits in its "explosive" breathing. The usage of high pressure threaded pipe created an easy, compact pressure vessel for holding the equivalent volume of the dolphin exhale.

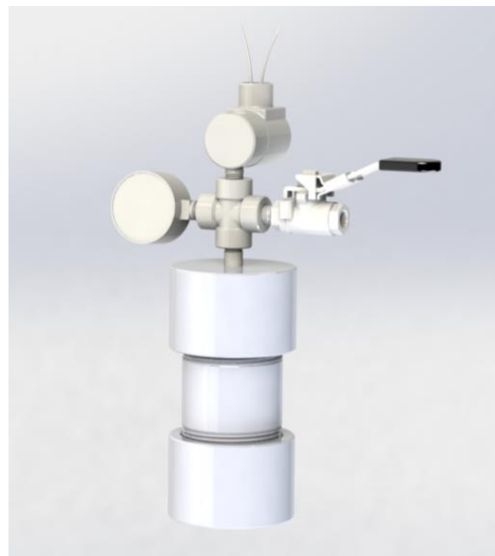


Figure 1

Attached to the top of the larger body pressure vessel is a small connecting pipe that would need to be drilled into and welded onto the cap of one side of the pressure vessel. Proceeding from this connecting piece would be a cross fitting that allowed for a fill valve, a pressure gauge, and a solenoid valve at the top for release of the high pressure air inside. The downside of this design, however, is the use of extremely high pressures, which in turn would force the air out of the solenoid valve at a rate much higher than desired. Consequently, this would require more piping or attachments downstream from the solenoid in order to slow the air back down before exiting. After further consideration and meeting with our sponsors, the high pressure system shown above was abandoned. Next, each team member pursued a different, unique design on their own in order to come back together with a design matrix, and hopefully arrive at the best available option for our project. The proposed designs are as follows:

Design Option #3

The third design option involved using a high volume low pressure fan to match the flow rate and exit velocity required to model a dolphin blowhole. This option proved in theory to be the cheapest, and most efficient option due to the fans low power requirements, compact size, and miniscule weight. However, finding a fan that is small enough, and efficient enough to match the required flow rates of a dolphin blowhole proved difficult. Two fan options were pursued in this design. The first, was a low power, lightweight, equipment cooling fan. Although this fan would allow for the correct amount of flow unchoked, whenever it is choked to the appropriate diameter, the fan will not meet the required flow rate. Constancy of flow cannot be assumed for an open atmospheric fan. The pressure calculations needed to approach a solution to this problem could not be done either, do to most manufactures not listing the pressure drop across their fans. This is most likely due to it being a negligible number. The second option pursued was a blower fan, although this proved to require too much power and weigh more than desired.

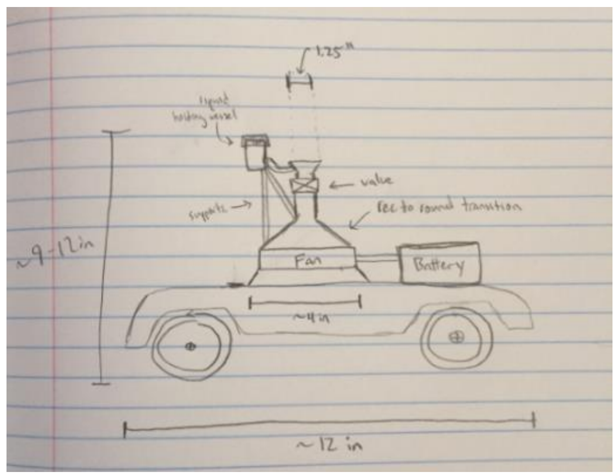
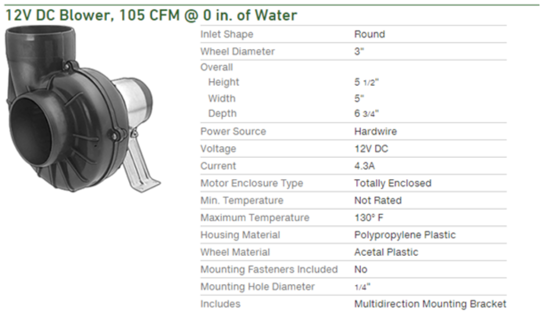


Figure 2



12V DC Blower, 105 CFM @ 0 in. of Water

Inlet Shape	Round
Wheel Diameter	3"
Overall	
Height	5 1/2"
Width	5"
Depth	6 3/4"
Power Source	Hardwire
Voltage	12V DC
Current	4.3A
Motor Enclosure Type	Totally Enclosed
Min. Temperature	Not Rated
Maximum Temperature	130° F
Housing Material	Polypropylene Plastic
Wheel Material	Acetal Plastic
Mounting Fasteners Included	No
Mounting Hole Diameter	1/4"
Includes	Multidirection Mounting Bracket

Figure 3.a

Low-Voltage Equipment-Cooling Fan

12V DC with Wire Leads, 3.62" Square x 1.26" Deep Overall, 50 CFM

Shape	Square
Overall	
Height	3.62" (92 mm)
Width	3.62" (92 mm)
Depth	1.26" (32 mm)
Airflow	50 cfm
Volume	43 dB
Voltage	12V DC
Current	0.23 A
Power Source	Electric
Electrical Connection	Wire Leads
Frame Material	Plastic
Blade Material	Plastic
Thermostat Included	No
Mounting Fasteners Included	No
Mounting Hole Diameter	0.17" (4.3 mm)
Specifications Met	CSA Certified, UL Recognized

Figure 3.b

Calculations:

This first table shows the calculations for finding the exit hole diameter given a flow rate and a desired velocity. The flow rate of 24L/s has been shown to be the peak output of a bottlenose dolphin. This kind of output velocity, even with half of the flow, is out of the scope of a small HVLP fan's capabilities.

Flow rate (L/s)	Flow rate(in^3/s)	Time interval	Exhale flow equivalent (in^3/s)
24	1464.569858	0.15	219.6854787
area of blowhole	exit speed (in/s)	exit speed(ft/s)	
0.785398163	1864.74826	155.3956883	
Required exit velocity	Required Flow Rate	Area Needed (in^2)	Blow Hole Diameter (in.)
69.06475035	1464.569858	21.20575041	5.196152423
100		14.64569858	4.318273103

Figure 4

The second table, below, is the ideal exit velocity calculations for the blower and fan found on Mcmaster Carr's website. However, choking the flow of a fan, unless in a system of constant flow rate, does not increase its velocity to the desired output of the blowhole simulator. The blower fan, although capable of the output desired, will require too much power, as shown in the picture of its specs above in figure 3.

*Calculations on pressure were assumed unnecessary due to already existing issues with velocity & flow.

From McMaster-Carr - 12 v DC blower					
Flow (CFM)	Flow(in^3/s)	exit diameter (in)	exit area (in^2)	Exit velocity (in/s)	Ideal Exit velocity (ft/s)
105	3024	3	7.068583471	427.808487	35.65070725
Adding a choke to reduce the cross sectional area					
Flow (CFM)	Flow(in^3/s)	exit diameter (in)	exit area (in^2)	Exit velocity (in/s)	Ideal Exit velocity (ft/s)
105	3024	2	3.141592654	962.5690958	80.21409132
From McMaster-Carr - equipment cooling fans (square)					
Flow (CFM)	Flow(in^3/s)	equiv diameter (in)	exit area (in^2)	Exit velocity (in/s)	Ideal Exit velocity (ft/s)
50	1440	3.96	7.068583471	203.7183272	16.97652726
Adding a choke to reduce the cross sectional area					
Flow (CFM)	Flow(in^3/s)	equiv diameter (in)	exit area (in^2)	Exit velocity (in/s)	Ideal Exit velocity (ft/s)
50	1440	1.25	1.22718463	1173.417564	97.78479704

Figure 4

Design Option #4

$$p_2 + \rho \frac{V_2^2}{2} = p_1 + \rho \frac{V_1^2}{2}$$

Design Characteristics	
Starting Flow (L/s)	24
1L = in^3	61.0237
1.5in Diameter (Area in^2)	1.767145868
Air Velocity (in/s)	828.7764054
Air Velocity (ft/s)	69.06470045
Tank Height(in)	5
Tank Size (in^3)	8.835729338
density of air (slugs/ft^3)	0.00238
(lbs/ft^3)	0.0765
(lbs/in^3)	4.42708E-05
atm (psia)	14.7
Assuming negligible temperature change:	
mass flow rate (lbs/s):	0.064837681
mdot=rho*V*A	
(in^3/s)	0.847551389
time for full discharge(s)	0.095923195
Pressure Tank Calculations:	
Pressure in Tank (psia):	
	29.904161

Figure 5

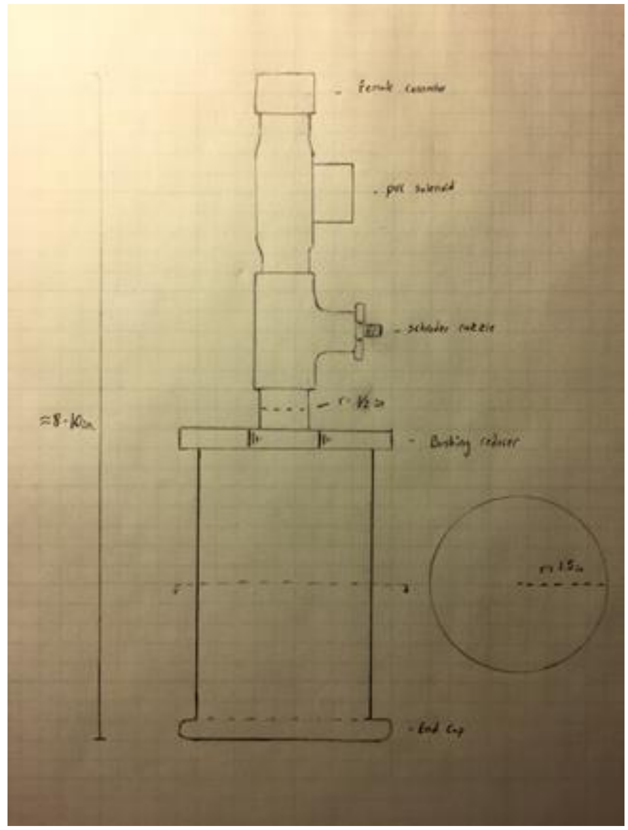


Figure7

The fourth design, most similar to our original design, involved the use of high pressure air in order to achieve the flow rate necessary to match that of a dolphins. There is one distinct difference in this design in comparison to our original, this is the characteristic of the flow that we show priority. If our original design we prioritized the volume of the dolphin and worked to be able to expel the full volume of a dolphin's lungs in a certain time, while in this design the prioritized characteristic is the velocity of the flow and flow rate itself.

Given the max flow rate of the dolphin blowhole exit, and given the area of the orifice, you can back calculate to find that the pressure needed to achieve the necessary max flow is only 30 psi, drastically lower than our original design. Due to this pressure difference we are able to downgrade on our materials, using PVC for that majority of our pressure vessel, connectors, and even valves. This design would have three individually controlled discharges that would simulate the “blow” of the dolphin. Each of these pressure vessels could be charged individually in order to have full control over the pressures, and in turn velocities and spread. This design is very simple and very easy to modify if there is a need to remodel the “blow” in a way we didn't originally anticipate. In addition, low pressures ensure that the design is very flexible and can be charged quickly with something as simple as a bike pump. This design excels in portability and flexibility. One downfall of this design would be the lack of continual usage. This design would only be able to discharge as many times as you have pressure vessels in the system before returning to the user to recharge the tanks. This will limit the time you would be able to run your trials consistently. However because of the low pressure and low volumes, the recharge time would be much shorter when compared to recharging a large tank for many trials.

One of the questions that has plagued this design is the idea of a transient pressure drop on the outside of the orifice during the “blow”. This would imply that the flow through the orifice would not be consistent throughout the discharge time. Because of a pressure being released from a vessel, the pressure drop would be higher upon initial release of pressure than any other time during discharge. However, while the pressure drop across the orifice of our designed pressure vessel might not be constant, it achieves the time, velocity and flow rate of our estimated dolphin blow. In addition, there is no empirical data signifying that the pressure drop across the exit flow of a dolphin blowhole is static. It is quite possible that it would be subject to change throughout the discharge of its breath, similar to our proposed design.

Due to the decreased strength of materials our design is much lighter weight and much more cost efficient. The total cost of our design is estimated to cost less that $500 and would be less than 10lbs. Again the simplicity, flexibility, portability , cost effectiveness, and decrease in weight are all strengths of this design and should be taken into consideration.

$ 2.41	Thick-Wall PVC Pipe Nipple for Water, Threaded on Both Ends, 1-1/2 NPT, 4" Long
$ 5.08	Thick-Wall PVC Pipe Fitting for Water, Bushing Reducing Adapter, 1-1/2 x 1/2 NPT
$ 6.95	Plastic Water Solenoid Valve - 12V - 1/2" Nominal
$ 3.76	Thick-Wall PVC Pipe Fitting for Water, Tee Connector, 1/2 NPT Female
$ 4.90	Thick-Wall PVC Pipe Fitting for Water, Cap, 1-1/2 NPT Female
$ 50.00	Battery 12vDC
$ 200.00	RC Car

Figure 8

Further Calculations:

Using the ideal gas law we can estimate the volume of air that we are compressing into our pressure vessel given the pressure vessel dimensions and the desired pressure within the pressure vessel.

Pressure Vessel:		Atmospheric Values:	
height (in)	5		
radius (in)	1		
volume (in^3)	15.70796	volume equivalent (in^3)	32.05707
pressure (psi)	30	pressure (psi)	14.7

Figure 9

Design Option #5

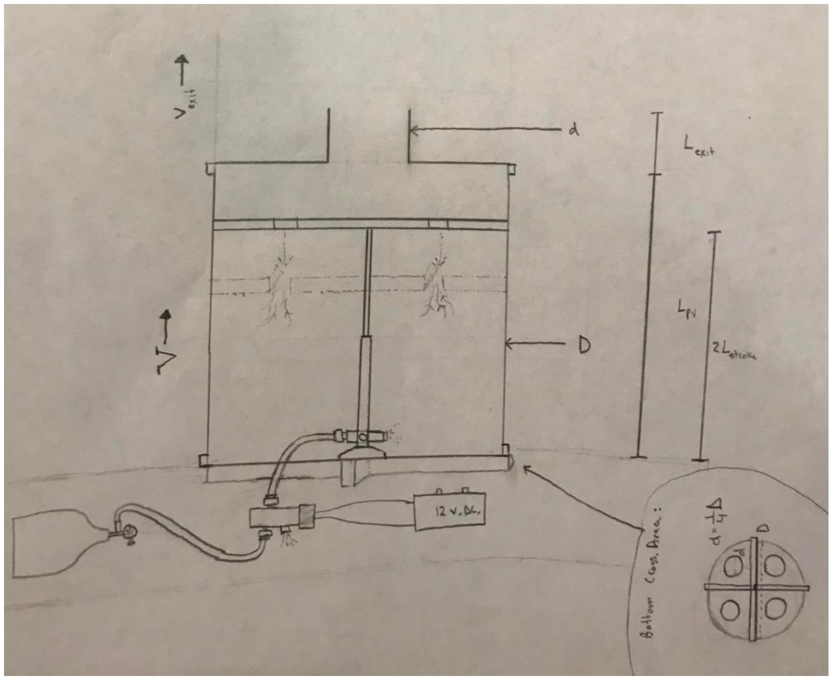


Figure 10

The fifth design option involves a mechanical system using a linear piston powered by a pneumatic cylinder. This design idea has the ability to perform multiple shots in one run (20+) and was preferred by our sponsors due to its very simple and easy concept and ability to be modified and model different magnitudes of excretion. This piston design allows complete control over all speeds, pressures, and in turn velocities and spread. This design also allows for the exit velocity and pressure drop to be constant for the duration of the shot which could not be achieved with the other design concepts.

Most of the work done for this design was in finding how to power the piston. The team initially thought to use an electrically powered linear actuator but after calculations, we could not find any linear actuators that met the appropriate stroke speed need to mimic a dolphin’s exit velocity. The team next looked into a spring powered piston but this approach needed many hand fabricated pieces to shoot the piston and pull it back into place. Our sponsors ideally desired a continuous shot system that would require no physical interaction to “recharge” the shot. In order to achieve this, the design would also entail having a linear actuator to remotely pull the piston into the starting position. The third and final design possibility was powering the piston with a single action pneumatic cylinder. This cylinder uses pressurized air to shoot the piston and an internal spring to pull it back in place. This is a little heavier and more expensive than the other options, however it is able to achieve more design characteristics that we found to be important in our blowhole design.

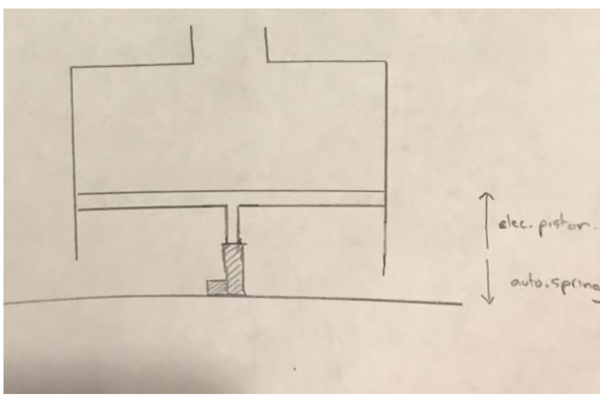


Figure 11

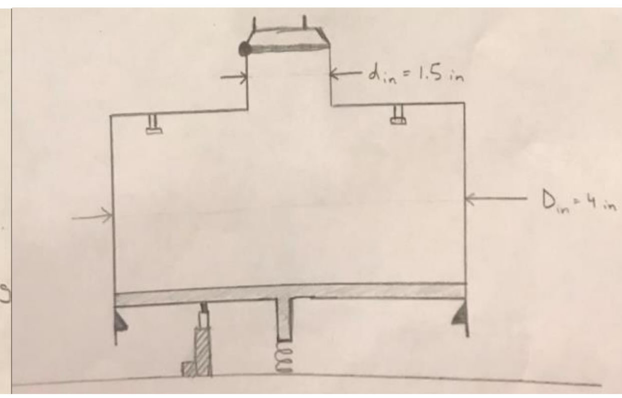


Figure 12

The table below shows calculations used to iteratively figure out what piston dimensions, pneumatic cylinder size, and pressure requirements were needed in our design to most closely match the exit velocity of a dolphins blow while remaining in a realistic flow rate range. The “Blowhole Calculations” section in the figure below is specifically used to find how much water is needed to match what normally pools up in a dimple of the average bottlenose dolphin's blowhole.

	Equation Table	Vessel Calculations		Pneumatic Calculations	
1	$V_1A_1 = V_2A_2$	Air Density (lb/ft^3)	**0.077**	Stroke Speed (ft/s)	**3.2**
2	$Q = AV$	Gravity (ft/s^2)	**32.174**	Power Factor	**0.6**
3	$P = F/A$	Piston mass (lb)	**0.454**	Stroke Force (lbs)	**42**
4	$P_1 + (1/2)\iota\rho v_1^2 + \iota\rho g h_1 = P_2 + (1/2)\iota\rho v_2^2 + \iota\rho g h_2$	Length.stroke (in)	6	Pressure.Cyl (Psi)	70
5	P.cyl = F/Power.fac	Length.PV (in)	13.5		
6	ΔV = Stoke.Length*Piston.Area	Length.Exit (in)	2		
7		Diam.Big (in)	5		
8		Diam.Small (in)	1		
9		Area.Big (in^2)	19.63		
10		Area.Small (in^2)	0.785	**Blowhole Calculations**	
11		Vel.Big (ft/s)	3.2	Avg. Length (cm)	**2.0**
12		^^^^^ (m/s)	0.97536	Avg. Width (cm)	**3.4**
13		Vel.Small (ft/s)	80	Avg. Dimple. D (cm)	**1.2**
14		^^^^^^^ (m/s)	**24.384**	Volume of Water (mL)	**8.2**
15		Flowrate.exit (ft^3/s)	0.436		
16		^^^^^^^^^^^ (L/s)	12.36		
17		Force.Big (lb)	42		
18		Pressure.Big (Psi)	2.139		
19		Pressure.Small (Psi)	0.009		
20		Force.Small (lb)	0.007		

Figure 13

Design five, the pneumatic powered linear piston design was chosen. This design was selected for its ability to perform multiple shots in one run (20+) and the fact that it was preferred by our sponsors for its very simple and easy concept and ability to be modified and model different magnitudes of excretion. This piston design allows complete control over all speeds, pressures, and in turn velocities and spread. This design also allows for the exit velocity and pressure drop to be constant for the duration of the shot which could not be achieved with the other design concepts.

With the key design decision made, many other smaller design decisions had to be made. The biggest decisions involved finding available parts to regulate pressures and erect the main structure of our design. The new design selected allowed for the replacement of specialty parts with more generic and readily available parts. Major design decisions made included: making the body out of PVC, using a provided air collector, abandonment of self-mobility systems, and the integration of a self-milled piston head. After organizing a new parts list, the online ordering process began while more available parts were purchased directly from the Lowe’s in Stillwater. The fabrication and assembly process began immediately following those purchases. This process began with fabrication of the outer PVC shell. Proper lengths of PVC pipes were cut, the piston head was milled from a half inch thick aluminum sheet, PVC end caps and the piston head were drilled and tapped to accommodate threaded fittings, and major PVC components were connected with teflon tape or PVC specific cement. In addition, developments in the water delivery system were made. A water delivery flap was fabricated and implemented into the exhaust pipes.

Figure 14

Figure 15

Below are the progress pictures of the assembly of the main body (6 inch PVC) with the one way valves and exhaust pipes. There are two models. One has an exit diameter of 1.5 inches and the other has a 1 inch diameter exit. At the base of the two models is the milled aluminum plate (0.5 inch thick, 6 inch diameter) that will be attached to the pneumatic piston. The board they sit on is the base in which all of our design would be securely held to. The prototype water delivery flap was fairly successful. The flap is hinged in the tube with a wire and held horizontally, from below, by a crossing wire to prevent the flap from getting flipped upstream by the vacuum created during piston retraction. The flap holds water sufficiently, and testing of the pneumatic cylinder revealed the flow output is strong enough to blow open the flap.

Figure 16

Figure 17

Figure 18

Detailed Description of the final Design:

Figure 20

Water tower & solenoid- Water tower suspends water at a higher height than that of the water flag allowing our system to run on a gravity fed water delivery system. The use and timing of the water delivery solenoid allows for the continual use of our design without having to refill the system or recharge.

Air chamber with 1" exit orifice (Dolph 2)- This test air chamber is used for the collection of further data on a variation of the exit diameter of the orifice. This allows for further testing and the confirmation of the design's success in reaching it's standards as well as the allowal of further testing on variations of dolphin size.

Arduino microcontroller- The arduino microcontroller is used for the implementation of the system's control logic. The arduino is used to time the solendoids that drive the system, and initiate the operator control.

Pneumatic solenoid- The pneumatic solenoid is used to release the regulated air into the pneumatic piston air chamber in order to drive the piston head.

Aesthetic design- Aesthetic design was added for visual appeal

Water delivery flap- The water delivery flap allows for the implementation of our water delivery system. The flap allows water to rest on top until a "blow" is fired and the flap is allowed to revolve and throw the water into the flow of the air. This replicates how water will rest on the surface of the blowhole of a dolphin and then will be caught up in the flow.

Air chamber with 1.5" exit diameter (Dolph 1)- This air chamber is used to replicate the exit orifice of a male adult bottlenose dolphin. Having a similarly sized exit orifice allows for accurate replication of a dolphin "blow".

Pneumatic piston- The pneumatic piston when pressurized moves the piston through the air chamber and pushes air out of the exit orifice. The piston when depressurized retracts using a spring to its original resting position.

Air pressure regulator- The air pressure regulator takes the high pressure stored in the HPA tank and regulates it down to a working pressure that can be adjusted for testing purposes. This regulated pressure is then used to drive the pneumatic piston.

HPA tank- The HPA tank is able to store air up to 125 psi and the volume allows for enough air to be stored for many trials of the design. This tank has to be charged by an external pressure source.

Evaluation of the final Design (design Calculations):

	Equation Table	Vessel Calculations	
1	$V_1A_1 = V_2A_2$	Air Density (lb/ft^3)	**0.077**
2	$Q = AV$	Gravity (ft/s^2)	**32.174**
3	$P = F/A$	Piston mass (lb)	**0.454**
4	$P_1 + (1/2)\iota\rho v_1^2 + \iota\rho g h_1 = P_2 + (1/2)\iota\rho v_2^2 + \iota\rho g h_2$	Length.stroke (in)	6
5	P.cyl = F/Power.fac	Length.PV (in)	13.5
6	ΔV = Stoke.Length*Piston.Area	Length.Exit (in)	2
7	$\Delta P = K^*(\iota\rho v^2/2)$	Diam.Big (in)	6
8	$h_L = K^*(v^2/2g)$	Diam.Small (in)	1.5
9		Area.Big (in^2)	28.27
10		Area.Small (in^2)	1.767
11		Vel.Big (ft/s)	5
12		^^^^^ (m/s)	1.524
13		Vel.Small (ft/s)	80
14		^^^^^^^ (m/s)	24.384
15		Flowrate.exit (ft^3/s)	0.982
16		^^^^^^^^^^^ (L/s)	27.80
17		Force.Big (lb)	42
18		Pressure.Big (Psi)	1.485
19		Pressure.Small (Psi)	0.009
20		Force.Small (lb)	0.016

Figure 21

Work order using the equations	
Eq.1.	Find V.Big
V =	5
Eq.2.	Find Q
Q =	0.982
N/A	Assume Vel.Small
V =	80
N/A	Assume Force.Big (stroke force)
F =	42
Eq.4.	Find Pressure.Small
P =	0.0088
Eq.4.	Find Force.Small
F =	0.0155
Eq.5.	Find Pressure.Cyl
P.cyl =	70
Eq.6.	Find pressure vessel Δvolume
ΔV =	0.0982
N/A	Find flowrate of actual piston
Q.act=	0.1178
Eq.7.	Find Pressure loss in fitting
ΔP =	73.44
Eq8.	Find Head loss in fitting
h_L =	29.84

Figure 22

Once finding the desired value for the exit velocity to be 24 m/s and the exit flow rate to be around 24 L/s, vessel and "L" piece calculations were performed to iteratively optimize the dimensions of the PVC dolphin body. All the necessary equations can be found in the equation table and our thought process can be followed under the yellow work order list. The first calculation performed is at the top of the work order list and the last is at the bottom.

Pneumatic Calculations	
Stroke Speed (ft/s)	5
Power Factor	0.6
Stroke Force (lbs)	42
Pressure.Cyl (Psi)	70
Pressure.Vessel.ΔV (ft³)	0.098
Actual flowrate (ft³/s)	0.118
^^^^^^^^^^^^ (L/s)	3.34

Blowhole Calculations	
Avg. Length (cm)	2.0
Avg. Width (cm)	3.4
Avg. Dimple. D (cm)	1.2
Volume of Water (mL)	8.2

"L" Piece Calculations	
Diam. (in)	1.50
Elbow.Height/Length (in)	3.125
Horiz.Length (in)	0.0
Vert. Height (in)	3.0
Total Length (in)	3.125
Total Height (in)	6.125
90° PVC Elbow K.value	0.3

Blowhole Measurements (Hawaii)			
Animal	Length (cm)	Width (cm)	Dimple Depth (cm)
1	2.4	3.8	0.7
2	2.1	3.6	1.3
3	1.7	3.3	1.5
4	2.2	3.1	1
5	2	3.5	1.5
6	2.5	3.6	1.7
7	1.3	3.4	1.1
8	2	3.5	1.1
9	2	3.3	1
10	3.5	3.9	1.2
11	1.3	3.2	1.5

Blowhole Measurements (Bermuda)			
Animal	Length (cm)	Width (cm)	Dimple Depth (cm)
1	2.3	3.6	1.2
2	1.5	3.5	0.5
3	2	3	1.2
4	1.7	3.2	1.2
5	2	3.3	1
6	2	3.5	1
7	2	3	1
8	2	3.8	1.3
9	1.7	3.5	1
10	1.6	2.8	1

Blowhole Measurements (Oahu)			
Animal	Length (cm)	Width (cm)	Dimple Depth (cm)
1	2.2	3.7	1.5
2	1.7	3.3	1
3	2.1	3.6	1
4	2.3	3.5	1.5
5	2.4	3.4	1.5
6	2.4	4	1.3

Figure 23 *Figure 24*

Blowhole measurements were taken by marine biologists in the field and emailed to Dr. Bruck for water collection data. By taking the average dimple sizes of these dolphins, we decided that 8.2 mL of water would be collected and sprayed with every shot. Our final design is calculated to deliver and exit velocity of 24.4 m/s and an exit flow rate of 27.8 L/s when the pneumatic piston is fed 70 psi of pressurized air. The pneumatic piston delivers 42 lbs of force with an internal flow rate of 3.34 L/s when shot at 70 psi.

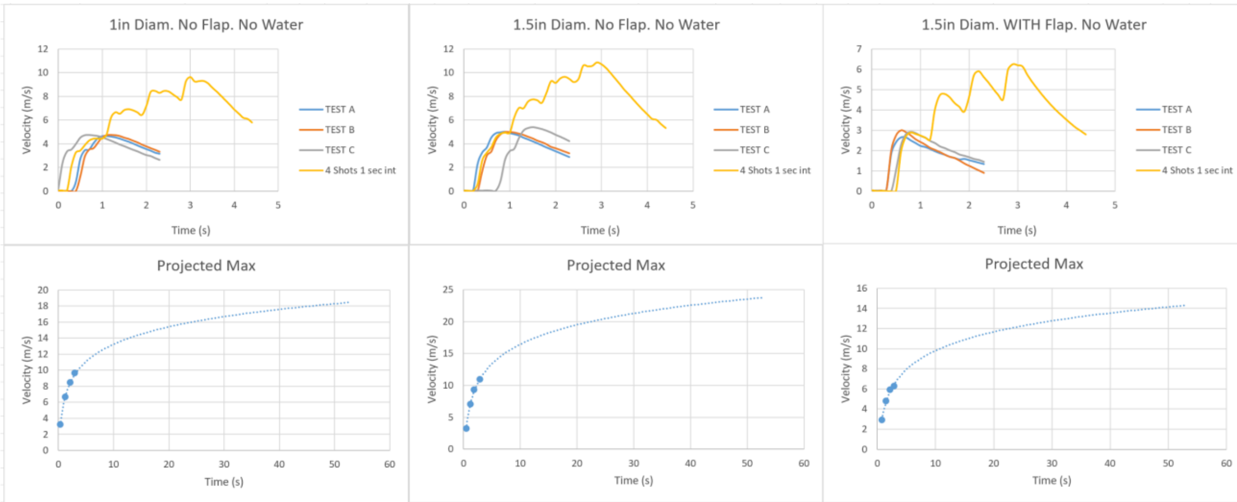


Figure 25

Avg Max (m/s):	4.70581
4 Shot Max Values	
0.4	3.231048584
1.3	6.643676758
2.2	8.448028564
3	9.617614746
PROJ Max (m/s):	18.5

Figure 26

Avg Max (m/s):	**5.13687**
4 Shot Max Values	
0.5	3.23104858
1.2	7.02209473
1.9	9.28878784
2.9	10.8856201
PROJ Max (m/s):	**24**

Figure 27

Avg Max (m/s):	**2.8493**
4 Shot Max Values	
0.8	2.89001465
1.5	4.79125977
2.2	5.91278076
2.9	6.2538147
PROJ Max (m/s):	**15**

Figure 28

Initial test readings were gathered with the use of a traditional anemometer that was borrowed from Dr. Jacob. 4 different tests were performed with 3 different exit pipes. All velocity readings for single shots were found to be between 2.8 and 5.13 m/s which were very low. The team concluded that these readings were low due to our anemometers inability to read instantaneous velocities. The anemometer needed a few seconds of constant flow to accurately read velocities. To overcome this challenge, the team fired off 4 shots consecutively with 1 second intervals in between each shot. This simulated a flow that was longer than one explosive shot and gave the anemometer more time to warm up and more accurately measure the exit velocity. The results of this test were graphed, matched with a logarithmic trend line, and projected max velocities were found to be between 15 and 24 m/s. These results were much closer to the desired values of our design but more testing was done to measure the exit velocity more accurately.

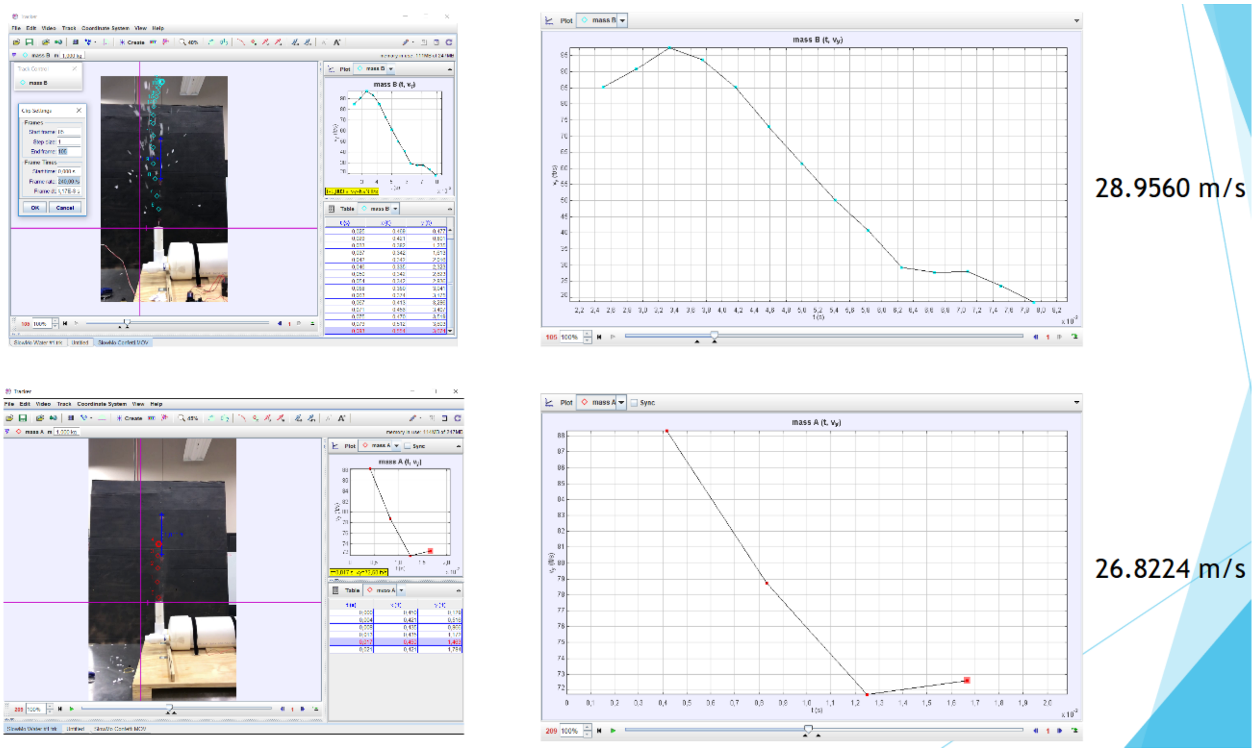


Figure 29

Videos of our test shots with water and confetti were analyzed for velocity readings. Confetti and water droplets were tracked frame by frame to find that our design shot water at 26.8 m/s and confetti at 28.9 m/s. These are higher than the desired 24 m/s which shows that our design can match what a dolphin can do in the wild. To lower the exit velocity of these shots to 24 m/s, reduce the amount of pressurized air that goes into the pneumatic cylinder from 70 psi to 60 psi.

Recommendations for Future Work:

Short term improvements that should be made include fabricating an improved water flap and reduce the height of the water tower. By implementing a hinge that allows the water flap more range of motion will reduce the dampening effect on the exit velocity and more effectively throw water into the air stream during exhalation. Matching the cross section of the exit piping and the flap more closely will also aid in pooling water more effectively during pre-exhalation. Reducing the height of the water tower provide more air clearance for drone collection methods and improve the visibility of each shot.

Long term improvements include implementing the self-mobility concept and adding mucus or some form of liquid additive for testing purposes. Implementing the concept of self-mobility with an RC car or boat would require fabrication of a similar design on a smaller scale and compacting all the components of this design. Including a liquid additive to future iterations of this design could prove very useful and may be simple to add into the water tower system seen in the current blowhole simulator. However, a vast amount of research would need to be done to understand what additives could and should be used to aid in testing processes.

Revised Gantt Chart:

Multiple changes occurred in our gantt chart throughout the duration of this project. The main impactful changes were to ditch the idea of custom fabricating 3 anatomically correct exit ports with a 3D printer, switching our horizontal motion component from an RC car to a car mount, and time delays encountered while ordering parts. As can be seen between weeks 10 and 11, not much work was completed since the team was simply waiting on parts to come in. This condensed the time we allocated for building and testing from three weeks each to around one and a half weeks each.

Project Name	Members	Project Duration	Project Start Date	Project End Date
Dolphin Blowhole Simulatior	Kevin Quinn Daniel Wigley Jason Fey	105	1/22/2018	5/7/2018

	YOU CAN CHANGE THESE					DO NOT CHANGE ->	Week - 1	Week - 2	Week - 3	Week - 4	Week - 5	Week - 6	Week - 7	Week - 8	Week - 9	Week - 10	Week - 11	Week - 12	Week - 13	Week - 14	IAB Event	Week - 15	Week - 16
Task	Task Description	Who	Task Duration (days)	Start Date		End Date	1/22/2018	1/29/2018	2/5/2018	2/12/2018	2/19/2018	2/26/2018	3/5/2018	3/12/2018	3/19/2018	3/26/2018	4/2/2018	4/9/2018	4/16/2018	4/23/2018	4/27/2018	4/30/2018	5/7/2018
1	Blowhole Research	All	40	1/22/2018		3/3/2018																	
2	Design blowhole system	All	28	1/29/2018		2/26/2018																	
3	Look into 3 different design approaches	All	7	2/26/2018		3/5/2018																	
4	Finalize desired approach	All	14	3/5/2018		3/19/2018																	
5	Implement horizontal motion	All	14	3/12/2018		3/26/2018																	
6	Order Parts	All	14	4/2/2018		4/16/2018																	
7	Build	All	14	4/9/2018		4/23/2018																	
8	Test	All	7	4/20/2018		4/27/2018																	
9	Final Documentation	All	7	4/23/2018		4/30/2018																	
10	Logbooks & document collection	All	7	4/30/2018		5/7/2018																	

Figure 30

Revised Budget Table:

The revised budget table below shows that our project cost right around $300. This was well below the $1000 upper limit we set at the beginning of the semester. This is very good, because this shows that the prototype could be made 2 times over without going over our limit. As mentioned above, future iterations of this project on a smaller size will be desired, so the low cost of the whole assembly is important.

Budget Table		
Quantity	Cost	Item
1	$31.99	Cylinder hook-up starter kit
1	$37.05	7/8 Bore Single-Acting univ.mount
1	$13.75	Flange Mount (5-8/18 (D)(E)(F))
1	Free	12v Battery pack
1	Free	AA Batteries (20pack)
1	$12.20	quick exhaust valve
1	$8.97	PVC fitting (6in diam. pipe)
4	$19.56	PVC fittings (6in diam. Endcap)
1	$3.69	PVC fitting (1-1/2in diam. Pipe)
1	$2.26	PVC fitting (1in diam. Pipe)
1	$8.39	PVC cement & primer pack
1	Free	Alluminum plate (for piston head)
1	$40.00	PVC 6 in. diameter 10 ft length
4	$3.00	check valve
1	$5.00	2x4 Plywood (base support)
1	Free	Air Accumulator (5-Gallon)
1	Free	Galvanized Pipe Cross Fitting (1/2 NPT)
3	$2.39	Threaded Reducer (Bushing)
1	$10.45	1/4 npt pressure gauge
1	$79.99	Air Regulator
1	$2.39	1/2 npt nipple
1	$0.88	1/4 npt quick connect
1	$5.59	1/4 quick connect barrell
1	$8.50	Pvc and miscellaneous plumbing
Total	$296.05	

Figure 31