EML4551-2

Team #508: Dow – Drone Payload

Sample Collection and Measurement

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Abstract

The abstract is a concise statement of the significant contents of your project. The abstract should be one paragraph of between 150 and 500 words. The abstract is not indents.

Keywords: list 3 to 5 keywords that describe your project.

Disclaimer

Your sponsor may require a disclaimer on the report. Especially if it is a government sponsored project or confidential project. If a disclaimer is not required delete this section.

Acknowledgement

These remarks thanks those that helped you complete your senior design project. Especially those who have sponsored the project, provided mentorship advice, and materials. 4

- Paragraph 1 thank sponsor!
- Paragraph 2 thank advisors.
- Paragraph 3 thank those that provided you materials and resources.
- Paragraph 4 thank anyone else who helped you.

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Notation

A17	Steering Column Angle
A27	Pan Angle
A40	Back Angle
A42	Hip Angle
AAA	American Automobile Association
AARP	American Association of Retired Persons
AHP	Accelerator Heel Point
ANOVA	Analysis of Variance
AOTA	American Occupational Therapy Association
ASA	American Society on Aging
BA	Back Angle
BOF	Ball of Foot
BOFRP	Ball of Foot Reference Point
CAD	Computer Aided Design
CDC	Centers for Disease Control and Prevention
CU-ICAR	Clemson University - International Center for Automotive Research
DDI	Driver Death per Involvement Ratio
DIT	Driver Involvement per Vehicle Mile Traveled
Difference	Difference between the calculated and measured BOFRP to H-point

DRR	Death Rate Ratio
DRS	Driving Rehabilitation Specialist
EMM	Estimated Marginal Means
FARS	Fatality Analysis Reporting System
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GHS	Greenville Health System
H13	Steering Wheel Thigh Clearance
H17	Wheel Center to Heel Pont
H30	H-point to accelerator heel point
HPD	H-point Design Tool
HPM	H-point Machine
HPM-II	H-point Machine II
HT	H-point Travel
HX	H-point to Accelerator Heel Point
HZ	H-point to Accelerator Heel Point
IIHS	Insurance Institute for Highway Safety
L6	BFRP to Steering Wheel Center

Chapter One: EML 4552C

1.1 Project Scope

1.1.1 Project Description:

The senior design team will develop a payload to attach to a drone. The payload will collect fluid samples in a timely manner without contamination. The samples will be transported back to shore by the drone for testing after being safely stowed in the payload.**1.1.2 Key Goals:**

The project description outlines our project's primary goal: to design a drone payload that functions as a sampling mechanism to collect liquids. The payload will be designed to optimize the amount of time and energy spent by having the drone collect multiple samples in one trip. The attached mechanism will not impede the drone's ability to fly. The number of components will be kept to a minimum, so the design is as light as possible. The payload will be compact and fit safely under the drone without interfering with its ability to fly, land, or remain stationary. The payload will be designed to prevent sample contamination. The sample apparatus will be constructed of materials compatible for use with a wide range of possible chemicals. To minimize oscillations of the payload, the attached cable will be kept in strong tension. The payload will be designed to minimize the drag and lift forces acting on the system from waves, currents, and wakes from vessels.

1.1.3 Markets:

The key goals for the project were determined with the primary market for the payload in mind, being Dow Chemical. This market also includes other chemical producers who would require highly mobile fluid sampling equipment. The secondary market includes agricultural organizations, disaster relief groups, municipal and federal water monitoring agencies, and environmental conservation groups. These groups would use the apparatus to assess the local water quality.

1.1.4 Assumptions:

Several assumptions will be made to more accurately define and control the scope of the project. The scope of the project is limited to the construction of the sampling apparatus, and apre-existing drone will be purchased or provided for use. The drone will only have the singular function of being the mode of transport for the apparatus and will not occupy any other roles. Furthermore, the drone will have a built-in camera.

The designed apparatus will take samples that are strictly liquids. Due to the differing nature of the fluids being sampled, the machinery will be decontaminated before being used with the next fluid. Some of the fluids being gathered may be dangerous or explosive chemicals, so the corresponding SDS sheets will be gathered and analyzed to ensure safe operation.

The FAMU-FSU College of Engineering machine shop will be available for access to manufacture most of the components. Specific custom parts will be sent to a professional company for manufacturing. The drone will not be flown in unsafe areas or unsafe weather conditions. Access to a safe flight test area to troubleshoot the apparatus design will be available. All funds will be supplied by the team sponsors and purchases will be executed through the FAMU-FSU College of Engineering.

We will be making a sampling apparatus that can take one sample based off the drone that is available to use. Another apparatus is going to be designed that would be adequate to use with Dow's resources and current drone fleet.

1.1.5 Stakeholders:

The primary stakeholders in the design project are Alicia Washington and Marcus Rideaux, who represent Dow Chemical as the project sponsors. The facility advisors, Dr. McConomy and Dr. Ordóñez, along with the teaching assistants, Caterina Arnold, Saralyn Jenkins, and Jordan Steverson, are also primary stakeholders in the project. Chemicals and other intrusive elements can contaminate and pervade water sources, alternative stakeholders include conservation groups, state environmental protection agencies, municipal water treatment plants, and other groups negatively affected by these environmental issues.

1.2 Customer Needs

1.2.1. Introduction:

Team 508 plans to develop a drone payload to carry samples from local water sources to collect and identify various types of algae without contamination. Algae blooms can remove oxygen from water and certain types of algae can release harmful toxins upon decomposition. These toxins can spread illness and kill wildlife, posing a real threat to the environment and local economy.

Customer needs are statements provided by the customer on what they want from a project. Engineers must interpret and quantify the needs of their clients to ensure their project is moving in the right direction. The following section discusses how the customer needs were obtained for Team 508, and what questions were asked to their clients. The questions, responses, and interpreted needs are included in table 1.

Table 1

Customer Needs and Interpretations

Question	Answer	Interpretation
What is the main objective of this project?	Dr. Ordóñez: To collect multiple water samples remotely and safely without contamination. Dow: To collect samples of different chemicals	The payload collects multiple liquid samples while preventing contamination.
Would you like the samples to be tested during flight?	Dr. Ordóñez: No. Dow: No.	The payload collects and stores samples which will be transported by the drone.
How many samples should the drone collect in one flight?	Dr. Ordóñez: At least 3. The drone payload should be able to distribute the samples equally while flying as well.	The payload balances multiple samples to keep the drone's center of mass constant.
What size samples would you need?	Dr. Ordóñez: That is a question for Marine Biologist, but you should consider a large payload of 1kg.	The payload is made of light-weight material and weighs less than 1 kg (2.2 lbs) including the samples.

Would the payload need to be universally applicable?	Dr. Ordóñez: Yes, it would be most beneficial if this could be attached to all drones. Dow: Yes	The payload can be applied to drone bodies of all shapes and sizes.
What different fluids would you like to be collected?	Dr. Ordóñez: The primary concern should be with collecting samples of seawater to check for algae blooms. Dow: The payload should be able to collect several kinds of chemicals used in our manufacturing processes.	The payload can collect samples from the ocean with algae blooms. The payload can collect samples from different chemicals.
Have you ever flown a drone with a payload? If so, what are the difficulties you encountered in the design?	Dr. Ordóñez: Stability is the number one concern. Be wary of the payload snagging and suspended wires.	The payload allows the drone to stay balanced. The drone can fly and land in a smooth, controlled manner with the payload attached.

	Dow: No sparks and combusting materials.	The payload is secure to the drone while in operation (flying/landing). The payload is made of inert materials that prevent explosive reactions with hazardous substances.

1.2.2. Customer Needs Discussion:

Team 508's customer needs were gathered during a face-to-face interview with faculty advisor Dr. Ordóñez. A brief in-person meeting was also established with the project sponsors from Dow chemical. Team 508 reached out to Dow via email to establish a follow-up meeting, but the next meeting is beyond the due date for this assignment. As such, a few of the questions are currently missing responses from the Dow sponsors, but they will be updated as soon as they are available. Team 508 worded the questions carefully to ensure the clients would be able to answer honestly without being affected by the team's pre-existing notions.

When asked what the main objective of the project was, Dr. Ordóñez claimed it was to safely collect water samples for testing, with emphasis placed on water contaminated by algae blooms. Dow Chemical, on the other hand, was interested in how the payload would be used to collect samples of different chemicals in their facilities. The goal of the project is to create a payload that can collect the liquid samples, prevent contamination, and store the samples until the drone has landed safely. Both Dow Chemical and Dr. Ordóñez agreed that it was not required for the samples to be tested mid-flight. This allows for the focus of the project to center around safely managing the drone and its payload.

Concerning the question about the number of samples, Dr. Ordóñez stated that the payload should be able to collect at least 3. Emphasis was placed on keeping the samples balanced within the payload, so as not to impede the drone's balance mid-flight. The sample size will be determined after considering Dow's needs and discussing it with a marine biologist. Team 508 is currently in communication with Dr. Tara Stewart Merrill at the FSU Coastal and Marine Laboratory.

The drone payload design will need to be universally applicable for both Dr. Ordóñez and Dow's needs. Dow Chemical has a wide variety of drones they use for their industrial operations. In terms of the different fluids that need to be collected, Dr. Ordóñez prefers that the payload be used for sampling algae water, while Dow prefers sampling various chemicals. The payload will be constructed from materials that are resistant to all the fluids tested. These materials will not affect the samples integrity, ensuring the fluids are accurately measured. When asked what issues the client encountered while flying a drone, Dr. Ordóñez mentioned that the payload would catch against obstructions. The sponsors from Dow mentioned that they did not want the drone to spark, due to the hazardous chemicals in their facilities. Team 508 will construct their payload from inert materials to avoid combusting with chemicals, and the payload will be designed to avoid snagging. Dr. Ordóñez also stated that the payload needed to be balanced in order to maintain the drone's weight distribution; this is the most important objective because the drone and payload must not be lost.

1.3 Functional Decomposition

1.3.1. Introduction

Functional decomposition divides the project's required actions and results into broad systems in accordance with customer needs. Breaking a system down into its parts allows for an effective method to approach potential solutions. Specialized functions are grouped together and assigned to various systems. Stability, safety, collection, and feedback make up Team 508's major functions. The Hierarchy Chart in Figure 1 shows the minor functions divided between systems and illustrates how multiple systems can be responsible for the accomplishment of a minor function. A Cross Reference Table was also created to show which minor functions are most crucial; this was determined by how many systems the function was applicable to. The Cross Reference Table is included in Table 2.

1.3.2. Discussion of Data Generation

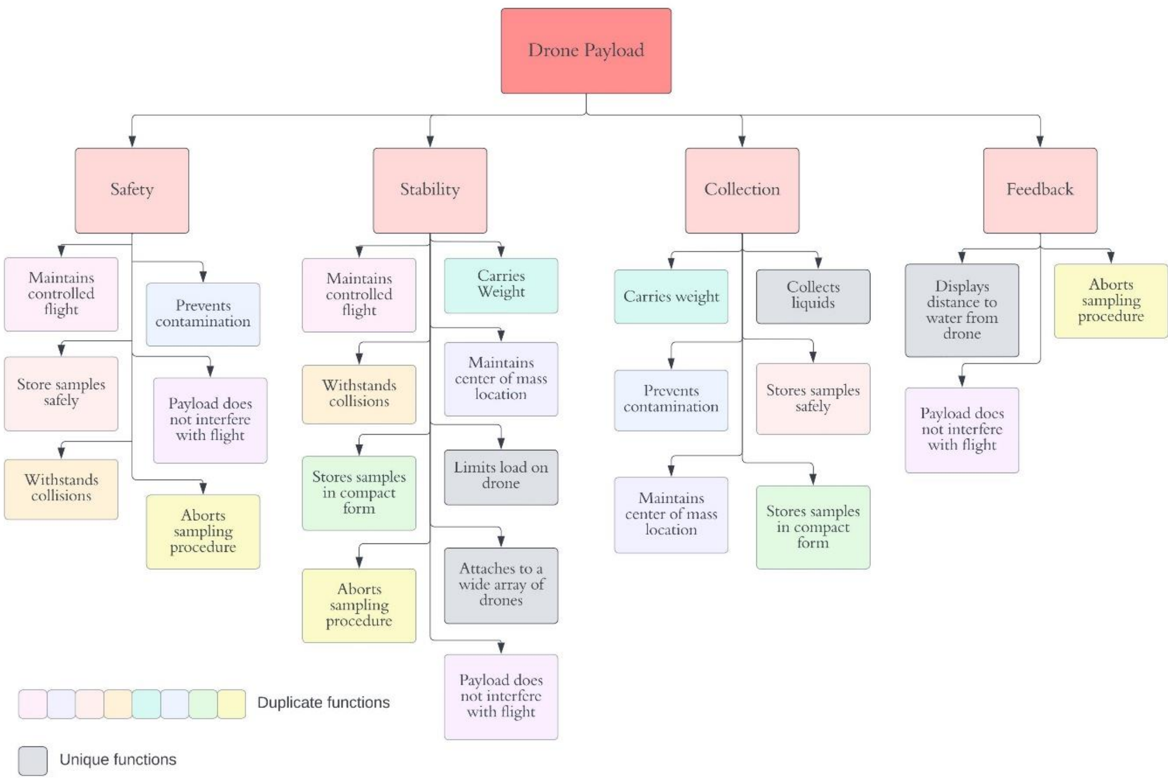
Data generation for the functions began with the project scope. The scope identified the objective, description, goals, markets, and stakeholders of the project. From this information, Team 508 was able to prepare questions to ask their advisor and sponsors to understand the project requirements. After meeting with Dr. Ordonez and Alicia and Marcus from Dow, the customer needs were interpreted from the answers provided. These interpretations served as the basis for the project functions.

1.3.3. Action and Outcome

The main goal of the drone payload is to obtain liquid samples, prevent contamination, and store the samples until safely landed. To achieve this goal, the design must maintain stability, provide feedback, collect samples, and keep the entire system safe. The payload must be able to decontaminate itself between samples. It should also be compact in order to avoid obstructing the drone's flight or landing.

Figure 1

Functional Decomposition Hierarchy Chart



1.3.4. Discussion of Systems

The Hierarchy Chart is useful for Team 508 and their stakeholders, because it provides a concise description of how the product would meet the needs of the customers. Separating the product into subsystems reduces the complexity of the project, so the functions for the drone payload were divided into four categories: safety, stability, collection, and feedback.

Safety was chosen as the first sub-system, because ensuring that the drone and payload return safely after sampling is paramount to the success of the project; if the drone and payload are lost during the process, it would not be possible to test the samples.

The second subsystem involves how the payload affects the stability of the drone. This is related to the safety of the drone and payload as well. The payload ensures that the center of mass of the drone system will not be affected by the collection of multiple samples. The payload remains compact to the drone while flying and uses a minimal amount of space to store the samples equally.

The collection subsystem involves how the payload will obtain and process the samples. After collecting a liquid sample, the payload decontaminates itself before collecting the next one. Once all the samples are collected, the payload stores them safely until the drone has returned.

The last system considered was the feedback of the drone. The drone is equipped with sensors to record vital data during the sampling process, such as the distance of the drone from the water and how far the payload needs to submerge to collect an adequate sample. This information is displayed in real-time to the user, who can send operator commands back to the drone.

Table 2

Functional Decomposition Cross Reference Chart

	Stability	**Safety**	**Collection**	**Feedback**

Carries weight	**X**		**X**	
Maintains controlled flight	**X**	**X**		**X**
Prevents contamination		**X**	**X**	
Store samples safely		**X**	**X**	
Withstands collisions	**X**	**X**		
Maintains center of mass location	**X**		**X**	
Stores samples in compact form	**X**		**X**	
Limits load on drone	**X**			
Attaches to wide array of drones	**X**			
Collects liquids			**X**	
Displays distance of drone to surface of liquid				**X**
Receives operator commands				**X**
Maintains in-flight feedback				**X**

Aborts sampling procedure	**X**	**X**		

1.3.5. Connection to systems

After reviewing the Cross-Reference chart above, the systems were ranked based on how many functions they related to. The system with the most influence was stability, which had roles in 8 minor functions. The other 3 systems – safety, collection, and feedback – all fulfilled an equal number of minor functions at 6.

Team 508 reasoned that the stability system was tied closely to the safety system; maintaining the stability of the drone-payload was a necessary aspect of ensuring the system was kept safe throughout the collection process. Stability holds a close relationship to the safety system and is the function with most influence on the project. Therefore, the team decided to choose stability as the system with the highest priority and safety as the second most important system.

Like a helicopter deploying a rescue ladder for a patient in an emergency airlift procedure, the drone must hold itself at a fixed position in midair while its payload gathers fluid samples and stores them safely. These tasks cannot be completed without the stability of the system's body. To collect and store the samples, the design cannot hinder the drone’s ability to remain stable throughout the process.

The product’s objective is to collect fluid samples and store them for flight without contamination, which has several risk factors to consider in its design: the technology in the drone is complex, delicate, and expensive. These factors, coupled with the exposure to potentially hazardous chemicals and unpredictable environmental factors led the design team to make safety a key function.

The team rationalized that the main issue with the payload would be designing the mechanism to collect and store the samples. Although collection and feedback have roles in the same number of minor functions, the feedback was deemed to be the least important of the systems. Many of the functions of the feedback involve transmitting data from the drone-payload to the user, which is accomplished via programming and sensors rather than building a mechanism.

Drones are semi-autonomous aircraft that are controlled remotely by a user who can see the drone's surroundings from on-board sensors. The cameras provide visual feedback to the controller. The team believes the drone's payload should provide feedback to its controller(s) as well. In addition, the recipients should not only be people operating and monitoring the sample collection procedure, but also non-human controllers that are part of the drone's control system. The feedback system provides quality assurance and accounts for disturbances.

1.3.6. Smart Integration

The Cross Reference Chart was used to determine which functions were the most important to the completion of the project, determined by how many systems they spanned across. An 'X' was marked inside a function's box if it fulfilled that system. By covering three systems, 'maintaining controlled flight' became the most important function. The flight path of the drone would be controlled via an end user after receiving feedback from the drone about the surrounding conditions. The drone would be stabilized to maintain controlled flight while sampling, which would greatly improve the safety of the system as well.

Carrying the weight, preventing contamination, storing samples safely, withstanding collisions, maintaining center of mass location, storing samples compactly, and aborting the sampling procedure were all equally important subfunctions and fell under two systems. The remaining minor functions were only applicable to a single system. The payload carries the weight of the samples after the collection process without affecting the stability of the drone. During the collection process, the drone-payload decontaminates itself for the safety of the samples and to maintain accuracy in each concentration.

Storing samples safely is another key aspect of the collection process, with the payload protecting the samples during the drone's return trip. The payload withstands collisions to improve the durability and safety of the system. If the drone collides with an obstacle, the stability of the system will not be affected by broken parts. Collecting samples does not affect the location of the center of mass of the system, as the samples are distributed equally throughout the payload. This is a key aspect in maintaining the drone's stability.

Storing the samples compactly means the collected samples will take up as little space as possible within the payload. The payload is also designed to be more compact to minimize the effects on the balance of the system. Aborting the sampling procedure is a fail-safe feature designed into the payload to save the drone during an accident. If the drone is caught against an obtrusion, the payload will be released to ensure the stability and safety of the drone on its return trip.

1.4 Targets and Metrics

1.4.1. Derivation of Targets and Metrics:

The original seventeen functions were divided into 4 main systems: stability, safety, collection, and feedback. 4 of the original minor functions were removed because they pertained to aspects of the drone's design, rather than the payload. The updated functional decomposition cross reference chart has been included in Table 2. After determining the main functions through functional decomposition, our team was able to establish each functions' corresponding targets and metrics. A metric is how the team will validate a function, but a target is the specific value to be designed around which requires unit analysis. Team 508 will use the targets and metrics to validate designs created during the concept generation process. Targets and metrics for the design of the payload were also determined that did not have corresponding functions. All the required targets and metrics are catalogued in Table 4, Appendix B.

The targets and metrics were determined from an open discussion held between all team members. The specific targets for the project's functions were found after the team conducted background research. Research included reading scientific papers, websites, specification sheets, and calculations. This section is divided into systems, and explains how each target was determined.

1.4.1.1. Stability

The payload will be designed to have a mass of less than 3 kg with all samples inside. A typical consumer drone is said to be able to carry between 0.5-3 kg of weight, so the upper limit was chosen as the maximum weight for the payload and samples (How Much Weight Can a Delivery Drone Carry? – DroneDek | the Mailbox of the Future, n.d.).

The drone will need to maintain a hover state during the sample collection phase. The desired orientation of the drone is 0 degrees to horizontal, to ensure there is no tilt caused by the payload on the system. This allows the sample to drop perpendicular to the surface of the water and the body of the drone.

For the payload to withstand collisions, the payload will be made up of low-density, high-strength materials, such as 3D printer filament or thermoplastics. Most drones possess a material strength of around 100 MPa so our payload is designed to be consistent with that (Coderman, 2019).

After discussing with Dr. Merrill at the FSU Coastal and Marine Laboratory, the required sample size was determined to be around 100 mL (g), so the payload will be designed with a max weight offset of 100 grams between any two sides of the payload when multiple samples are collected.

The payload will be kept compact to the drone body, with the team choosing 1 cubic centimeters to ensure enough clearance for the drone to land without obstruction.

The next two targets are closely related; the payload will be able to handle a max load of 35 N, and the tension between the sample and payload will be less than 5 N. Because the payload is designed with a max weight of 3 kg, the force due to gravity will be approximately 30 N. The team wants to limit the force of tension between the drone and the payload to less than 5 Newtons before the collection process is aborted. 5 newtons were chosen as the maximum, given that the force of tension one sample applies to the drone-payload system is approximately 1 Newton.

0.98 N = (100 grams) * (9.8 meters/seconds^2)

With 1 N being the approximate force of tension when a sample is collected, the team chose a factor of safety of 5 to account for any obstructions during the sampling process, such as the extra force of a wave or strong wind.

Another goal of the design is to create a universal attachment. After discussing with Dr. Ordonez, the team decided on making the payload applicable to at least 3 drone bodies to focus the direction of the project.

1.4.1.2. Collection

The derivation of the targets for the max weight of the payload, maintaining the center of mass of the payload, and storing the samples compactly were discussed in the section on stability.

To prevent contamination, the samples must be isolated after collection, with 0 mg/L desired contamination from outside substances.

The previous target is also related to storing the samples safely, with 0 mL desired volume lost from each sample after collection and storage. This would protect the integrity of the samples and avoid damaging any software or hardware of the payload.

After consulting with Dr. Merrill at the FSU Coastal and Marine Laboratory, the team determined the size of each sample should be 100 mL in order to identify the type of algae in the water. This size allows for a sufficient testing sample while keeping the storage bay small enough to not impede the landing gear of the drone.

1.4.1.3. Safety

The derivation of the targets for maintaining controlled flight, withstanding collisions, and aborting the sampling procedure were discussed in the stability section. The derivation of the targets for preventing contamination and storing samples safely were discussed in the collection section.

The payload maintains controlled flight, with balance as the metric and 0 degrees orientation to ground. The sample prevents contamination, with the metric being parts per million and 0 mg/L of each sample being contaminated by other liquids. The payload stores samples safely, with 0 mL volume lost after the sample is collected and stored. The payload can withstand collisions, which corresponds to a tensile strength of 100 MPa (Coderman, 2019). The payload aborts the sampling procedure when the tensile force between the payload and sample is over 5 Newtons.

1.4.1.4. Feedback

Several minor functions that satisfied feedback were considered but ultimately removed from consideration for the targets and metrics. These minor functions did not fit in the scope of the project, as they applied to the design of the drone rather than the payload.

The derivation of the targets and metrics for maintaining controlled flight and aborting the sampling procedure were discussed in the stability section.

The distance from the payload to the liquid should be displayed within 5 centimeters of accuracy, because the team expects the size of the sampling apparatus to be no more than 5 centimeters long. Thus, the feedback to the payload will be able to tell if the sample is in the liquid or not.

1.4.2. Critical Targets and Metrics

The critical targets and metrics were determined via open discussion between teammates. Each member of team 508 was tasked with choosing functions they believed were vital to the success of the project. From this procedure, the functions with the highest number of votes were chosen as critical functions. The 4 critical functions that were chosen were: the payload stores samples safely, the payload does not affect the center of mass of the drone, the payload must be universally attachable, and the payload can abort the sampling process if necessary.

The target for storing samples safely is 0 mL volume lost after collection and storage, to ensure the samples maintain their accuracy. For the payload to maintain its center of mass, the weight distribution must be unaffected. The required sample size was determined to be around 100 mL (g), so the payload will be designed with a max weight offset of 100 g between any two sides of the payload when multiple samples are collected. Another goal of the design is to create a universal attachment. After discussing with Dr. Ordonez, the team decided on making the payload applicable to at least 3 drone bodies to focus the direction of the project. 5 N was chosen as the max tension force before the payload would abort the sampling process. The force of tension one sample applies to the drone-payload system is approximately 1 newton. The team chose a factor of safety of 5 to account for any obstructions during the sampling process, such as the extra force of a wave or strong wind.

1.4.3. Discussion of Measurement

Various tools will be required in order to validate concept designs. For testing critical targets and metrics, sensors such as strain gages and pressure sensors will be used in order to measure tension between the payload and sample. A scale will be used to measure the weight distribution throughout the payload when samples have been collected. A shaker machine will be used to simulate flight conditions for the drone and payload, and a measuring cup/test tube will be used to measure the loss in volume for each sample after the system has been shaken. The testing methods for the critical targets and metrics are discussed in further detail in the method of validation section.

1.4.4. Method of Validation

Tests must be performed to validate whether designs meet the critical targets and metrics. To test whether the samples will be stored safely, with minimal volume lost from each sample, the volume of each sample will be measured before being placed into the payload. A shaker machine can be used to simulate the jostling effect of the drone while it is subjected to external flight conditions, such as wind or sharp turns. Once the payload and samples have been shaken, the payload will be unloaded, and the leakage from each sample will be measured by comparing the final volume amounts to the initial amounts.

To ensure the center of mass does not deviate by an excessive amount, the weight distribution of the payload will be measured at each corner. A scale will be used to measure the force applied by the payload at each corner after several samples have been placed inside. At this time, the weight between the two sides must not vary by more than 100 grams, which will be the estimated weight of a single sample.

The sampling process must be aborted should the sampling apparatus become entangled or snagged on something. This procedure allows the drone and payload to separate from the sample being collected in order to save the system. The sampling apparatus will be connected to a strain gauge that will sense the sample is snagged when the upwards force exerted on the tether exceeds 5 N. At this point, a mechanism will be employed to sever the tether and free the drone.

The critical target involving mounting configurations doesn't require any instrumentation to validate the metric. The universal capabilities of the payload will be tested by attempting to attach it to the underside of at least 3 drone body types. If the payload is compatible with these bodies, the target will be met. The mounting configuration goal can be accomplished by incorporating multiple mounting locations into the design. Several different drone platforms will have their bodies considered for mounting ideas, and the sturdiest ones will be selected to allow for uniform use among many different drone bodies.

1.4.5. Summary of Targets and Metrics

The targets and metrics generated for the functions help define the parameters the project will adhere to. A full list of these parameters can be found in table 4. Multiple concepts will be weighed based on how well they meet the outlined targets and metrics. More emphasis will be placed on fulfilling the four critical targets:

1. The selected payload design concept should safely store the samples upon collection, by limiting loss of liquid volume in the sample to 0 mL.
2. The design should distribute the weight of the entire system evenly, by having at most 100 grams of weight offset at each corner of the payload.
3. The payload design should be able to mount onto at least three different drone designs without interfering with its ability to collect samples, or the drone flight characteristics.
4. The payload design should abort the sampling process when needed, namely when the tension between the payload and sample exceeds 5 N.

Table 3 reiterates the critical targets and their corresponding functions. Critical targets are the ones most important to the success of the project and were selected based on the priorities of the company sponsors and team members. The full catalog of functions and their targets was included in table 4 in the appendix.

Table 3

Critical Targets and Metrics Summary Table

Major Function	*Critical Function*	*Metric*	*Target*
Safety/Collection	**Stores Samples Safely**	**Volume**	**0 mL Loss**
Stability/Collection	**Maintains Center of Mass**	**Weight Distribution**	**max 100 g offset**
Stability	**Attaches to wide Variety of Drones**	**Mounting Configurations**	**3 Distinct Attachment Methods**
Stability/Safety/ Feedback	**Aborts sampling procedure**	**Force**	**5N tension between payload and sample**

1.5 Concept Generation

1.5.1 Introduction

Concept Generation involves meeting as a group to brainstorm as many ideas as possible, and then refining these ideas based on the needs of the project sponsors and advisors. In an effort to brainstorm 100 ideas for the sampling payload, team 508 used various concept generation tools to determine characteristics to incorporate into the design. These tools included biomimicry, the anti-problem, battle of perspectives, and the morphological chart which are explained in detail in the next section on concept generation tools. The team also took inspiration from state-of-the art sampling designs and various fields of drone technology.

Multiple ideation sessions were dedicated to developing concepts. None of the concepts were judged during this phase. Once the team decided on 100 concepts, 5 medium fidelity and 3 high fidelity concepts were chosen. Each medium and high-fidelity concept includes a sketch and explanation to fully define the concept.

1.5.2 Concept Generation Tools

Biomimicry

Biomimicry was used by the payload design team to generate ideas inspired by natural phenomena. The payload's main objectives are to attach to a drone body and collect samples from a liquid source. After samples are collected, the payload must store them without contaminating any of them.

Considering these factors, one member discussed with the team how Frigatebirds, a species of marine sea bird, prey on small fish at the ocean surface. Frigatebirds wait for fish to reach the surface before scooping them into their beaks. If frigatebirds get their feathers wet, they would be unable to fly and would drown. Since the main body of the payload will be attached to a drone, it would be preferable to avoid getting most of the system wet. Thus, the sample collection method should be as minimally invasive as possible.

The other concept formed from brainstorming upon nature was using octopus-like telescoping tentacles that scoop up water samples in a cupped-handlike form. This idea lacks compactness but could simplify the collection and storage processes.

'Asknature.org' was used by the team to look up how nature solves issues like collecting water. An example that was provided involved bromeliads, which are funnel-shaped flowers which act like pitchers. Nicolson (2009) discussed how bees drink and store water to maintain homeostasis, which was used to create another concept as well.

Anti-Problem

The anti-problem technique involves identifying a specific issue we hope to resolve and coming up with solutions to solve the opposite problem. For instance, to solve the issue of how to prevent sample contamination, we instead looked at examples of how to actively contaminate the samples. While seemingly contradictory, this method helped us determine what characteristics our designs should avoid and allowed us to brainstorm from a new angle. Two problems we hoped to solve were 'How to Contaminate Samples?', and 'How to Discard Samples?' The solutions and causal factors to these questions were included in tables 4 and 5.

Table 4

Anti-Problem 1: How to Contaminate Samples

Solution:	**Causal:**
Shake samples together violently	Mixing sample concentrations
Expose samples to air	Outside materials get into samples
Coat sampling apparatus with pesticides and other chemicals	Samples are filled with toxins

Table 5

Anti-Problem 2: How to Discard Samples

Solution:	**Causal:**
Open a hatch on the payload midflight	Samples spill out
Crush the samples	Sample containers are destroyed
Tip the payload over and dump it out	Samples tipped over
Burn the sampling apparatus	Sample concentrations are incinerated
Crash the drone and payload	All samples are lost

Battle of Perspectives

The battle of perspectives is a concept generation process where the group is split into two opposing groups. The groups are then tasked to find a solution to our problem with their assigned "groups mindset."

The first battle was between a young, poor, environmentalist individual vs a multibillion-dollar company. The reason for using these two teams was to find how someone with "unlimited" money would solve this problem to comply with environmental concerns vs how an individual would solve this out of love for the environment. The problem statement given to both teams was: "Multiple samples must be taken from the water to test for contamination without contaminating any other body of water as well as not disturbing the sample as it was taken."

Table 6

Battle of Perspectives 1

Companies Solution	**Individuals Solution**
Using a fleet of lightweight and agile drones, they would approach and sample each area individually and return to base. The sample processing takes a small amount of time.	Using a fishing rod with a test tube attached at the end, it was cast out into the contamination area and pulled back some to collect the sample.
What was learned from the teams?	
The sample should be attached simply to the apparatus, using fishing line or some other thin attachment method. This would provide an inexpensive attachment method that could be easily interchanged for a new area. Using a MCU with one drone an automated flight	

path could be decided that would travel to each sample location and collect and retrieve a sample and then carry on to next location.

The second battle teams we constructed was a state water environmental company vs a competition team. The state water company has somewhat limited resources and cares about the samples being accurate and safe. The competition team cares about collecting as many samples as quickly as possible.

Table 7

Battle of Perspectives 2

State Environmental Solution	**Competition Team Solution**
Using a state issued observation drone the water was surveyed each morning to observe for any algae blooms starting. If there was anything disconcerting in the water, the observation drone marked its location via GPS and a sampling drone was sent autonomously and collected the sample as needed. The drone could take multiple samples and store them in a "dark box." The collection drone could take up to 5 samples.	The competition team had a high-speed agile fixed wing drone. It had an undercarriage that could store ten samples. As the drone flew it would approach the sampling area and drop the first sample below attached via a string/line. It would drag the sample through the area for a very short time before pulling up and retrieving the sample from the water. It was collected in the sample bay and a fresh test tube was cycled on to the line.
What was learned from the teams?	

Using a survey approach would be beneficial, maybe having the drone be autonomous with a live video feed that showed the water. If the person overlooking the feed noticed anything it could press a sample button that would start a sampling process. A fixed wing drone could work to collect samples, but this would create possible contamination issues. The process of speed is important though, as the battery life of the drone will be limited with the extra payload added.

An example concept that was obtained from this method is a magazine style chamber filled with test tubes. When prompted, one is detached and dropped to take a sample. A reeling contraption will be used to retrieve the sample(s) and store it in a lightweight, compact box.

1.5.3 Morphological Chart

A morphological chart was created by dividing the mechanisms of the payload into three categories: collecting, storing, and attaching to a drone body. 5 different methods for each mechanism were decided upon for each section, and a combination of ideas from each category were used to create 50 concepts for the generation phase. The concepts generated using the morphological chart are included in Appendix D.

Table 8

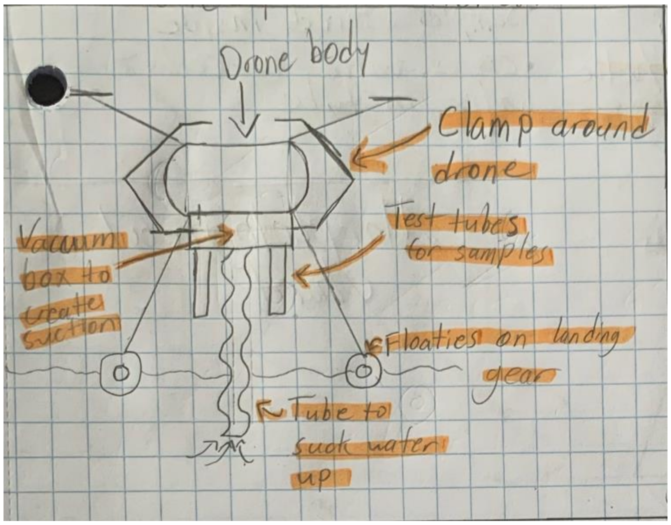
Morphological Chart

Collection	Storage	Attachment
Osmosis	Semi-sealed box	Bolted to drone
Clamshell	Open-air holster	Velcro/cinch/ratchet straps
Sealed one-way cap	Magnet on sample	Hard clamps
Needle suction	Velcro cap to drone	Cotter pin/quick release pin

Sponge	Store all liquid together	Glue/epoxy

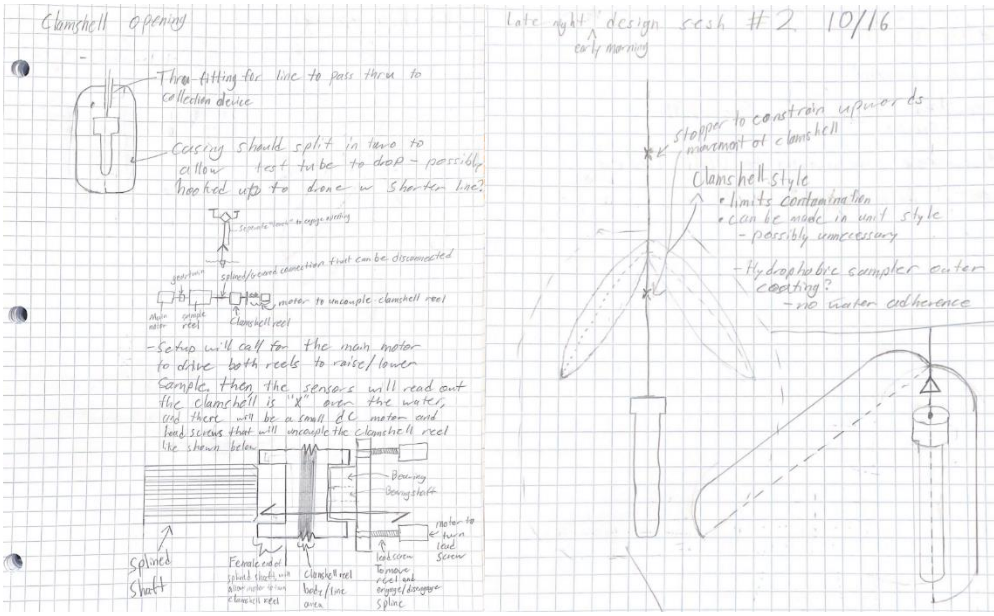
1.5.4 Medium Fidelity Concepts

Concept 1 – Needle suction collection in open air container



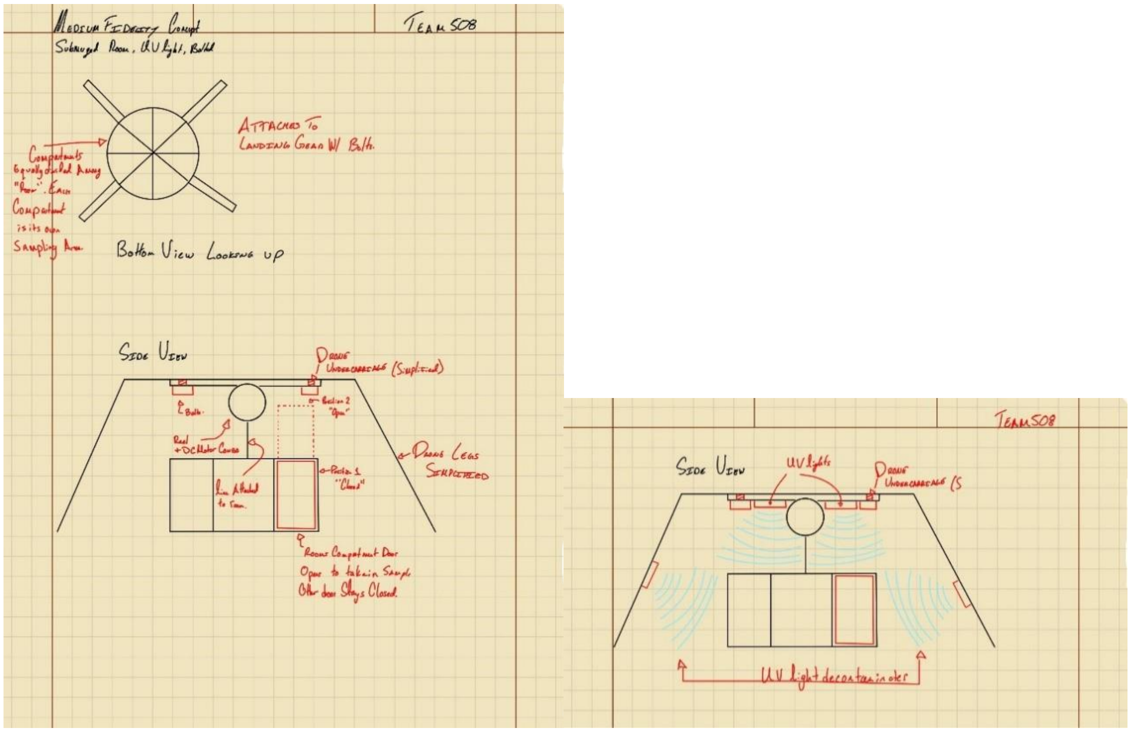
The figure above displays a vacuum type design for collecting the samples. This concept would require the drone to land on the water during the collection phase. After the sample is collected it is distributed into test tubes through the storage bin. Inside the payload are the components for the vacuum. The payload would be held to the drone by clamps on all sides.

Concept 2 – Clamshell reel collection stored in an open-air holster



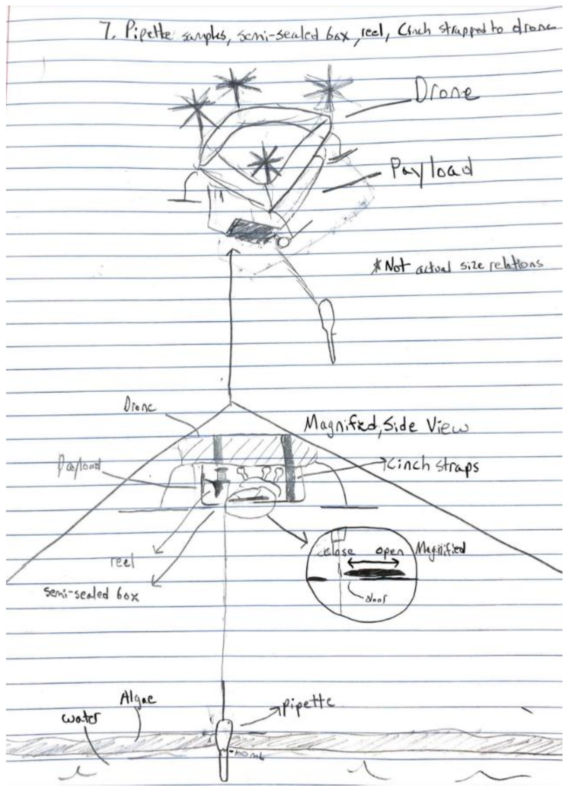
The figure above shows the clamshell design which encases the test tube, so the sample is not affected by the outside elements such as sunlight, contaminants, or wind. A reel is used to lift the sample up after the water is collected, the clamshell then covers the sample as it is being reeled up. These samples with the clamshell will be stored in their own unique location for the duration of the flight in an open-air holster. The payload is attached to the drone with rachet straps.

Concept 3 – Submerged room collection with UV light filter



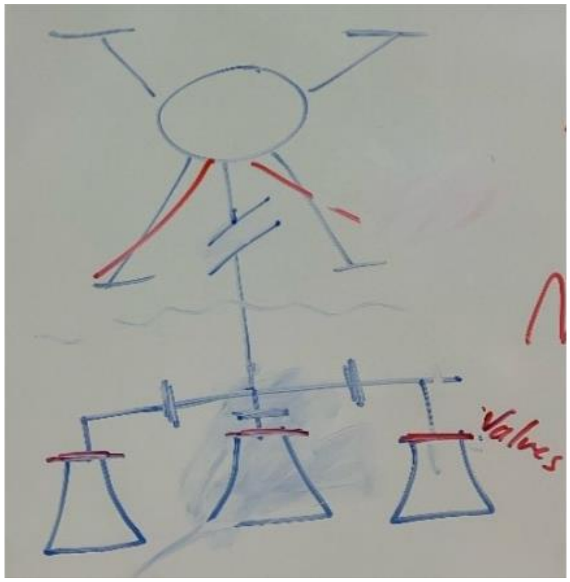
This concept fully submerges the storage area in the algae water. The individual rooms represent spaces for each sample to be collected and stored. At the first collection stop one door will open allowing for the sample to flow in. After the collection process the room is reeled in and strong UV lights are turned on to decontaminate the submerged room. The material the room is made from is opaque and does not allow the sample to be damaged by the UV lights.

Concept 4 – Pipette and reel collection with semi sealed storage



This design concept features a storage area that opens to let out a reel with an attached pipette and closes to store the sample inside with a door. The water-algae sample is collected using a squeezable pipette that can hold over 100 mL of water. The reel and spool raise and lower the line tied to the pipette, with a motor for power. This spool and reel would use similar technology that fishing rods use to let out and reel in fishing line.

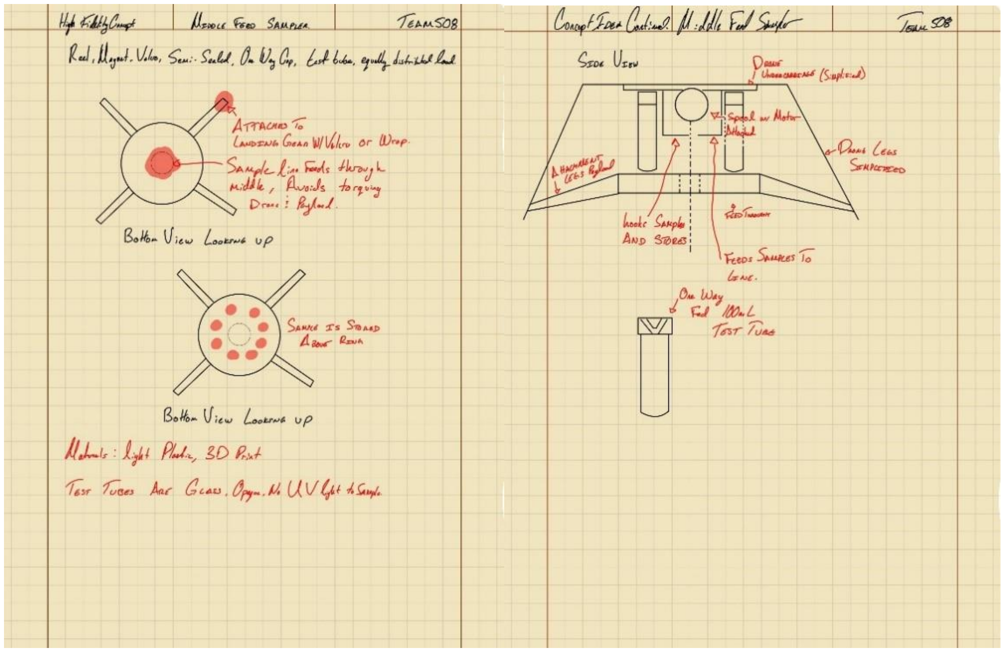
Concept 5 – Submerged valve collection with open storage



This concept is the simplest design possible. The attachment to the drone is a rod that has samples attached perpendicularly. The rod with the samples attached would be submerged in the water. At the first collection location, the right most sample valve would open to allow for water to flow in. The valve would then close, and the drone would fly to the next collection area where the next valve would open. This concept would require only a mechanism to open and close the valves at the correct timing. Everything else would not be automated.

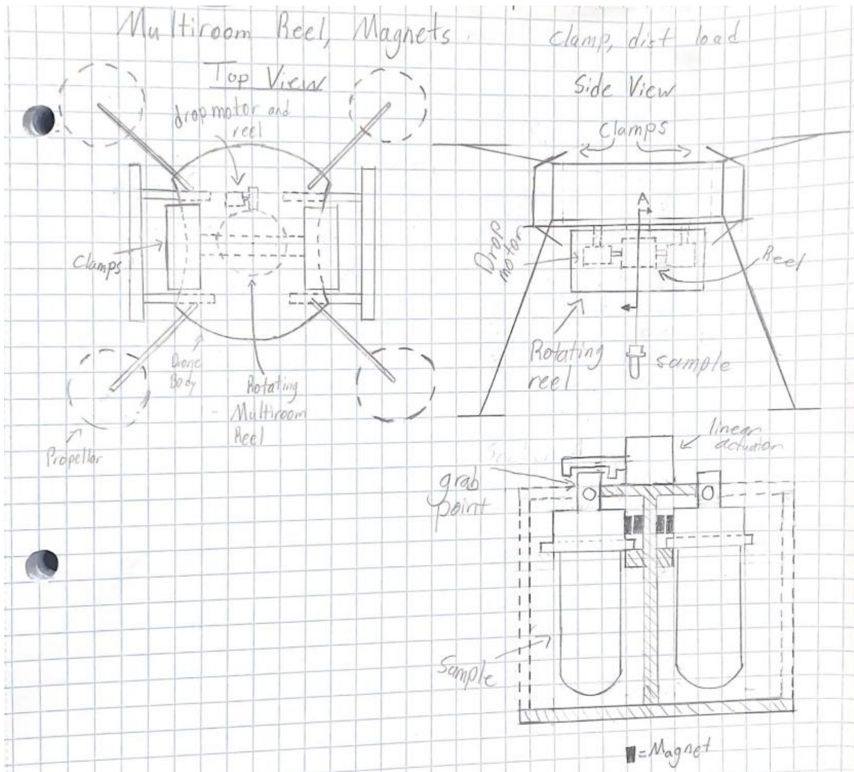
1.5.5 High Fidelity Concepts

Concept 6 – Multiroom reel collection mechanism with a one-way cap



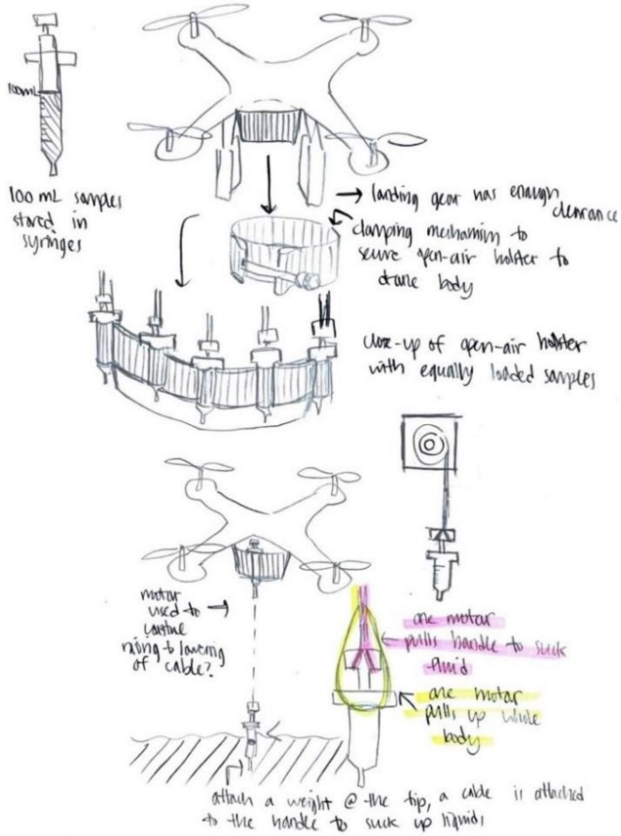
The figure above shows a reel mechanism used for collection that will reel test tubes up and down from the storage area. Once the sample is collected, the test tubes will be reeled up and stored in individual rooms equally distributed throughout to ensure the weight of the payload to be balanced. A magnet will be placed on the test tube and in the storage area to reduce movement of the test tubes while in flight. Velcro straps across the top of the drone would be used to secure the payload to it, making installation simple. Water can enter the test tube due to the one-way cap being pushed down from the water pressure entering from above. The rubber cover will straighten out under the pressure of the water after the test tube is filled, stopping the flow of water and sealing the tube.

Concept 7 – Single dynamic reel



This concept is a drone payload that uses a reel collection mechanism. The samples are stored in separate rooms, one for each sample. The reel collection will turn to an empty room for each sample. At collection location one, the reel mechanism will collect the first sample and store it in its unique location. The reel mechanism then moves to the next sample storage location and goes through the collection process, then placing the new sample in its correct location. The samples are held in place by the caps they are pushed into. As a result, the sample moves less during flight. The payload is held to the drone by a clamp mechanism.

Concept 8 – Syringe collection design with open air storage



The figure above shows the main mechanisms involved in the syringe collection with open-air storage design. Syringes will be used to collect and store 100 mL of liquid samples. A cable or extension will be tied to the main body of the syringe, and another cable will be tied to the handle. The main body cable will be lowered via a motor to the surface of the liquid. A weight will be attached to the syringe to ensure it sinks through the liquid. A second motor will be used to pull on the handle of the syringe to suck up the fluid. The main body motor will then haul the entire collected sample back up to the payload. The payload will consist of an open-air holster which is clamped to the body of the drone. The syringes will slide through the holster and be held snug upon retrieval.

1.5 Concept Selection

Concept Selection was completed using a quantitative approach that gives qualitative results. We created the Binary Pairwise Comparison, House of Quality, Pugh Charts, and Analytical Hierarchy charts to evaluate the team's generated concepts. Customer needs, engineering characteristics, and state-of-the-art market designs were all used to complete the tables. The discussion of how the tables were consulted to determine a final concept begins in the following section.

1.5.1 Binary Pairwise Comparison

The Binary Pairwise Comparison (BPC) chart compares a set of qualitative statements against each other. Since it is binary the comparison is either a 0 or a 1. Using the customer needs gathered from discussions with Dow and Dr. Ordonez, the comparison criteria were formed. The team used condensed statements from the customer needs to find which needs were critical to the design.

Table 9

Binary Pairwise Comparison

	1	2	3	4	5	6	7	8	9		Sum
1. Multiple Samples	-	0	1	1	1	0	1	1	0		5
2. Store Samples	1	-	1	1	1	0	1	1	0		6
3. Balance Samples	0	0	-	0	0	0	1	0	0		1
4. Payload is light weight	0	0	1	-	0	0	1	1	0		3
5. Universal	0	0	1	1	-	0	1	0	0		3
6. Collect Samples	1	1	1	1	1	-	1	1	0		7
7. Compact	0	0	0	0	0	0	-	1	0		1
8. Does not interfere with Landing Gear	0	0	1	0	1	0	0	-	0		2
9. Does not critically impede flight	1	1	1	1	1	1	1	1	-		8
Sum	3	2	7	5	5	1	7	6	0		
Check	0	0	0	0	0	0	0	0	0		

Table XX states the nine customer needs, with a comparison of each need along the diagonal. After completing the table and holding an open discussion, it was found that Customer Need #9, "*Does not critically impede flight*" was the most important customer need. We came to this conclusion since the objective of the project could not be completed if the apparatus was lost during sampling. The two next most important needs were #2 "*Store Samples*", and #6 "*Collect Samples*". Both needs reflect the main objectives the payload must accomplish during the sampling process. Once the comparison of customer needs was completed, the sums on the rightmost column of the table were used as importance weight factors for the House of Quality. These values showed which customer requirements took precedence over the design selection. The analysis of the House of Quality begins in the next section.

1.5.2 House of Quality

After the comparison of customer needs, 11 engineering characteristics were selected. These characteristics are shown in the figure below with their units (if applicable) as well as an arrow to indicate if we want that value to increase or decrease. The engineering characteristics are then compared to the customer needs to determine which engineering characteristic will have the biggest effect on the design. The importance weight factors of the customer needs from the binary pairwise comparison were also applied, showing the relative importance between them.

Table 10

House of Quality

Improvement Direction		↑	↓	↓	↑	↓	↓	↑	↓	↓	↓	↓
Units		Years	cm^3	W*hr	Kg	Kg	N	N/A	Seconds	Dollars	N/A	MPa
Customer Requirements	Importance Weight Factor	Lifespan	Size of Apparatus	Energy Usage	Weight limit	Overall Weight	Aerodynamic Drag Force	Weight Distribution	Sampling Speed	Total Cost	Water/Dust Resistant	Material Strength
1. Multiple Samples	**5**	1	9	3	3	9	3	3	3	3	3	3
2. Store Samples	**6**	0	9	1	3	3	9	9	3	3	3	3
3. Balance Samples	**1**	0	1	1	1	1	3	9	1	0	0	1
4. Payload is light weight	**3**	3	3	9	3	9	0	3	0	3	0	9
5. Universal	**3**	1	3	0	0	0	0	0	0	3	0	0
6. Collect Samples	**7**	3	3	9	9	9	3	9	9	9	9	3
7. Compact	**1**	3	9	3	1	3	9	9	1	1	0	1
8. Does not interfere with Landing Gear	**2**	1	9	0	0	0	0	0	0	0	0	0
9. Does not critically impede flight	**8**	9	3	3	0	9	9	3	0	0	0	0
Raw Score (#)	**1529**	**115**	**190**	**139**	**107**	**229**	**174**	**183**	**98**	**115**	**96**	**83**
Relative Weight %		7.52	12.43	9.09	7.00	14.98	11.38	11.97	6.41	7.52	6.28	5.43
Rank Order		7	2	5	8	1	4	3	9	6	10	11

We ranked the relation of each characteristic to each need with a rating of either 0, 1, 3, or 9. A 0 rating meant the characteristic and need shared no relation. A 9 rating meant that the characteristic and need were heavily related. The most important engineering characteristic was *Overall Weight* since it had the largest raw score and therefore, largest relative weight percentage. The other important characteristics were *Size of Apparatus*, *Energy Usage*, *Aerodynamic Drag Force*, and *Weight Distribution*. These characteristics all had raw scores and relative weight percentages that were in the top 5 of the 11 total engineering characteristics. The bottom six engineering characteristics were dropped due to low relation to the customer needs.

1.5.3 Pugh Chart

The five most relevant engineering characteristics determined from the House of Quality were used as selection criteria in the Pugh Chart. For the first iteration, a market option was selected as a datum and eight concepts - five medium fidelity and three high fidelity - were compared against it. The market option chosen was a drone sampling apparatus that pumped water through a hose to a sampling container. The hose was non-retractable. We compared the concepts to the datum for each selection criterion with a plus (+), minus (-), or S. The plus (+) meant that the concept was better than the datum, the minus (-) meant that it was worse, and the S symbol meant it performed similarly to the datum.

Table 11

Pugh Chart Iteration 1

		Concepts							
Selection Criteria	Market Option	Needle suction	Clamshell Reel	Submerged Room	Pipette Reel	Submerged Valve	One Way Reel	Multiroom Reel	Syringe Collection Open Air
Size of apparatus	Pump W/ One Sample	-	-	-	S	S	S	-	-
Energy Usage		+	+	-	+	+	S	-	+
Overall Weight		S	S	-	S	S	-	S	S
Aerodynamic Drag Force		+	-	-	S	-	+	+	+
Weight Distribution		+	S	S	S	-	+	+	+
# of pluses		**3**	**1**	**0**	**1**	**1**	**2**	**2**	**3**
# of Minuses		**1**	**2**	**4**	**0**	**2**	**1**	**2**	**1**

Once the comparisons were made, we decided to drop three concepts from the list: *the Clamshell Reel*, *Submerged Room*, and *Submerged Valve.* These concepts had significantly more disadvantages than advantages when compared to the market datum. The *Multiroom Reel* was used as the datum for the second Pugh chart iteration for having an equal number of pluses (+) and minuses (-).

Table 12

Pugh Chart Iteration 2

					Concept			
Selection Criteria			Option		Needle Suction	Syringe Collection Open Air	Pipette Reel	Separate Reels One Way cap
Size of apparatus			Multiroom reel		+	S	+	S
Energy Usage					-	S	S	+
Overall Weight					+	+	+	+
Aerodynamic Drag Force					-	S	S	S
Weight Distribution					S	S	S	S
# of pluses					**2**	**1**	**2**	**2**
# of Minuses					**2**	**0**	**0**	**0**

The *Pipette Reel* was eliminated from consideration for potential concepts after completing the second Pugh chart iteration. The number of pluses was comparable for all concepts that were compared to the *Multiroom reel,* so the team decided to remove the pipette design after holding an open discussion about the technical feasibility for each of the designs. It was reasoned that the pipette would have to be squeezed before being submerged into the liquid to collect a sample. The accuracy of the sampling technique would depend on how tightly the pipette was squeezed. If the pipette did not collect an adequate 100 mL sample, it would be difficult to empty this sample and restart the process in a timely manner. At this stage, the remaining 3 concepts were kept in consideration and compared using the Analytical Hierarchy chart.

1.5.4 Analytical Hierarchy Chart

The analytical hierarchy process (AHP) quantifies the selected concepts versus the remaining engineering characteristics. The first part of the AHP compared the engineering characteristics against each other in the criteria comparison matrix in table 13.

Table 13

Criteria Comparison Matrix

	Criteria Comparison Matrix [C]				
	Size of Apparatus	Energy Usage	Weight Distribution	Overall Weight	Aerodynamic Drag Force
Size of Apparatus	1	0.33333333	1	0.14285714	0.333333333
Energy Usage	3.00	1	3.00	0.33333333	3
Weight Distribution	1.00	0.33	1	0.2	1
Overall Weight	7.00	3.00	5.00	1	5
Aerodynamic Drag Force	3.00	0.33	1.00	0.20	1
Sum	15.00	5.00	11.00	1.88	10.33

The possible rankings given were 1, 3, 5, 7, and 9, with the rows being compared to the columns. A row characteristic that was given a high value in comparison to a column characteristic meant that the former was more important to the project. These values were normalized in table 14 in order to obtain the criteria weights for each characteristic.

Table 14

Normalized Criteria Comparison Matrix

	Normalized Criteria Comparison Matrix [normC]					
	Size of Apparatus	Energy Usage	Weight Distribution	Overall Weight	Aerodynamic Drag Force	Criteria Weights {W}
Size of Apparatus	0.07	0.07	0.09	0.08	0.03	0.07
Energy Usage	0.20	0.20	0.27	0.18	0.29	0.23
Weight Distribution	0.07	0.07	0.09	0.11	0.10	0.09
Overall Weight	0.47	0.60	0.45	0.53	0.48	0.51
Aerodynamic Drag Force	0.20	0.07	0.09	0.11	0.10	0.11
Sum	1.00	1.00	1.00	1.00	1.00	1.00

The Normalized Criteria Comparison Matrix considered the values chosen in table 14 and gave criteria weights to the characteristics. Here, the overall weight of the payload had the highest criteria weight, with the energy usage being the next highest criteria. These two characteristics had significantly higher weights than the other 3 characteristics. In order to verify if these weights were valid, they were run through a consistency check in table 15.

Table 15

Consistency Check

Consistency Check		
{Ws} = [C]{W}	{W}	Cons = {Ws}./{W}
Weighted Sum Factor	Criteria Weights	Consistency Vector
0.34	0.07	5.08
1.19	0.23	5.22
0.44	0.09	5.17
2.65	0.51	5.21
0.57	0.11	5.12
	Lambda	5.16

The consistency check was used to determine the consistency ratio. If the criteria weights were consistent with the previous analyses done in the House of Quality and Pugh Charts, the consistency ratio would fall under 0.10.

Table 16

Consistency Ratio

Consistency Index (CI)	Consistency Ratio (CR)
0.04	0.04

Here, the consistency ratio was 0.04 for our evaluation process, which meant that the team could continue with the final selection. At this stage, tables were created to compare the remaining concepts against each other for each engineering characteristic. An example was included in table 17, where the concepts were compared based on the size of the payload.

Table 17

Example of Engineering Characteristic vs Concepts

Size of Apparatus			
	Separate Reels One Way cap	Multiroom reel	Syringe Collection Open Air Storage
Separate Reels One Way cap	1	1	0.33
Multiroom reel	1.00	1	0.20
Syringe Collection Open Air Storage	3.00	5.000	1
Sum	5.00	7.00	1.53

The weighting of these values was 1, 3, 5, 7, and 9. A rating of 9 meant that the concept along the row of the cell was significantly better than the concept along the column of the cell in terms of meeting the engineering characteristic. The matrix transpose of each user-inputted cell (highlighted green) computed the inverse of the green cell as its value. Once the sum values were obtained for each engineering characteristic comparison, the final concept matrix was obtained in table 18.

Table 18

Final Concept Matrix

Concept	Alternative Value
Separate Reels One Way cap	0.51
Multiroom reel	0.17
Syringe Collection	0.33

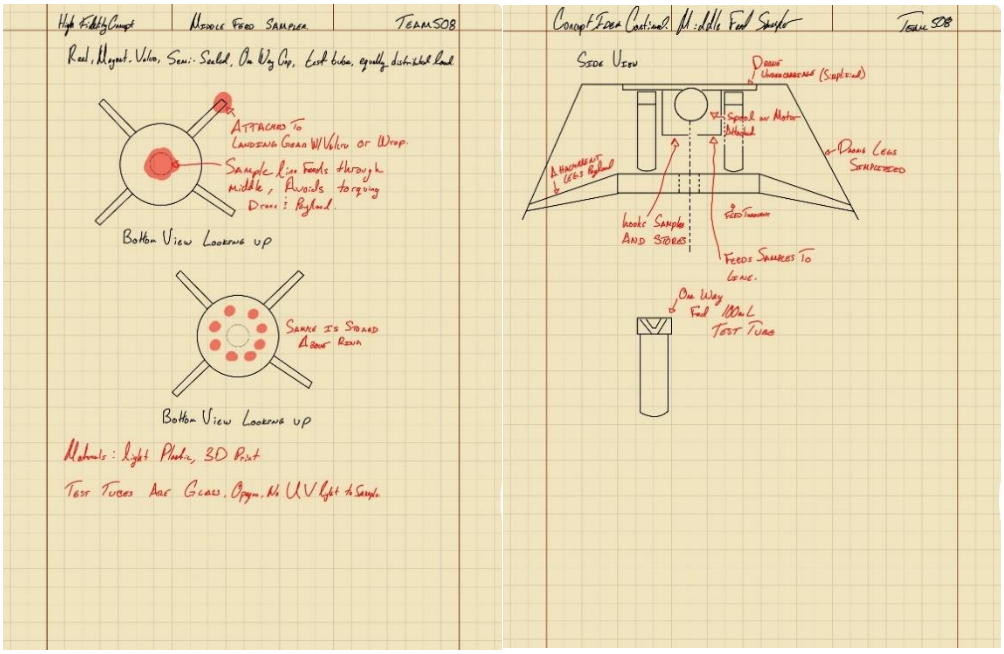
The final concept matrix in table 18 returned the recommended final concept based on the quantitative values that had been chosen throughout the selection process. The concept with the highest alternative value was the *Separate Reels One Way cap,* with a value of 0.51. The team held an open-discussion regarding the 3 final concepts, and whether to accept the outcome. The team eventually agreed that the Separate Reels One Way cap was the most logical choice, as it had the highest weights for the weight distribution and overall weight of the payload. It also scored reasonably high for the energy usage and aerodynamic drag force.

1.5.5 Final Selection

The final selected concept was the Separate Reels with One-Way Caps. Using the data gathered from outside research and advice from sponsors to follow through the analytical concept selection process, the final idea was chosen.

Figure 2

Preliminary Sketch of a One-way Cap, with reel, and motor.



The concept is based upon the idea of using fluid properties to collect the samples rather than actively getting fluid in the sample ourselves. The apparatus would lower the test tube into the water using a motor attached to a reel. A line would be fed from the reel lowering the sampling tube into the water. Using sensors and software on the apparatus, the distance to the water would be recorded. The test tube would be weighted so that as it is lowered, the bottom would hit the liquid first. Once the one-way cap is fully submerged, the liquid will flow over the top, where gravity will pull the liquid downwards. The downward flow of liquid will put enough force on the cap to push it down until it reaches a flat rubber plate. At this moment, the flat rubber plate will also be displaced downward until it reaches the bottom of the cap. The rubber portion of the test tube cap will straighten out after the test tube is full and seal the cap with the algal water inside.

1.8 Spring Project Plan

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement:

To professionally represent the FAMU-FSU College of Engineering while pledging to give Dow Chemical an ambitious and devoted work ethic throughout the design process.

Team Roles:

Dominic Bellocchio: Point of Contact, Systems Engineer

Dominic will monitor the design modifications and their effects on the overall design.

Tauben Brenner: Manufacturing Engineering

Tauben will examine materials and production procedures to identify the best possible combinations for different components.

Roberto Lacasa: Programming Engineer

Roberto will write programs that define the logical flow of the system's actions and reactions to inputs and outputs.

Matthew Lancaster: Control Systems Engineer

Matthew will create and put mechanisms into place that will regulate the project's dynamic systems.

Dylan Ma: Design Engineer

Dylan will design the mechanical parts and how they interact with the electrical components of the project.

The team will decide whose abilities are most suited to complete tasks that are outside the purview of particular responsibilities. These roles are subject to be amended by the team as more information is known about the project. A meeting once a month will take place to update the roles and goals of our project.

Communication:

The primary method of communication between team members will be through in-person meetings held three days a week. The primary point of contact outside of our meetings will be through email. A secondary point of contact will be via text message and Microsoft Teams. Team members are expected to check the team group chat and school email regularly and must respond within 48 hours if contacted. At least four out of the five team members must agree to hold an emergency meeting before it may be arranged. An email to schedule an emergency meeting must be sent out at least 24 hours in advance. It is expected that each team member will inform the other members of any unforeseen time conflicts or other obligations that would prevent them from attending a meeting. Recurring time conflicts should be maintained and updated on "when2meet" so that team members are always aware of each other's availability.

Original point of contact with professional sponsors will be through email. Emails must be reviewed by at least two other teammates before sending. Throughout the rest of the process, back and forth emails, virtual meetings, and in-person meetings will be conducted to communicate with the sponsor.

Recap and recognition will occur on Monday mornings immediately following a completed assignment. We will use this time to recognize our teammates positive contributions to our assignment or politely give constructive criticism in a respectful and professional manner. The schedule for the following week will be discussed and finalized.

Dress Code:

Business professional attire is required for sponsor meetings and presentations in person, for meetings that take place virtually, business casual is acceptable Business casual is required for all virtual sponsor meetings, class events with a professional speaker present, and for faculty advisor meetings with Dr. Ordóñez.

Attendance Policy:

Team members are required to attend every regularly scheduled team meeting unless unforeseen circumstances arise. Team members are required to notify the rest of the team as soon as an unforeseen circumstance presents itself. If a team member is absent for a meeting, it will be documented as excused or unexcused in the Excel attendance document. The absent teammate is responsible for material missed during the meeting.

A total group intervention will be held after more than two days without communication with a team member or if a team member has two repeated absences in a row from meetings without an acceptable excuse. There must be an explicit request for the member's response to merit the intervention. We will get in contact with Dr. McConomy if the issue persists for another 48 hours following the group intervention or if the issue with communication or productivity happens again. When we reach out to Dr. McConomy, we want him to contact the teammate directly after explaining what our problem with the group member is. We want to use Dr. McConomy to try to motivate the teammate. There will be no meetings from Friday at 5 p.m. until Sunday at 11 a.m. or if our meeting times fall on days the school is closed (ex: Labor Day).

Statement of Understanding:

By signing below as a team member of Team 508: Dow - Drone Payload Sample Collection and Measurement, I agree to follow this code of conduct for the duration of the project. I understand a majority vote must take place to make any changes to this code of conduct.

Roberto Lacasa:

Tauben Brenner:

Matthew Lancaster:

Dominic Bellocchio:

Dylan Ma:

Appendix B: Work Breakdown Structure

Work Breakdown Structure **Team 508** **Company: Dow Chemical** **Project: Drone Sample Collection and Measurement**			
Tasks	Subtask	Assignee	
Setting up Meeting with Sponsor		Dominic Bellocchio	
	Email Sponsor Meeting Times		
	Receive Correspondence and Meeting Time		
Setting up Meeting with Advisor		Dominic Bellocchio	
	Email Advisor Meeting Times		
	Recieve Correspondence and Meeting Time		
Setting up Meeting with Marine Biologist		Matthew Lancaster	
	Look for Marine Biologist contact		
	Reach Out and Schedule Meeting		
Meetings		Everyone	

	Prepare Questions and Talking Points		
	Meeting Minutes		
	Confirm All Information has been Covered		
Project Description		Dominic Bellocchio	
Key Goals		Roberto Lacasa	
Markets		Matthew Lancaster	
Assumptions		Tauben Brenner	
Stakeholders		Dylan Ma	
Review and Check Grammar		Roberto Lacasa	
Submission		Dominic Bellocchio	
Schedule Meeting		Tauben Brenner	
	Email Sponser and Advisor		

	Confirm meeting time		
Prepare Questions		Dylan Ma	
Record Answers		Roberto Lacasa	
Interpret Answers		Dominic Bellocchio	
Writing Report		Tauben Brenner	
Edits/Revisions		Matthew Lancaster	
Submission		Matthew Lancaster	
Drone Platform		Tauben Brenner	
	Price		
	Quality/Hardiness		
	Modification Friendly		
	Over Water Flight Characteristics		
	Waterproof/Water Resistance		
	Accessory Mount Locations		
	4 - 6 - 8 Rotors		

	Cargo Carrying Capabilities		
Water Sampling Procedure		Matthew Lancaster	
	Amount of Water Needed		
	Depth of Water Sample		
	How to Collect Water for Sample		
Weight Reduction Methods		Dylan Ma	
	Lightweight Material Comparisons		
	Light Motors		
Cross Contamination/Decontamination		Dominic Bellocchio	
	What Decontamination Processes Work		
	When is Cross Contamination Deadly		
GPS Interfacing		Roberto Lacasa	
	How to Save Sample GPS Coordinates		
	How to Overlay Sample onto Map		
Other Drone Sampling Methods		Dylan Ma	

	Ice Coring Drone		
	Other Potential Water-Sampling Designs		
Drone Recovery Gear		Dominic Bellocchio	
	Ways to Save in Case of Over-Water Disaster		
	Hardiness Needed for Over-Land Crash		
Decide on physical capabilities of design		Matthew Lancaster	
Record Action List		Dylan Ma	
Create Graphics and Charts		Tauben Brenner	
	Check Formulas in Cells		
	Check Format of Charts		
Record how Functional Decomposition Data was Gathered		Dylan Ma	
Edits/Revision including Grammar		Dominic Bellocchio	

Submission		Roberto Lacasa	
Making Powerpoint		Matthew Lancaster	
	Adding Useful Graphics		
	Proper Format Selection		
Editing Powerpoint		Roberto Lacasa	
	Eliminate unuseful content		
	Confirming All Important Information Provided		
Submitting VDR 1		Dominic Bellocchio	
Presenting VDR		Everyone	
	Coordinating a Time to Practice		
	Being Ready to Present VDR 1		
	Having Entire Group Dressed Formally to VDR 1		
	Present VDR 1		

Meeting with Sponsor		Roberto Lacasa	
	Email Sponsor		
	Confirm Meeting Time		
Meeting with Advisor		Dominic Bellocchio	
	Email Advisor		
	Confirm Meeting Time		
Ensure Functions have Targets		Matthew Lancaster	
Figure out Testing Methods		Tauben Brenner	
Derivation of Targets		Dylan Ma	
Discussion of Measurement		Roberto Lacasa	
Writing Report		Matthew Lancaster	
Edits/Revision including Grammar		Tauben Brenner	
Submission		Dominic Bellocchio	

Block Off Time		Dominic Bellocchio	
Gather Project Requirements		Dylan Ma	
Brainstorm with Different Techniques		Tauben Brenner	
	Crapshoot		
	Biomimicry		
	Forced Analogy		
	Opposing Views		
Record Every Idea		Roberto Lacasa	
Compile Ideas Into List		Matthew Lancaster	
Revisions/Edits		Dylan Ma	
Submission		Roberto Lacasa	
House of Quality		Matthew Lancaster	
Pugh Charts		Dylan Ma	
AHP		Roberto Lacasa	

Final Selection		Tauben Brenner	
Writing Report		Dominic Bellocchio	
Revisions/Edits		Roberto Lacasa	
Submision		Matthew Lancaster	
Discuss assembly, operation, testing, and transport conditions for design		Matthew Lancaster	
Look up information about safety hazards from governing body (ASME)		Tauben Brenner	
Discuss measures to prevent identified hazards		Dylan Ma	
Obtain Emergency Contacts for Each Member		Dominic Bellocchio	
Revisions/Edits		Roberto Lacasa	
Submission		Dylan Ma	

Rough Sketch		Dylan Ma	
Gathering Materials		Dominic Bellocchio	
Construction of Prototype		Roberto Lacasa	
Experimental Testing		Matthew Lancaster	
	Set Up Testing Equipment		
	Measuring Metrics		
	Record flaws with Design		
Quality Control		Tauben Brenner	
Order Needs		Roberto Lacasa	
Gather Vendor Identification		Matthew Lancaster	
Completeness Identification		Tauben Brenner	
Cost Identification		Dylan Ma	

Rough Draft		Dominic Bellocchio	
Revision / Edits		Tauben Brenner	
Final Draft		Roberto Lacasa	
Submission		Dominic Bellocchio	
Schedule Meeting		Matthew Lancaster	
	Email Advisor	Dominic Bellocchio	
	Email Sponsor	Dominic Bellocchio	
	Confirm time with advisor	Roberto Lacasa	
	Confirm time with sponsor	Matthew Lancaster	
Meet with Sponsor		Everyone	
Meet with Advior		Everyone	
Meeting Minutes		Dylan Ma	

Rough Draft		Roberto Lacasa	
Revisions/Edits		Dominic Bellocchio	

Appendix C: Target Catalog

Table 4

Targets and Metrics Catalog

Major Function	*Minor Function*	*Metric*	*Target*
Stability/Collection	**Carries Weight**	**Mass**	**3 kg**
Stability/Safety/ Feedback	**Maintains Controlled Flight**	**Balance**	**0° Orientation to Ground**
Safety/Collection	**Prevents Contamination**	**Parts Per Million**	**0 mg/L**
Safety/Collection	**Stores Samples Safely**	**Volume**	**0 mL Loss**
Stability/Safety	**Withstands Collision**	**Tensile Strength**	**100 MPa**
Stability/Collection	**Maintains Center of Mass**	**Weight Distribution**	**max 100 g offset**
Stability/Collection	**Stores Samples Compactly**	**Volume**	**1 cm^3 clearance of drone legs**
Stability	**Payload Limits Load on Drone**	**Force**	**35 N**
Stability	**Attaches to wide Variety of Drones**	**Mounting Configurations**	**3 Distinct Attachment Methods**
Collection	**Collects Liquids**	**Volume**	**100 mL**
Feedback	**Displays distance of payload to liquid**	**Distance**	**±5 cm**
Stability/Safety/ Feedback	**Aborts sampling procedure**	**Force**	**5N tension between payload and sample**
Miscellaneous	**Functionless**	**Opinions of users**	**Easy to use**
Miscellaneous	**Functionless**	**Minimum lifetime**	**100 flight hours**
Miscellaneous	**Functionless**	**Insulated**	**0% exposure for sensitive components**
Miscellaneous	**Functionless**	**Number of samples collected per run**	**4 samples**

Miscellaneous	**Functionless**	**Assembly Time**	**15 minutes**

Appendix D: List of 100 Concepts

Brainstorming

1. Using a syringe like needle/tube and sucking samples out of the water, pump provides suction.
2. Distributing different samples to different test tubes on drone. No sample dropping necessary.
3. Using a camera/microscope combination with Wi-Fi connection to observe and test water on site. No collection necessary.
4. Room submerged in the water with door openings for each sample.
5. Non-submerged “room” concept that includes an arm that collects water.
6. Magnets are used to attract and release sample tubes.
7. Heat the water so it becomes a gas then condensation is collected in storage bay.
8. Syringe design used to suck up the water that has a 100mL line on it.
9. Vacuum sucks up water to specific areas in the storage bay.
10. Plunger type design pushing water into a sample.
11. Pipet type mechanism to collect, water is kept in pipet as sample.
12. Water gun sucking up the water and sprayed in a test tube to store.
13. Cast out fishing line attached to a sample tube, then reeled in.
14. Using tampons to absorb water and keep it in its unique storage area.
15. Straws are dipped in the water then the top is sealed so the pressure doesn’t release the water.
16. Attach a human to the drone to collect samples and store the samples on them.
17. U-tube manometer to force fluid into a sample with pressure differences.
18. Petri-dish is lowered, where algae are collected and subsequently kept.
19. Drop large rock into water and collect the upwards spray from impact.
20. Hydrophobic-hulled drone vessel collects surface samples through hole in hull.
21. Seine dropped from flying drone and dragged to collect algae samples without water.
22. A FlowCytoBot (*Automated sensor provides Texas with early warning of Red Tide*) is lowered from the drone and can sample alga types and concentrations via a laser and an extremely high-definition camera.
23. Use a plastic bag to collect water from drone and hope it does not leak.
24. Large main drone releases multiple mini drones that collect one sample each and then come back to attach to main payload.
25. Make the algae come to us: provide a light source that sucks the algae up from the water.
26. Blow compressed air upwards while submerged in water to force water up into sample.
27. Water wheel with cups attached to move water up using rotary motion.
28. Payload has 6 small “rooms” each with its own spool and test tube to reel up and down.
29. Archimedes screw into the water to raise it without a scoop.
30. Treat all algae as bad algae and treat when seen visibly, no sampling necessary.
31. Straws that flow directly from the water source into a test tube (suction required).

32. Filling balloons with algae water to collect and store.
33. Using an arm device that lowers into the water and scoops it into a sample.
34. A claw, like a backhoe to collect the water.
35. A sample housing holding a reservoir for test tubes that feeds test tubes down through hole in the middle, decontaminating samples with exterior UV light.
36. Creating a whirlpool vortex so the sample can remain stagnant while water flows inside.
37. Lowering waterproof zip lock bags to fill and store algae water.
38. A net that is lowered and only collects the algae, no water.
39. Shooting mini submarines downwards into the water.
40. Statistically determine patterns of algae blooms and follow patterns for treatment.
41. Use hover craft like boat that stays inches above water. Manually take samples.
42. Don't even collect a water sample, take HD pictures of algae w/ GPS location to then run through an image processor and show it to Biologists to determine if the algae are bad or good.
43. Bring a lab kit with us in the drone to test at the spot so we don't need to carry the sample back to land.
44. Shovel technique to collect water and dump it into a unique storage area for each sample.
45. Spool design with a cord to hold a test tube for collection, stored with equally distributed samples to keep the drone stable. The payload is attached with a clamp type design.
46. Release an untethered sample from the payload into the water to collect the sample then float at the surface, making it easy for an arm extending from payload to grab it and bring it back up.
47. Pressurized Canister (CO_2) and one-way valve to make low pressure system to suck water up.

Biomimicry

48. Bromeliads use the force of gravity to guide water into a storage area.
49. Bees drink and store water to cool the hive.
50. Frigate bird - Collect samples from the surface of the water by using an extended arm with a sack on the end to swoop the surface of the water to make a sample collection.
51. Octopus-like telescoping tentacles that scoop up water samples in a cupped-handlike form.

Morphological Chart

52. Using the collection method of osmosis, the passing of fluid through a membrane to pass the water into a semi-sealed box which is fitted to the apparatus. The apparatus is bolted to the drone.
53. With the process of osmosis, the sample could be taken and stored in a semi-sealed box and the apparatus is attached to the drone with some form of strap, the type being Velcro, cinch, or ratchet.
54. Using osmosis, the sample would be collected and stored in a semi-sealed box and attached via hard clamps to the drone.
55. The osmosis method could be used with the semi sealed box storage method, and the apparatus attached with a pin. The type of pin can range from a cotter pin or a quick release pin.

56. Using the osmosis method with the semi sealed box storage method, the apparatus could be attached to the drone with a high temp and water-resistant glue or epoxy.
57. Using a clamshell collection apparatus, the sample could be stored in a semi sealed box and the apparatus would be bolted to the drone.
58. A clamshell sampling apparatus would collect the sample and store it in a semi sealed box, that is connected to the apparatus, which was attached to the drone with Velcro straps.
59. The clamshell sampling method would collect and store the samples in a semi-sealed box which is attached to the drone with hard clamps.
60. Using cotter or quick release pins to attach the apparatus to the drone the samples would be stored in a semi sealed box after being collected with a clam shell sampling part.
61. A clamshell collection mechanism will open to collect samples and close to store them in a semi-sealed box, attached to the drone via glue.
62. A sealed one-way cap will collect water and release any pockets of air. These samples will be stored in a semi-sealed box to block from sunlight and outer contaminants. The payload will be bolted to the drone body.
63. A sealed one-way cap will collect water and release any pockets of air. These samples will be stored in a semi-sealed box to block from sunlight and outer contaminants. The payload will be strapped to the drone body.
64. A sealed one-way cap will collect water and release any pockets of air. These samples will be stored in a semi-sealed box to block from sunlight and outer contaminants. The payload will be clamped to the drone body.
65. A sealed one-way cap will collect water and release any pockets of air. These samples will be stored in a semi-sealed box to block from sunlight and outer contaminants. The payload will be pinned to the drone body.
66. A sealed one-way cap will collect water and release any pockets of air. These samples will be stored in a semi-sealed box to block from sunlight and outer contaminants. The payload will be glued to the drone body.
67. Needle suction will be used to collect liquid samples similar to a syringe and store them in a semi-sealed box which is bolted to the drone body.
68. Needle suction will be used to collect liquid samples similar to a syringe and store them in a semi-sealed box which is strapped to the drone body.
69. Needle suction will be used to collect liquid samples similar to a syringe and store them in a semi-sealed box which is pinned to the drone body.
70. Needle suction will be used to collect liquid samples similar to a syringe and store them in a semi-sealed box which is clamped to the drone body.
71. Needle suction will be used to collect liquid samples similar to a syringe and store them in a semi-sealed box which is glued to the drone body.
72. Sponge is lowered to absorb water sample, then raised and stored inside a semi-sealed box to them out of open air/sunlight, with the payload bolted directly to the frame of the drone.
73. Sponge is lowered to absorb water sample, then raised and stored inside a semi-sealed box to them out of open air/sunlight, with the payload strapped to the frame using Velcro or cinch straps.

74. Sponge is lowered to absorb water sample, then raised and stored inside a semi-sealed box to them out of open air/sunlight, with the payload secured to the frame with clamps.
75. Sponge is lowered to absorb water sample, then raised and stored inside a semi-sealed box to them out of open air/sunlight, with the payload secured to the drone with a series of quick release cotter pins.
76. Sponge is lowered to absorb water sample, then raised and stored inside a semi-sealed box to them out of open air/sunlight, with the payload secured to the body using glue or epoxy.
77. A sampling apparatus will be lowered and collect water through osmosis, with the samples being stored in an exposed open-air holster and the entire payload is bolted to the drone body.
78. A sampling apparatus will be lowered and collect water through osmosis, with the samples being stored in an exposed open-air holster and the entire payload is strapped to the drone body using Velcro or cinch straps.
79. A sampling apparatus will be lowered and collect water through osmosis, with the samples being stored in an exposed open-air holster and the entire payload is strapped to the drone body using quick release cotter pins.
80. A sampling apparatus will be lowered and collect water through osmosis, with the
81. samples being stored in an exposed open-air holster and the entire payload is strapped to the drone body using glue or epoxy.
82. Open-air holster clamped to the drone, collecting water though a semi-permeable membrane (osmosis).
83. Bolted down, open air holster that collects water through a claw-like clamshell.
84. Open-air holster that is strapped to the drone, collecting water through a claw-like clamshell in the water.
85. Open-air holster secured to a drone using pins, collecting water with a claw-like clamshell.
86. Open-air holster that glues to the drone and collects water with a clamshell that opens and closes, sealing in water.
87. An open-air holster clamped to the drone, collecting water with a claw-like clamshell.
88. Bolted down, open-air holster that has a sealed one-way cap that lets water in without trapping in air too.
89. Open-air holster strapped to the drone, using the seal one-way cap to collect water without air.
90. Open-air holster, secured to the drone by a pin, collecting water with a sealed one-way cap.
91. Sealed- one way cap to collect water, stored in the open-air, with the main body clamped to the drone.
92. Sealed one way cap with an open-air holster held to the drone by glue.
93. Needle Suction with an open-air holster, that is bolted on the drone.
94. Needle Suction collection with an open-air holster with the attachment being straps.
95. Needle Suction used for collection with an open-air holster storage held up by pins.
96. Needle Suction as the collection mechanism with open-air holster that attaches with clamps.

97. Needle Suction collection used with an open-air holster storage with the payload held by glue.
98. Sponge sucks up the water then held in an open-air holster and bolted to the drone.
99. Sponge used as the collection with an open-air holster storage held to the drone by straps.
100. Sponge collection mechanism with an open-air holster storage and drone attachment is pins.
101. Sponge retains water with an open-air holster storage and drone attachment is clamps.
102. Sponge is plunged into water to collect the water, then stored in an open-air holster, the payload is then attached to the drone with glue.
103. Osmosis is used to collect the water and stored by having a magnet on the sample with clamps.
104. Sponge absorbs water, the sample in then stored with a magnet and attached with pins.
105. Needle suction collects the water, the storage is a magnet on the sample and attached with straps.
106. Sealed one way sample to collect the water with a magnet on Sample for safe storage, the payload is held to the drone with glue.
107. Suction style collection with a Velcro cap to drone with the attachment to the drone being glue.
108. Sealed one way sample collection with a Velcro cap to drone for safe storage and straps to keep the payload on the drone.
109. Sponge collection that wrings out to store all liquid together, the payload is attached with straps.

Appendix A: APA Headings (delete)

Heading 1 is Centered, Boldface, Uppercase and Lowercase Heading

Heading 2 is Flush Left, Boldface, Uppercase and Lowercase Heading

Heading 3 is indented, boldface lowercase paragraph heading ending with a period.

Heading 4 is indented, boldface, italicized, lowercase paragraph heading ending with a period.

Heading 5 is indented, italicized, lowercase paragraph heading ending with a period.

See publication manual of the American Psychological Association page 62

Appendix B Figures and Tables (delete)

Table 1
The Word Table and the Table Number are Normal Font and Flush Left. The Caption is Flush Left, Italicized, Uppercase and Lowercase

Level of heading	Format
1	**Centered, Boldface, Uppercase and Lowercase Heading**
2	**Flush Left, Boldface, Uppercase and Lowercase**
3	***Indented, boldface lowercase paragraph heading ending with a period***
4	***Indented, boldface, italicized, lowercase paragraph heading ending with a period.***
5	*Indented, italicized, lowercase paragraph heading ending with a period.*

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