Conceptual Design Document

BEACAN

University of Colorado
Department of Aerospace Engineering Sciences
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Project Customers

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Nomenclature

$Al - Li$	=	Aluminum Lithium
$CARTHE$	=	Consortium for Advanced Research on Transport of Hydrocarbon in the Environment
CFD	=	Computational Fluid Dynamics
$ENIG$	=	Electroless Nickel Immersion Gold
FEM	=	Finite Element Method
$FTDI$	=	Future Technology Devices International
$GNSS$	=	Global Navigation Satellite System
$GNSS$	=	Global Positioning System
I/O	=	Input and Output
$MEEV$	=	Multi-Mission Earth Entry Vehicle
$MOSFET$	=	Metal-Oxide-Semiconductor Field-Effect Transistor
$NiMH$	=	Nickel Metal Hydride
$Nitinol$	=	Nickel-Titanium Alloy
$NOAA\ AOML$	=	National Oceanic & Atmospheric Administration's Atlantic Oceanographic & Meteorological Laboratory
PCB	=	Polychlorinated Biphenyl
RAM	=	Random Access Memory
SIM	=	Subscriber Identity Module
SMT	=	Surface-Mount Technology
SVP	=	Surface Velocity Program
$TiAl$	=	Titanium Aluminum
$UART$	=	Universal Asynchronous Receiver-Transmitter
UAV	=	Unmanned Aerial Vehicle
USB	=	Universal Serial Bus

1. Project Description

1.1. Project Overview

Ocean currents are studied for applications involving search and rescue, navigation, and the spread of pollutants. In 2010, the Deepwater Horizons oil rig exploded causing an 87 day environmental emergency where an estimated 3.19 million barrels of oil leaked into the Gulf of Mexico [24]. During containment efforts, prediction of oil dispersion highlighted the need for better understanding of the currents in the Gulf of Mexico. In 2012, the University of Miami performed the first large scale deployment of ocean drifters in the Gulf, in efforts to study sub-mesoscale oceanic flows [23]. A drifter is a buoyant device that flows with ocean currents and records and transmits positional data. Current drifters are bulky and are typically deployed from ocean vessels. This presents multiple issues. Deployment costs are high; as ship time can exceed $10,000 per day [29]. The high cost of ship time leads to short deployment windows that result in bulk drifter deployment within a small area in a short period of time. Overall, deployment is costly due to the current structure of ocean drifters.

These highlighted issues can be addressed by designing a light-weight (<0.5 [kg]), low cost (<$1000) drifter that can be deployed via an Unmanned Aerial Vehicle (UAV). The team will design the drifter to track positional data along with designing a UAV wing mountable deployment mechanism that can store and deploy up to 2 drifters per wing. Here, the term UAV is used as a general blueprint for design. The team does not have access to a specific UAV and the customer will not consider potential UAV models until a successful deployment method and drifter has been achieved. A deployment mechanism will be capable of attaching to the underside of each wing of a UAV. The drifter will then be integrated to the deployment mechanism, with each mechanism possessing the capability to house 2 drifters. The deployment mechanism will release 1 drifter upon receiving an input signal. Once the drifter is deployed and successfully following a current, positional data will be recorded every 5 minutes and transmitted to a ground station up to 800 [km] away with a transmit latency of no longer than 24 hours. The team will also propose a method for comparing performance metrics of the drifter with drifters currently on the market. The team will solely focus on design of deployment mechanism and drifter. Integrating both components to a UAV or researching effects upon UAV flight dynamics is outside the scope of this project. To initiate the deployment mechanism, a signal will be manually input. Upon completion and deliverance of one deployment mechanism and one drifter, the customer will then look to acquire a potential UAV and examine integration methods, potentially posing as a problem for future senior design teams.

With a successful project, work will be initiated to release, in the Gulf of Mexico, 3-4 drifters per day over the span of 1 year. This work will further aid in environmental research by studying the large Loop Current and mesoscale eddies in the Gulf of Mexico. The Loop Current is a warm ocean current that flows northward between Cuba and the Yucatán Peninsula then loops clockwise across the Gulf of Mexico into the Gulf Stream.

Deployment costs will be drastically reduced along with an increase in deployment location precision via UAV

1.2. Concept of Operations

The Concept of Operations (CONOPS) diagrams show visual representation of the intended use of the drifter and the testing and verification procedure.

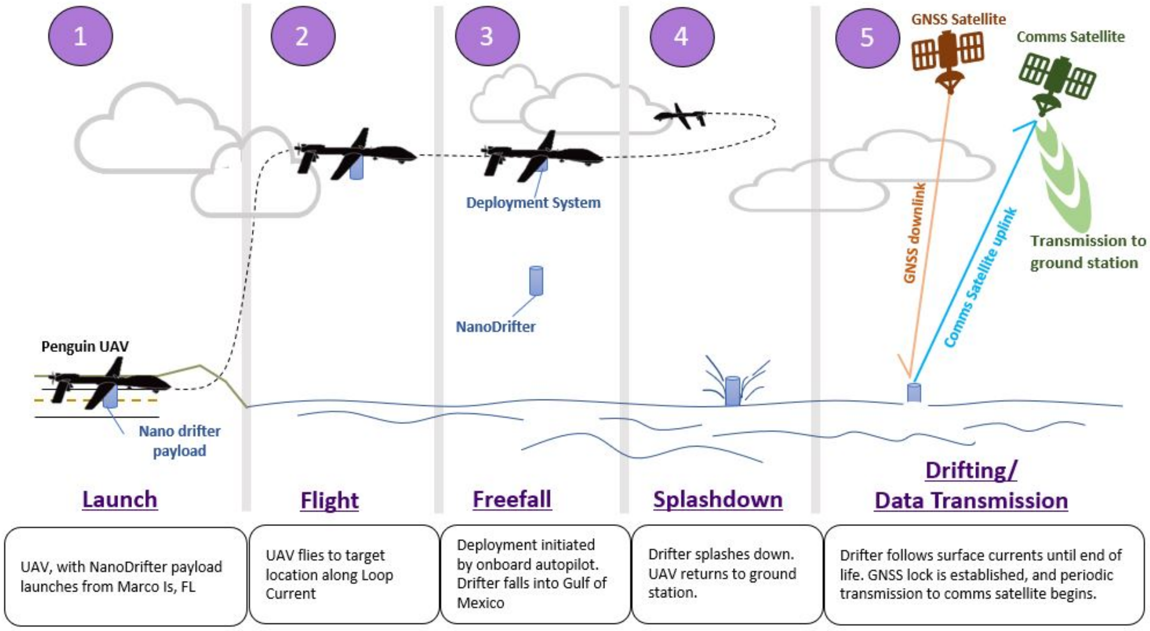

Figure 1: Mission Concept of Operations

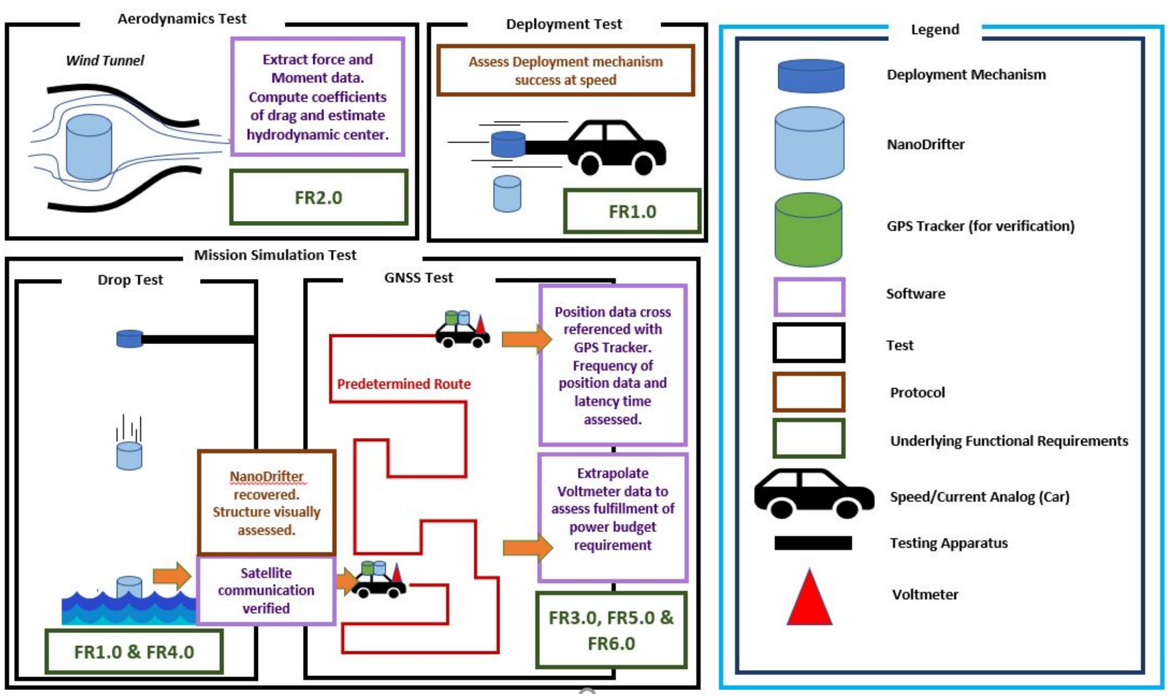

Figure 2: Testing Concept of Operations

1.3. Functional Block Diagram

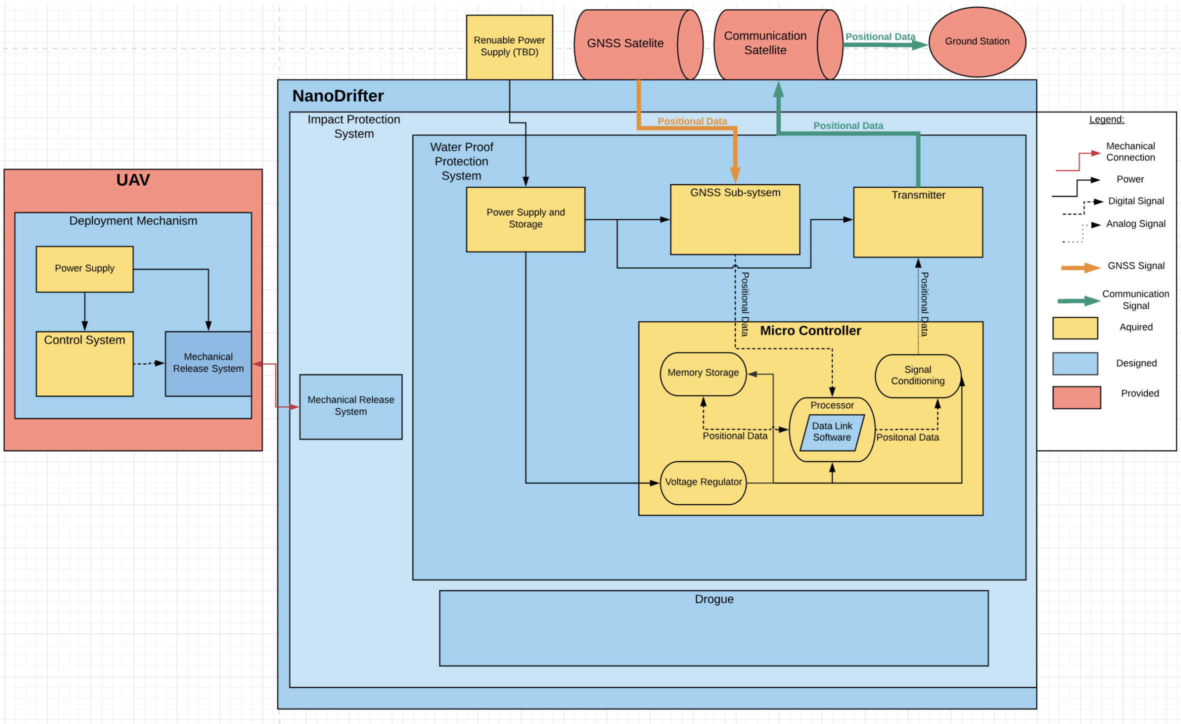

Figure 3: Functional Block Diagram

1.4. Functional Requirements

FR 1.0 Deployment system shall by initiated via an input voltage signal

FR 2.0 BEACAN drifter shall follow ocean currents in the Gulf of Mexico

FR 3.0 BEACAN drifter shall maintain a 3 months lifespan

FR 4.0 BEACAN drifter shall maintain full structural and component functionality after ocean impact from UAV deployment

FR 5.0 When following a current, BEACAN drifter shall find and store position coordinates on average every 5 minutes

FR 6.0 BEACAN drifter shall transmit stored position coordinates to a ground station up to 500 miles away at least every 24 hours

FR 7.0 Mass of 4 BEACAN drifters and 2 deployment mechanisms shall not exceed 2.7 [kg]

FR 8.0 The cost of manufacturing 1 drifter and the communications package shall not exceed $1000

2. Design Requirements

FR 1.0: Deployment system shall be initiated via an input voltage signal

Motivation: Integration to a UAV is outside the scope of this project. A simple input signal will be used to activate deployment mechanism for project verification.

Validation Method: Simple system test using input signal.

- **DR 1.1: 1 buoy shall be deployed per input signal**

  Motivation: Customer wants the ability to drop a single buoy at a time.

  Validation Method: Simple system test using input signal.

- **DR 1.2: Deployment power will be provided from potential UAV**

  Motivation: Team will not have to include deployment mechanism into power budget

  Validation Method: Stated as requirement by customer

FR 2.0: The drifter shall follow ocean currents (in the Gulf of Mexico
Motivation: Drifter shall be used to track ocean currents
Validation Method: Testing and modeling

- **DR 2.1: The hydrodynamic center of the drifter shall be greater than 30 [cm] in depth**

  Motivation: The lower the hydrodynamic center, the more likely to get caught in current flow. Typical drifters on the market have average hydrodynamic centers around 30 [cm] in depth.

  Validation Method: Validate via finite element analysis

- **DR 2.2: The drifter shall not be perturbed by surface effects**

  Motivation: The drifter will have difficulty following currents if surface effects, such as wind, have a significant impact on the drifter motion.

  Validation Method: Wind tunnel testing and finite element analysis

- **DR 2.3: The drifter shall maintain stable orientation in the water**

  Motivation: The GNSS antenna shall not. Therefore it is crucial to know orientation will allow for successful data collection and transmission.

  Validation Method: Float testing along with Finite Element Method analysis

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FR 3.0: The drifter shall maintain a 3 month lifespan
Motivation- The customer has found that the most useful position data will be tracked from a 3 month operating drifter.

- **DR 3.1: The material of the drifter shall not degrade in aquatic conditions for 3 months**

  Motivation: The drifter needs to maintain full functionality for 3 months. Material degradation before 3 months will result in an unsuccessful mission.

  Validation Method: Study of material properties

- **DR 3.2: The drifter shall maintain structural integrity from shear/normal ocean forces**

  Motivation: Ocean current combined with surface frictions result in stresses on the drifter. Structural failure before 3 months will result in an unsuccessful mission.

  Validation Method: FEM analysis along with strength tests and analysis of material properties.

- **DR 3.3: The drifter shall maintain buoyancy**

  Motivation: If the drifter loses ability to follow currents the mission is a failure.

  Validation Method: FEM analysis along with strength tests and analysis of material properties.

- **DR 3.4: The drifter shall have power for transmission and positional data collection and storage**

  Motivation: The drifter must have power to collect position coordinates along with power for transmission. If power fails, data cannot be obtained.

  Validation Method: Verification of established power budget using extrapolation methods over 3 months.

FR 4.0: The drifter shall maintain full functionality after ocean impact from UAV deployment
Motivation- A large component of the design is making sure the drifter is fully functional upon reaching the water from being deployed from the UAV.

- **DR 4.1: Drifter shall maintain structural integrity**

  Motivation: Drifter must maintain structure for mission success.

  Validation Method: Drop tests along with FEM analysis

- **DR 4.2: Communication and electrical subsystems shall maintain full functionality**

  Motivation: The communication and electrical subsystems must maintain full functionality after impact or else the mission is a failure.

  Validation Method: Impact test with post impact validation.

FR 5.0: When following a current, the drifter shall find and store position coordinates on average every 5 minutes

- **DR 5.1: The drifter shall establish GNSS lock**

  Motivation: GNSS lock will be required to download position coordinates to the drifter

  Validation Method: Simple component test.

- **DR 5.2: The position coordinates shall be accurate to 60 [m]**

  Motivation: Accuracy constraint give by customer. Accuracy will deem position coordinates useful to study.

  Validation Method: Simple component test at positions where coordinates are known to a high accuracy.

FR 6.0: The drifter shall transmit stored position coordinates to a ground station up to 500 miles away at least every 24 hours

Motivation: Constraint Given by customer.

- **DR 6.1: Drifter shall establish uplink to chosen communications satellite**

  Motivation: Needs to successfully uplink to a potential communications satellite before transmission can occur.

  Validation Method: Simple component test

FR 7.0: Mass of 4 drifters and 2 deployment mechanism shall be less than or equal to 2.7 [kg]

Motivation: Constraint given by customer. Customer came to constraint based around researched UAV data for mass affect on range.

Validation Method: Mass measurement.

FR 8.0: Cost of manufacturing one drifter and required communications package shall not exceed $1000

Motivation: Upon a successful design, the customer plans to mass produce drifter to deploy in the Gulf of Mexico. Due to manufacturing cost, customer would like to keep each drifter under $1000.

Validation Method: Tracked through design process

3. Key Design Options Considered

3.1. Configuration

3.1.1. Drogue

Given the effectively arbitrary nature of any drogue, which, for nautical purposes, is anything used to increase drag, it is difficult to partition the design space based on any particular geometry. There are of course conventions and similar configurations that arise from imitation and iteration of design, but given the critical weight requirement of the final design, we do not want to limit the scope of potential designs by choosing any characteristic shape at this stage. However, from a study of existing drogue designs, we can identify certain design considerations and options that will be crucial to later design stages.

3.1.1.1 Parachute Drogue

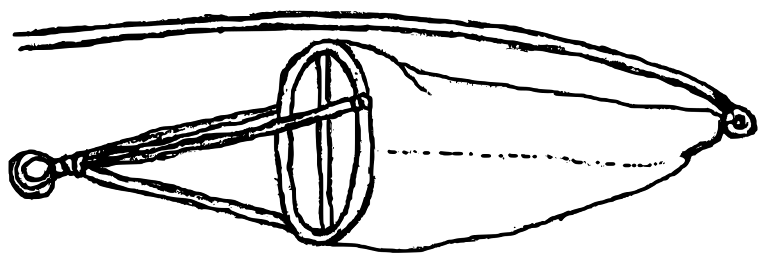
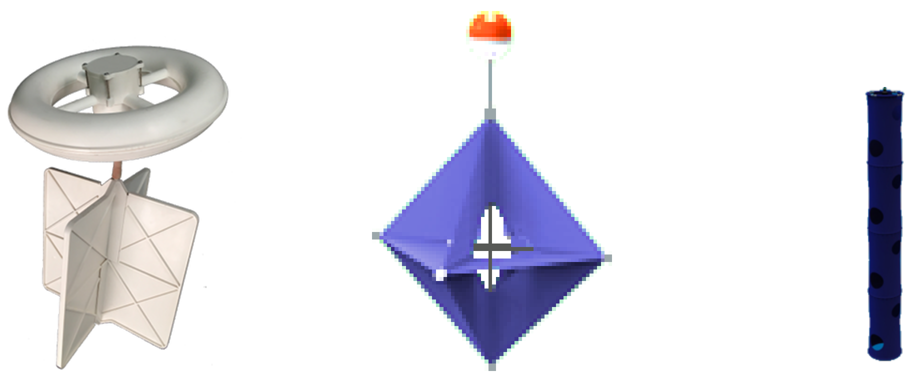


Figure 4: A typical parachute drogue

The parachute drogue[a] is the typical drogue design consisting of a parachute-like apparatus that tows behind a vessel. They are usually used to increase the stability of boats at speed, so they will likely not be as effective for a idly drifting buoy. In addition, the excess material will be inefficient for meeting weight requirements, and is liable to become tangled during the descent or while drifting in the ocean.



a) CARTHE drifter **b) Microstar drifter** **c) SVP Drifter**

Figure 5: Lagrangian float drogue examples

Pros	**Cons**
Simple design	Inefficient for idle drifting
Stability at speed	Could become tangled
Wide use in boating	Requires additional deployment mechanism

3.1.1.2 Rigid Body Drogue

A more characteristic drogue for our purposes can be found on the array of research buoys developed by Pacific Gyre. One such example is the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE) drifter. As shown in Figure 5a, the drogue consists of two perpendicular rectangular plates. The rigid body drogue provides a simple solution to the drogue configuration is easily modeled and robust. However, the necessity of a solid drogue will narrow the material design options. The rigid body drogue may also preclude a deployment strategy based on structural or weight requirements.

[a]It should be noted that the term ”parachute drogue” is only a qualitative description utilized by this document and does not represent any accepted or formal definition, as the ”parachute drogue” configuration represents what is usually depicted as just a drogue design. Because we are interested in drogues for Lagrangian drifters, a niche subset of drogues, we have made this particular distinction.

Pros	Cons
Easy to model	Most cumbersome during deployment
Simple design	Fewer design options
Proven application for Lagrangian drifters	

3.1.1.3 Collapsible Drogue

There are a few examples of collapsible drogues on Lagrangian drifters. The Microstar (Figure 5b) drogue shares a tetrahedral arrangement with the CARTHE drogue but features a collapsible polyester structure. Finally, there is the SVP drifter (Figure 5c) which utilizes a ”holey sock” design composed of a series of rigid rings connected in a nylon cylinder with opposing holes that are rotated 90° from each other in the different sections. The deployment of this drogue is depicted in Figure 6. The collapsible drogues will offer versatility for different stages of the mission as well as opening the design space to a host of flexible and rigid materials. They will, however, require a more involved design process and may necessitate novel deployment structures or mechanisms.

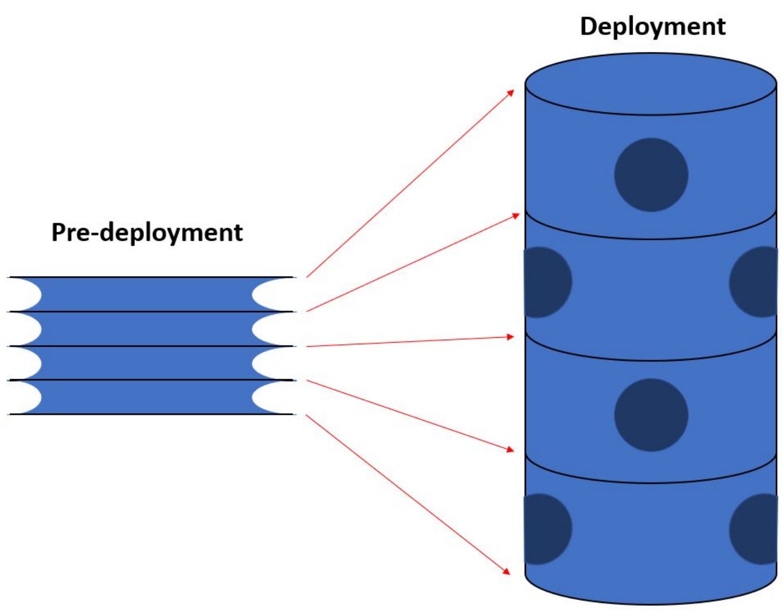


Figure 6: Overview of SVP drogue deployment

Pros	Cons
Easy to model	Requires additional deployment mechanism
Provides most options for deployment	Less rigid structure
Common design solution for Lagrangian drifters	

3.1.1.4 Geometric Considerations

From a preliminary overview of these Lagrangian drifters it can be seen that they all feature a quarter-turn rotational symmetry. This is likely to reduce variations in the drifting qualities of the drogue for the various transient orientations between the drogue and the targeted surface currents. This of course precludes any deliberate controls on the alignment of the drogue which would complicate the hydrodynamic design process. Whether active or passive, these controls would have to be finely tuned to account for the array of complex phenomena the drifter might encounter: surface waves, eddy currents, turbulence and other viscous effects. Given the budget constraints and depth of experience of the group, it would be ambitious to attempt to implement any such control system.

In effect, the main ”control” implemented for the existing research buoys is the equilibration of chaotic systems. All of the drogues employed for Lagrangian drifters rely on a irregular and transient structure to induce turbulent flow. According to National Oceanic & Atmosperic Administration’s Atlantic Oceanograpic & Meterorological Laboratory

(NOAA AOML) this is precisely the function of the holes in the SVP drouge, specifically to disrupt "the formation of organized lee vortices"[3]. Lee vortices refer to periodic eddies resulting from a flow having to traverse some physical obstacles. Commonly studied for meteorological purposes, lee vortices are responsible for many severe weather patterns such as the Denver Cyclone[4]. Less an actual problem, these regular vortex sheets are symptomatic of an aerodynamic shape interacting with a flow. Although an aerodynamic shape would still follow the predominant current direction, there would be some cumulative error associated with the relatively steady body forces on such a shape. From a heuristic standpoint, this is analogous to the distinction between a leaf and a glider in the wind; both will follow the major currents, but the leaf will give a higher fidelity approximation of the flow's direction at any point.

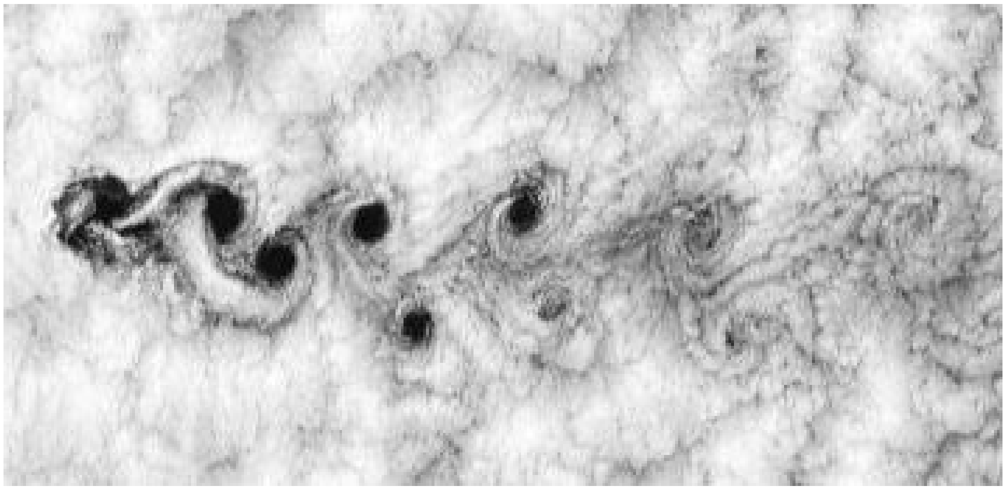


Figure 7: Satellite image of lee vortices off of Alejandro Selkirk Island near Chile[4]

3.1.2. Drogue - Float Interface

Given the requirements of the drifter, there are a seemingly limited range of possible configurations in which can be employed. The nature of the drifter requires a floating component of some sort in order to transmit GNSS data. The need for the GNSS transmission to occur above water relies heavily on the weight restrictions. Since the GNSS transmission from underwater has much greater attenuation, the uplink to a satellite would require more power and would be limited to shallow depths. Since power will be limited by the weight requirement, where even renewable energy sources may be needed for a three month longevity of transmitting data, requiring more data seems unfathomable and therefore this option is not being consider worth a trade study. The configurations being considered will therefore be composed of a drogue and float.

3.1.3. Deployment Configuration

A design consideration that is largely dependent on other aspects of the drifter, is the deployment configuration, namely, how the drifter will be configured so that the structure and electronics survive being dropped from 300 meters. The configuration relies on both the materials selection trade study as well as the power device selection trade study. Material selection will determine whether the descent speed of the drifter needs to be slowed, such as by parachute or passive aerodynamic control. Power device selection will determine if the effects of the impact can be mitigated, by absorption through the structure, enough for the electronics to remain functional.

3.1.3.1 Parachute

The first consideration for the configuration is the weight. Since a parachute has mass, the consideration on weight reduction relies heavily on if the parachute can enable a lighter material selection. This relies on impact analysis of different materials and their corresponding weights, which is a trade study of its own. If a parachute allows for a less dense material to be used, such that the weight of the structure plus the parachute, is less than that of the structural material required for the drifter to survive impact without a parachute, then a parachute seems to have a clear advantage as the drifter has a constricted mass budget. To more generally break the dependencies on material, it can be assumed that the weight of the parachute will be additional. To get a good idea of what size parachute will be needed, we will assume the worst case scenario for the weight of the drifter being 500 grams and the coefficient of drag of the drifter being 0.5 which simulates the drifter being a sphere and having very low drag. Even with these considerations a 50 gram, 30" parachute could slow the drifter to roughly 6 meters per second. At worst the parachute will only add 50 grams of total weight to the drifter and at best the parachute will save weight.

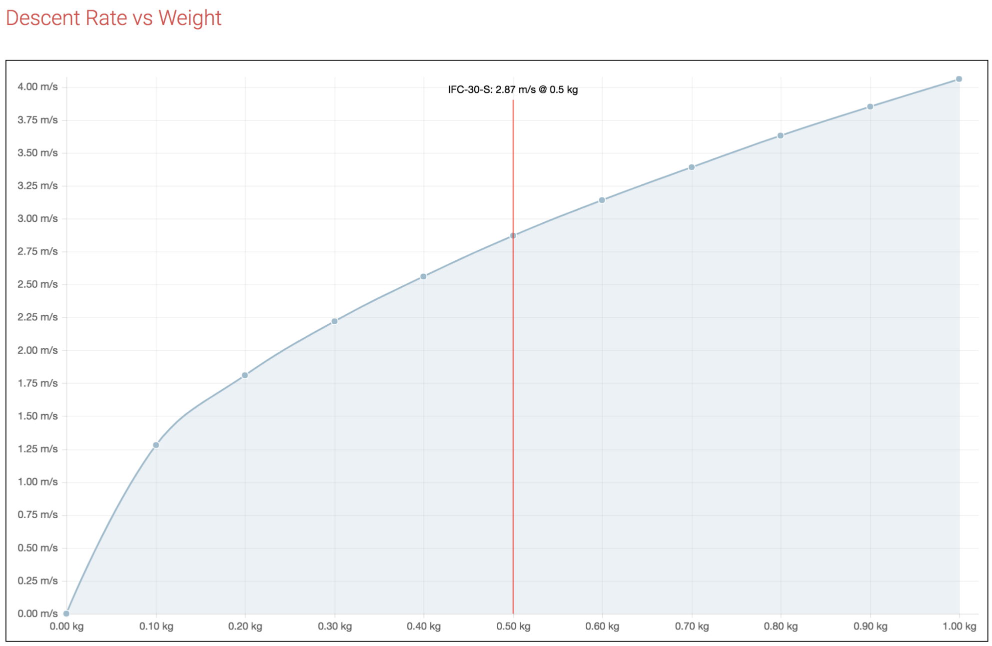


Figure 8: Decent Rate With Parachute

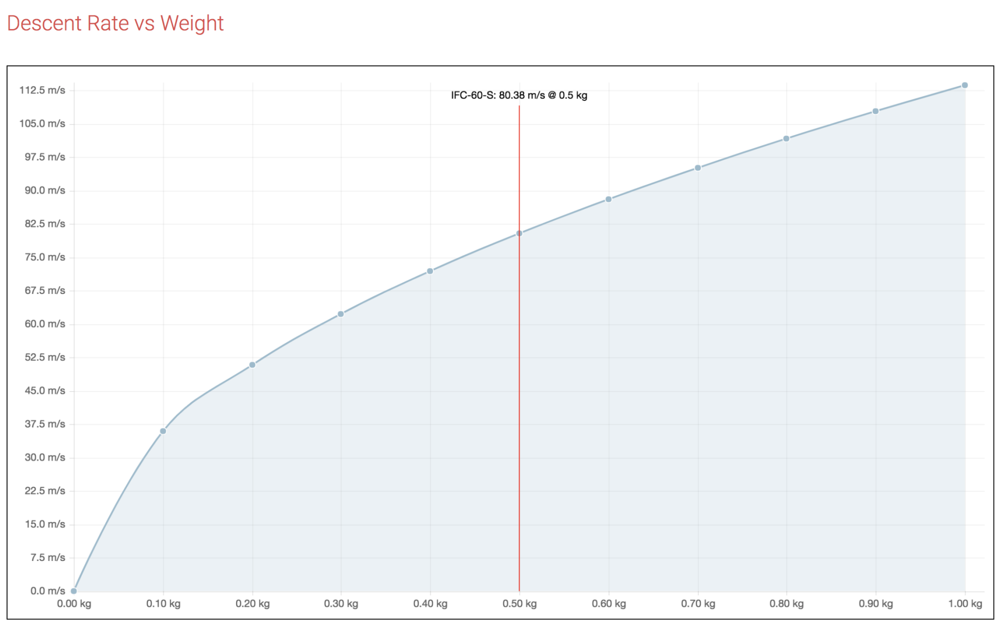


Figure 9: Decent Rate Without Parachute

The next consideration for the configuration is flexibility in design. The parachute configuration may also be needed more generally - for the purpose of widening the design possibilities. With a seemingly strict weight requirement, the material selection for both the float and drogue will be very narrow if terminal velocity impact becomes a factor. A parachute may not only be the only way to make such light material survive impact, but even if a light material can survive without the parachute - the possible material choices are certainly much larger. Another instance of the parachute giving a more flexible design option is when considering the power and transmission of data design.

In the case where the battery weight required to endure a three month duration exceeds the weight requirements of the drifter, a renewable resource such as photo-voltaic cells would be required. This would greatly effect the deployment configuration. In the case where photo-voltaic cells are needed, a parachute configuration may be needed so that the cells wont need to survive a terminal velocity impact. For this reasoning the parachute scores high in the design flexibility attribute of the trade study. Below are figures on the impact energies for a drifter with and without a 30" parachute described in the preceding paragraph. The plot illustrates why the range of possible material considerations will be greater with a parachute as impact at terminal velocity will be extreme.

When considering designs for configuration, the reliability of the configuration is the most important attribute of each of the choices. The reliability of the parachute is rather hard to tabulate. The parachute is the only deployment configuration that actually has heritage. This obviously gives the design higher reliability since the only other UAV deployable drifter, the MicroStar[3], was deployed with a parachute. The parachute, however, also is rather unreliable when considerations of the parachute actually opening from an automated deployment from beneath a UAV wing. There is a considerable margin for the tangling of the parachutes lines. Weighing both these options levels the reliability of the parachute to be rather par.

Figure 10: MicroStar's Parachute Configuration

The last consideration, is the added complexity that the parachute brings to the drifter. The parachute will have two phases that add to the complexity. The parachute will first need to open post deployment. The parachute will then need a way of detaching from the drifter once the drifter reaches the water. The detachment is pivotal due to the added unwanted effects a parachute in the water would have on the drifter if it were still attached. The parachute would act like an anchor and slow the drift speed of the drogue causing it to follow an unnatural drift pattern and defeat the purpose of the drifter. This two phase requirement adds a good deal of complexity when considering successfully landing in the water.

Pros	**Cons**
Wider materials selection	Added complexity
Has heritage (MicroStar)	Moderate reliability
Force on impact is greatly reduced	Adds Weight
Gives more possible renewable resource options	

3.1.3.2 Passive Air Resistor

In the event that after deployment, the descent of the drifter needs to be slowed, but a parachute is unfeasible due to complexity or weight restrictions, a passive air resistor could be used. A passive air resistor would be rigidly attached to the structure of the drifter, and provide a means of slowing the drifter down before impacting the water. Two examples of passive air resistors include a mono-copter airfoil and a simple structure with a high drag coefficient.

A monocopter and its design principles are shown in Figure 11. The monocopter utilizes the physics of how a maple seed pod falls in order to create wing-tip, wing-root, and leading edge vortices which result in a rotational motion of the seed that acts to reduce descending velocity. A summary of the pros and cons of using this design is shown in the table below.

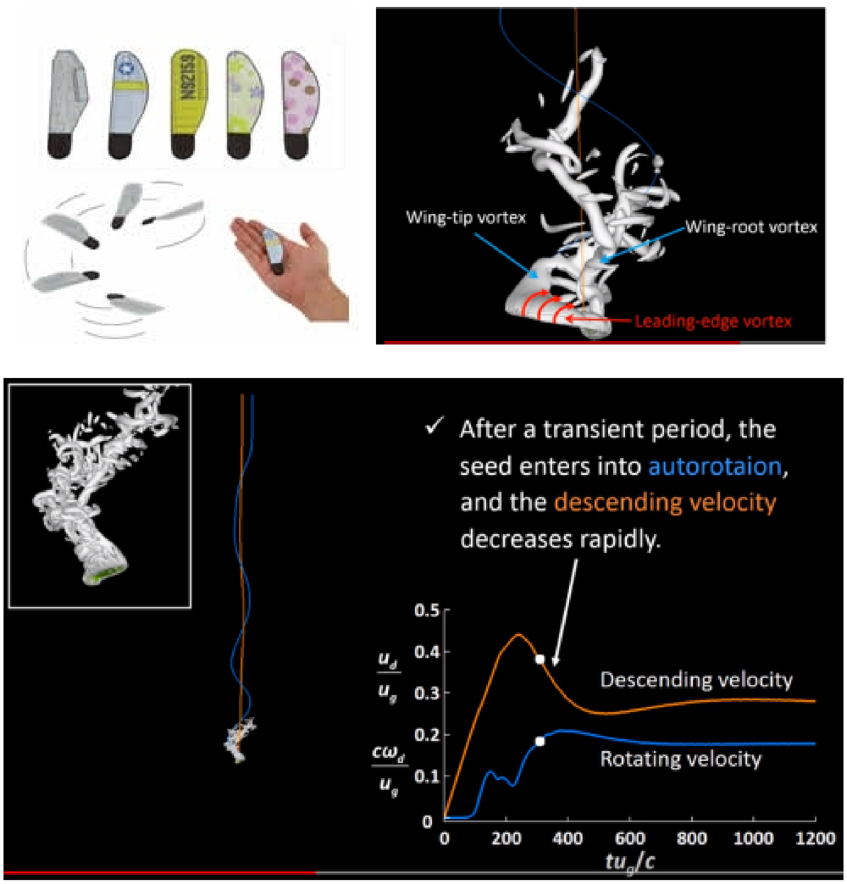


Figure 11: Monocopter design principles. An example of a manufactured monocopter airfoil is shown in the top left. The top right depicts the vortices created by a maple seed pod when falling. The bottom image shows how an increased rotational velocity produced by the seed pod corresponds to a decrease in the descent velocity.[8] [9] [10]

Pros	**Cons**
Physically part of structure (no need to detach after landing)	Limited flight heritage
Possible dual use as drogue	Limited reference material
Potential for significant reduction in descent speed	Severely effected by wind
	In-depth aerodynamic study required
	Difficult to manufacture and implement

Figures 12 shows various shapes and their corresponding coefficients of drag. The desired shape for passively slowing the descent of the drifter would have a high drag coefficient when the velocity vector is pointing into it. The aerodynamic drag created by the forward shape would hopefully produce enough force to significantly slow the drifter. This could be incorporated onto the drifter as the overall shape of the structure, or as a type of nose cone. However, this approach would also necessitate some form of stability or controls to keep the drifter in the optimal drag orientation while falling. The pros and cons of using such a design are shown below.

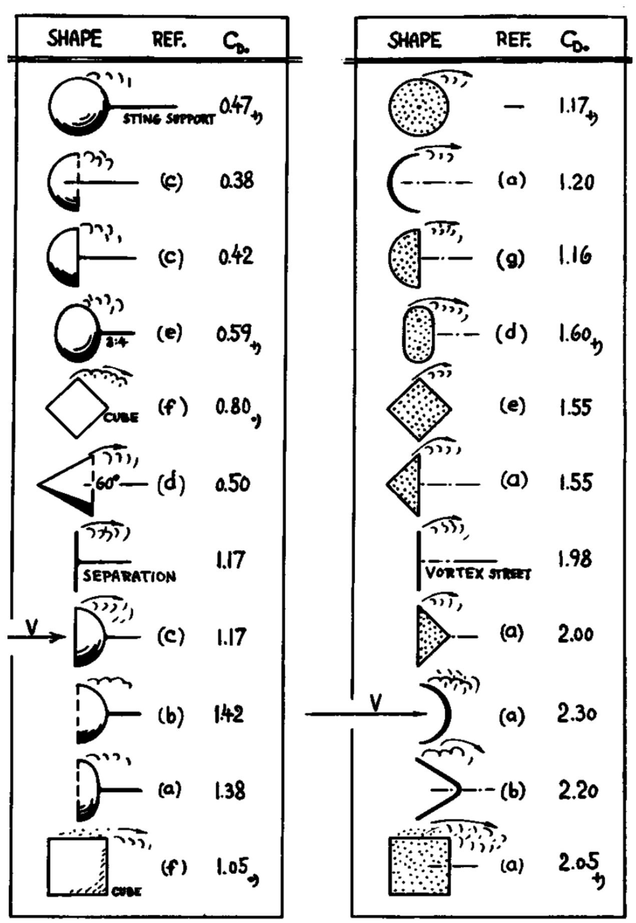


Figure 12: A comprehensive lists of common shapes and their coefficients of drag. From the chart, optimal shapes would include half circles with openings toward incoming velocity and flat plates perpendicular to the velocity.[13]

Pros	**Cons**
Simple shape - easy to manufacture	Must remain oriented correctly during flight and descent
Embedded within the structure	May require a substantial area to have a significant effect
No external components required	May result in additional drifter mass
Proven to reduce speed	

3.1.3.3 Impactor Structure

Finally, if it is determined that the electrical requirements can survive an impact without the need to be slowed down, a structure designed to mitigate or absorb energy could be used for the drifter deployment configuration. Two types of impact structure are considered here, a rigid structure and a structure with a crumple zone.

A rigid structure could come in two forms, a wide-area body, or a 'piercing' type body. The wide-area body would impact the water with a large surface area in order to spread out the impact force over a wider area, effectively reducing the force experienced by the internal components. This could be similar in shape and function to NASA's Multi-Mission Earth Entry Vehicle (MMEEV) shown in Figure 13. The other option for a rigid impact structure is the 'piercing' type body which would function by attempting to penetrate the water to the greatest depth possible in order to reduce the impulsive force experienced on the drifter. In effect, this design would use the viscosity of the water as a type of damper instead of a solid barrier. The further the drifter 'pierced' the less impulsive force it would experience. In order to produce this 'piercing' effect, the drag on the face that came in contact with the water would have to be reduced as much as possible. A very general diagram of the type of faces that could be used to produce the desired 'piercing' effect is shown in Figure 14. The table below shows the pros and cons of using a rigid body impactor.

Figure 13: NASA's MMEEV designed to return samples from space to Earth. MMEEV is designed to puncture the atmosphere at high speeds before impacting the surface of Earth. [14]

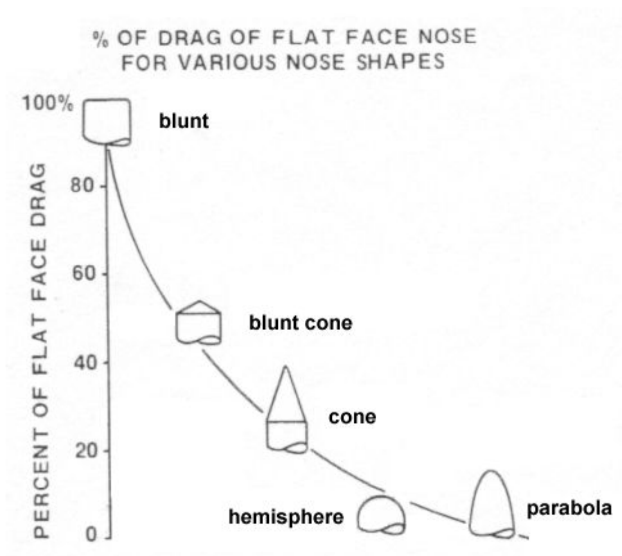


Figure 14: Various types of front area shapes and their effects on drag.[15]

Pros	Cons
Standard manufacturability	Must impact in correct orientation
Part of the structure	No reduction in descent speed
No external components required	
No significant addition of mass	

A structure with a crumple zone may also be a solution for mitigating impact effects. Crumple zones are widely used on cars and trains today with high levels of success. The theory behind this design is that an assigned section of the drifter would absorb the energy of the impact and translate it into a non-rigid part of the structure that would collapse, absorbing the additional energy instead of transmitting it to the internal components. An example of a crumple zone on a car is shown in Figure 15. The table below shows the pros and cons of using a crumple zone on the drifter.

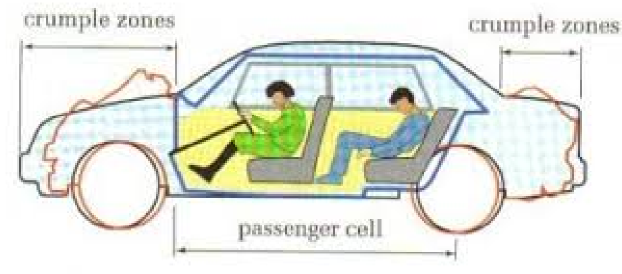


Figure 15: An example of the crumple zone on a car. Note the planned deformation zones for absorbing impact energy away from the passenger cell.[16]

Pros	**Cons**
Proven capability	Must impact in correct orientation
Large amount of available literature	No reduction in descent speed
No external components required	May be difficult to manufacture
No significant addition of mass	Requires a structural analysis

3.2. Power Generation

This section describes the exploration of the design space of if we should use batteries or in-situ power generation in order to ensure enough power is provided to fulfill the three month mission life. We are looking at three options, one of taking along all the power we need, and the other two for generating power. These three options were batteries, solar and wave power.

	Battery	Solar Power	Wave Energy
Example Product	BR-2477A/GAN	313070005	Shake Flashlight
Weight	8g per 1AH	33g	100g
Power Flux	-0.3%/ mo.	1 W	.02W
Durability	High, solid batteries	Low, very thin	High, magnet and wire
Complexity	Very simple, plug and play	Simple, needs recharging batteries also	Simple, moving parts

3.2.1. Battery

Batteries are a very stable and well known technology. However our team has serious concern that we will not be able to take along enough batteries to provide power for the whole 3 [month] mission. The lithium coin cell batteries are very light weight for their energy density and have a very low self discharge rate.

Pros	Cons
Known energy capacity	High weight
Stable batteries	Self discharge rate
Very well known technology	Need many batteries

3.2.2. Solar Power

Solar Panels have advanced leaps and bounds over the last decade or two. The latest commercially available solar panels are able to put out 1 [W] at 5.5 [V] in a form factor of 80 [mm] by 100 [mm]. This component comes with a hard board backing, but in general solar panels are fragile items. Choosing this item would enable power to be generated in-site, and allow much less weight to be brought in batteries.

Pros	Cons
Energy positive	Fragile
Low weight	Weather dependent
Low total volume	Wide but thin

3.2.3. Wave Energy

Another option for in-site power generation is to capture the wave energy. This could be accomplished by using a linear alternator whereby the rising and falling of the float versus the drogue would move a magnet through a coil and generate electricity. This was the best of the ”exotic” options (such as: wind, nuclear, thermal) but still would generate very little power for how much it weighs. One commercial application of a linear alternator is the shake flashlight where a full minute of vigorous shaking only lights a very dim LED for 4 minutes! The wave motion would be significantly less energetic than a human shaking a flashlight.

Pros	Cons
Dampens motion	Heavy
Generates energy	Very low energy generation
	Mechanical motion can fail

3.3. Power System

3.3.1. Battery

For all three of the power generation options we will need batteries. Self-evident for the battery option, and the renewable options need batteries to store the power generated and buffer against times when power cannot be generated (night, still waters). This section examines 4 common different battery architectures. We discounted more exotic types of batteries because of price or difficulty sourcing. Air batteries are promising and can be very light weight but the ones available now are roughly comparable in energy/mass and have the major flaw of being necessarily open the the ambient environment and failing when wet.

	Lithium	Lithium Coin	Alkaline	NiMH
Capacity	1Ah	1Ah	1.3Ah	1Ah
Weight	22g	8g	11g	21g
Volume	50*30*6 mm	24.5mm dia.	10*44 mm	14mm * 42mm
Voltage	3.7 V	3.3 V	1.5 V	1.2 V
Rechargable	Yes	No	No	Yes
Cost	$10	$4	$0.15	$4
Self-Discharge rate	8% / mo.	0.3% / mo.	7% / mo.	0.3% / mo.
Temp Range	-25 to 60 C	-25 to 125 C	-18 to 55 C	-20 to 40 C

3.3.2. Lithium

The regular Lithium Batteries are very energy dense but also rather expensive and heavy. The other benefits are that they are stable in a large range of temperatures and provide 3.7 V for a 1 cell battery. The lithium is rechargeable as well, which along with it’s high voltage explains it’s ubiquitous usage in commercial applications.

Pros	Cons
Rechargeable	Larger volume than non-rechargeable
Low weight	High weight compared to non-rechargeable
High voltage	Expensive

3.3.3. *Lithium Coin*

The Lithium Coin cell battery is a much smaller and much less massive version of a lithium battery. The greater energy density come from it not being rechargeable. This makes the weight about two and a half times less and the cost also far less. The battery has significantly lower self- discharge rate and also a much higher temperature limit. The cost is also lower.

Pros	Cons
Low volume	Non-rechargeable
Low weight	Many individual pieces
High voltage	Circular form factor not optimally efficient

3.3.4. *Alkaline*

Alkaline batteries are the same batteries that have graced our shelves for decades in the familiar form factor of AAA through D cell. They are cheap and a very mature technology. The weight is slightly greater than lithium while the volume is comparable.

Pros	Cons
Low volume	Non-rechargeable
Low weight	Higher volume
Very cheap	Low voltage

3.3.5. *NiMH*

Nickel metal hydride (NiMH) battery fits into the middle of the trade space. It is rechargeable, but also is cheap and has a low discharge rate. However the weight is high, as is the volume. Overall the NiMH battery is cheap, but does not have good weight or energy density values.

Pros	Cons
Rechargeable	Non-rechargeable
Small volume	Higher weight
Low Cost	Low voltage

3.4. Satellite Communication Module

BEACON drifter needs to establish communication link to send position data to a server at 804 [km]. Due to the requirement limitations such as the total weight of the drifter, sending data using basic low band radio signal may not keep a positive communication with that server for 3 months period. Thus, satellite communication modules are used to transmit data to a satellite in LEO, then those data are sent to a personal own web or email to a specific code language. Since it's required to sent data once a day, an interface board processors will store all position data every 5 minutes once for 24 hours period. Each position data carry a 8 bytes of data, so 2304 bytes of data per day shall be sent via a communication module. Satellite communication transmitters availability depends on the number of satellite in network. The performance of each module depends on the data rate for a specific period of time. For example, some modules can send one message with 30 minutes latency, others can send one message per second. This feature changes the cost of communication modules significantly. The primary objective of selecting communication modules is to send 288 position data with minimum power usage, then turn communication modules off.

	Iridium RockBlock mk2	**Globalstar GSP-1720**	**Iridium 9603N SBD Transceiver**	**STX3 Globalstars**
Power	(Run) 5V @ 100 mA (Transmission) 5V @ 450 mA (Sleep mode) 5V @ 20 uA	(Run) 5V @ 100 mA (Transmission) 5V @ 730 mA (Sleep) 5V @ 130 uA	(Run) 5V @ 100mA (Transmission) 5V @ 145 mA (Sleep) 5V @ 39 mA	(Run) 3.3V @ 2.25mA (Transmission) 5V @ 390 mA (Sleep) 5V @ 60 uA
Data	0.272 kbps	9.6 kbps	0.272 kbps	72 bits every 30 minutes
Cost	$250	$400	$195	$82
Size	76 mm x 51.5 mm x 19 mm	119 mm x 65 mm x 15 mm	31.5 mm x 29.6 mm x 8.1 mm	28.70 mm x 20.57 mm x 4.13 mm
Weight	0.065 kg	0.060 kg	0.0114 kg	[redacted]
Communi-cation	UART, AT command	USB-B	AT Command	Requires a circuit board setup
Available Antenna	Built-in Antenna	Built-in Antenna	Need External Antenna	Need External Antenna
Antenna Gain	18 dB	31 dB	Need External Antenna	Need External Antenna

Table 1: Satellite communication module

3.4.1. Iridium Modem Rockblock mk2

Iridium modem RockBlock mk2 allows users to transmit and receive short messages every 10 seconds. The RockBlock uses the iridium satellite network which consists of 66 satellites in orbit. Iridium modem is powered from the direct header connecter or via optional FTDI/USB adapter. Iridium modem functions in three modes, run mode, sleep mode, and transmission mode. Run mode, for example, needs a minimum of 5 [V] at 100 [mA]. Sleep mode leaves the modem awake all the time while using 20 [A] of current. It needs 20 seconds from power up to transmit data successfully, and it uses short burst data service and only sends 340 bytes of data roughly every 10 seconds, assuming a perfect view of the sky. Messages sent from RockBlock can either be delivered to own web or personal email, and will be hex encoded. Each 340 bytes message costs $0.98, Iiridum provides a different service for projects with +100 devices for 12 month contracts. Rockblock weights only 67 [g] and has one UART serial interface port, as well as good transmission power of 18 [dB]. An external plug-on antenna can be used to increase transmitter gains. [[34]].

Pros	Cons
66 satellites in Orbit	340 Bytes of data per message only
Cost of data service and Iridium modem don't exceed $400	One message every ten seconds
Light weight	No USB port
Multi-power saving modes	

3.4.2. Globalstar GSP-1720

Globalstar GSP-1729 also allows two-way communication at 9.6 kbps(kilo-bits per second). it costs $400 and requires a SIM card that costs $41, and monthly data service that costs $7.5 per message. The drifter will collect 8 bytes of data every 5 minutes, by the end of the day, 2304 bytes of data will be saved in the microcontroller memory. This means that each message costs $0.75. Globalstar also works on three modes, run mode needs 0.5 Watt-hour and transmission modes needs 3.67 Watt-hour. This means that Globalstar needs more energy during transmission mode than that of Iridium modem. However, Globalstar weight only 60 [g] and has a transmission gain of 31 [dB]. It also has a built in antenna, and a USB-B connector for serial interface. [35].

Pros	Cons
Can send 9.6 kbps at once	Expensive modem and Data Service
High transmission gain	Needs so much of power when transmissting data
Light weight	No UART port but only USB-B for serial interface
Multi-power saving modes	

3.4.3. Iridium 9603N SBD Transceiver

Iridium 9603N short burst data capable of delivering two-way communication and combines the global coverage of the Iridium satellite constellation. Iridium 9603N is a single board with Iridium-built core transceiver, and multi-pin interface connector and antenna connector. It only support AT command for serial interface, and needs an external antenna to transmit data.Thus, the cost of the entire system would be higher than that of the Iridium RockBlock. It transmits 2.72 [kbits] every 10 seconds. The cost of the data service for Iridium satellite is $0.98. [36].

Pros	**Cons**
Light weight	Needs External Antenna which would increase the cost of the system
Uses Iridium's 66 satellites to transmit and receive data	7 massages will be send each day to send all the position data , which will cost $7 each day.
	Needs so much of power during sleep and transmission modes

3.4.4. STX3 Global module

STX Globalstar is a simplex module that uses Globalstar simplex data network. It transmits one-way data message every 30 minutes. It only sends 9 bytes of data per massage, but creates 3 redundant messages with 5 minutes of latency. It must be mounted on a defined host PCB that provides power, and needs an RF connection to the transmitter antenna. [37].

Pros	**Cons**
Uses Globalstar data network	Needs experience with circuit board design
	Requires external antenna and host PCB
	Only 9 bytes of date every 30 minutes

3.5. Interface Board Processors

BEACON drifter needs an interface board processors to store position data once every 5 minutes, process data in hexadecimal, then sends all data in one package to communication module. It also needs a minimum of 2304 bytes of memory space for 1 day period, and a timer to receive position data for a GNSS once every 5 minutes and send them to a communication modules every 23 hours. Interface board processors is classified into several categories such as microcontrollers, digital signal processors, and board computer. Interface board processors have different processor chips which operate on different frequency. Oscillator Frequency determines the speed of the processor chip. Since BEACON drifter needs basic data processing, the speed of the processor isn't important. However, It is important to a minimum of of 2304 bytes of data, as well as two clock timers.

	Raspberry Pi Zero	**Arduino Trinket Pro**	**ADSP-21065L DSP**
Power	5 V @ 1A	5 V @ 150 mA	5 V @ 3.6 A
Data rate	1 GHz processor chip	16 MHz	450 MHz
Memory Size	512 MB of RAM	28kB flash, 2 kB of RAM	1 MB of RAM
Ports	- Two micro USB	Two USB - FTDI	UART
Costs	$5	$ 9.95	$388
Weight	9 grams	2.6 grams	[redacted]
Size	65 mm x 31 mm x 5.0 mm	38 mm x 18 mm x 2.0 mm	[redacted]

Table 2: Interface board processors

3.5.1. Raspberry Pi Zero

Rasberry Pi Zero is a light weight, widely single board computer. They are capable of interfacing with peripheral devices. It has a powerful processor chip for data processing. it costs between $5 and $40. It needs 5 [V] of power on active mode, since it has a powerful processor, it draws a large amount of power. Raspberry Pi runs operation systems such as Windows and Linux, and can process codes written in Python, Matlab, C, and C++ languages. Single power board requires an external ADC to be able to support 24 channels. The Raspberry Pi Zero has a 1 [GHz] processor that needs 1[A] to operate successfully. It has a 512 [MB] of random access memory (RAM), and USB and UART port for serial interface. It only costs $5 and weight 0.009 [kg]. The team has used Raspberry before, and Iridium modems has provided codes that works on Raspberry Pi computers. [[38]].

Pros	Cons
Powerful Processor	Team is not experienced with ADC
costs only $5	Draws a large amount of power to function
Light weight 9 grams	
Supports Multi-languages	

3.5.2. Microcontroller

Microcontroller contains a microprocessor (MPU) for data processing, input/output ports to interface with peripheral devices, and memory to store data. There are thousands of different microcontrollers in market, such as Arduino, and PIC family. Microcontrollers have many analog input channels for the ADC, and several ports such as USB,FTDI, and UART for serial interface. Different microcontrollers have different processor chips which might be slow but power efficient. Most microcontrollers operates on several power modes such as run mode, idle mode and sleeping mode. Arduino Trinket Pro uses a 16 [MHz] processor that needs 150 [mA] to function on run mode. It has a 28 [kB] flash program, and 2 [kB] of random access memory (RAM). It uses USB and FTDI ports for serial interface, and weight 0.0026 [kg] only. The team is experienced with Arudino Trinket, and several drifters on the market uses Arduino Trinket for data processing. [[39]].

Pros	Cons
FTDI for serial interface	Slow Processor which needs more time to process data
costs only $9.98	Low RAM and Flash Memory which cant store all position data for 3 months
Light weight 2 grams	Arduino language only
Several power mode including sleep mode	

3.5.3. Digital Signal Processor

A digital signal processor(DSP) is similar to microcontrollers, except that they have a specialized microprocessor for digital signal processing operations. The primary objective of digital signal processor is to measure, filter, and manipulate digital signals. ADSP-21065L DSP has a 450 [MHz] processor that draws 3.6 [A] of currents, and it has 1 [MB] of random access memory. This means that position data can be stored in the ADSP's memory without the need to overwrite data each month. It uses UART port for serial interface, as well as other serial interface ports. However, most Satellite communication modems requires UART or USB for serial interface. The team, however, doesn't have an experience with Digital signal processors, and doesn't understand the special consideration behind programming a digital signal processor. [40].

Pros	Cons
Designed for Digital signal processing	Team has no experience with DSP
Several interface ports	Draw large amount of power
Powerful processor	Difficult to learn

3.6. GNSS

The GNSS is the type of service that allows receiving of highly accurate positional data for satellites. The criteria for real time predication is necessary for the project at hand. The reason why GNSS component is necessary is because it is the only technology on board that can receive position, altitude, and time. Therefore an accurate research analysis was conducted on different types of GNSS devices.

	Adafruit Ultimate	WI-GNSS-XX	Venus638FLP	Copernicus II
Power	3.0-5.5V @ 25mA (Tracking) @ 20mA (Navigation)	5V @ 220mA (Single Power Mode)	2.8-3.6V @ 29mA (Tracking) @ 20mA (Navigation)	2.7V @ 48mA (Single Power Mode)
Weight	0.0085 kg	0.025 kg	0.0045 kg	0.0017 kg
Cost	$39.95	$86.00	$49.95	$74.95
Cold Start	34 s	38 s	29 s	38 s
Dimension	25.4 x 34 x 0.25 mm	63.5 x 63.5 x 0.21 mm	10 x 10 x 1.3 mm	26.5 x 35 x 0.21 mm
Antenna Gain	28 dB	28	30 dB	36 dB
Position Accuracy	+/- 1.8 m	+/- 2.5 m	+/- 2.5 m	+/- 3 m
Port	UART	USB	UART, SPI	UART, USB

3.6.1. Adafruit Ultimate

The Adafruit Ultimate GNSS is truly a remarkable GNSS module for receiving accurate positioning data. One of the key features is the antenna functionality where you can snap on a bigger antenna if needed. This will come useful when mass producing drifters entirely. When placing drifters in different oceans across the world the location and weather will vary from place to place. Therefore, some locations will need bigger antennas and others won't. Another pro is the built-in data loggers that help to reduce power consumption on board. This is accomplished by the micro-controller inside the GNSS module along with the empty flash. The micro-controller can be set to automatically log-in data and then go to sleep where it won't need to communicate with the GNSS anymore. Finally, the last benefit is the enable pin feature is able to switch off the module by utilizing the micro-controller. This is critical when saving power and cutting down costs. The sleep-mode functionality is a great tool to have [30] .

A downside to this module is that it sometimes has trouble locking on a position when searching for a signal. Although the accuracy is slightly better than its competitors the trade-off is locking on the position 100% of the time. The last drawback is that it has the weakest antenna gain compared to its competitors. Where if we need that extra 5 [dB] people will pay a lot of extra money for it [30].

Pros	Cons
Antenna Functionality	Lock on difficulty
Built-in Data logging capability	Slightly Lower Antenan Gain
Enable Pin Feature	
Sleep mode	

3.6.2. WI-GNSS-XX

The WI-GNSS-XX is an embedded GPS module that is absolutely phenomenal. The module comes with several ports to be used for power connections. This is a great feature where you can host the CPU and do not need to reconfigure your set up because there is only one port. You can freely connect the interfaces to the USB, RS232, and UART easily [31]. Another advantage is the autonomous signal acquisition capability. It can autonomously acquire a satellite signal and instantly provide dependable time and lock on positions in severe and inclement environments. The last positive feature for this module is the terminal block. The terminal block can grant access to the PPS signals which will authorize the system for ease of integration of GPS timing [31].

The first downside is the huge amount of volume it takes. This is definitely a critical design aspect as a drifter is already compact and crowded with mission-ensuring components. The larger the volume capacity the more we have to adjust for the other subsystems. Furthermore, the weight is significantly larger and just more massive than it's competitors. The last disadvantage is the single power mode option. It would be useful to put the module to sleep whenever possible [31].

Pros	Cons
Autonomous Signal Acquisition	Large Footprint
3 Interface Ports	Expensive
Terminal Block	Single Power Mode

3.6.3. Venus638FLP

The Venus module is a unique integrated GNSS board made by SparkFun. It is a high performance module, which is usually at lost cost. The sleep mode function is a great tool to have when trying to preserve power and cost. The module offers a very high sensitivity acquisition. This module by far takes up the least amount of volume space which is valuable for a project like ours. The weight is also a plus where again, weight is a critical requirement [32]. The Venus module indeed dominates in cold start up time which is the time to first fix position. Finally, the massive-correlate single parameter search engine effectively allows robust search for all of the available satellites orbiting space and can acquire even the faintest signals [32].

The only downside that this GNSS has is the mediocre position accuracy. Although the difference is hardly even significant, it must be taken into account as every meter of accuracy has an impact for the customer [32].

Pros	Cons
Sleep Mode	Second-Rate Accuracy
Very Small Foorprint	
Fast Cold Start up	
Correlator Signal Engine	

3.6.4. Copernicus II

The Copernicus II is one the simplest designs for GNSS modules out in the market. A GNSS chip is attached to the module which is able to receive positional data using an almanac device. When this A-GNSS feature is enabled the cold fast start up can be modeled as a hot start up. THE DIP (dual-in-line-package) board contains an impedance-matched end-launch with a standard SMA connector that will smoothly work with SMA antennas. The Copernicus II has an on board LNA (low noise Amplifier) and autonomous gain control circuit board. This does not require human input[33].

The issues that arise with this module is that its lacking hardware. The GNSS chip comes only with one I/O port[33]. This makes it extremely difficult to program the needs of the project. Furthermore, it essentially lacks other ports such as USB, UART, and SPI. However, this is the trade-off with simplicity. We thought this might be a good design option for our project as our design needs to be relatively simple and robust[33].

Pros	Cons
Trimble Technology	NO Hardware rest feature
DIP Board	Only one serial port
Passive Antenna	No Antenna protection is provided.

3.7. Material Selection

Engineering designs must take into account how the problem they are exploring will effect material properties of a design. The team found the study of material properties to be a critical element and worth exploring in great detail in relations to the design . The drifter must be dropped from considerable heights into water and thus must withstand the effects of the impact. Even more, the drifter must float for 3 months which means that the material properties must make for an overall buoyant structure as well as one that is durable in water over long periods of time. Maybe most critical of all is the mass requirement that will challenge this team. It was quickly seen that the mass requirement for a drifter of 0.5 [kg] demands a material that can handle the aforementioned difficulties as well as remain below what seems like a nearly optimal mass condition. For this reason the team has deemed material selection an essential category for careful consideration.

3.7.1. Ceramics

Ceramics are lighter than most conventional metals with their most attractive property being their corrosion resistance and resistance to heat. They are used widely in aerospace applications mainly for insulation in which thermal protection is necessary. The main challenges associated with ceramics are manufacturing and cost. They are slow and costly to process, and if not machined correctly will see a drastic decrease in the overall strength of the structure. The hardness of ceramics after solidification makes shaping structures a major issue. When these materials fail they will do so instantly and catastrophically, so there is little room for error when designing to survive an impact. However, ceramics are insoluble in water and have extremely low water absorption properties making them a material of interest for long term exposure in aquatic environments [7].

3.7.1.1 Oxides

Oxides are compounds which are made up of oxygen and any other element. The most common oxide ceramic used is aluminum oxide or alumina (Al_2O_3). This material exhibits high mechanical and compressive strength along with corrosion and wear resistance. Common applications of alumina include formulation of body armor, abrasion protectors, and electric insulators.

3.7.1.2 Nitrides

Nitride ceramics are composed of nitrogen and also have the benefit of being wear resistant as well as corrosion resistant. Silicon Nitride(Si_3N_4) is able to withstand greater shear stresses than oxides and are just stronger overall. Silicon Nitride is conventionally manufactured for use in the automobile industry as engine components due to their low wear.

3.7.1.3 Carbides

Carbides are the hardest category of ceramics. Silicon carbide is the most popular variation and offers an option which provides creep resistance and structural durability. It sees use mainly in applications where high endurance is necessary, such as car clutches and bulletproof vests. However, as with all ceramics, carbides suffer from extreme brittleness. Additionally, silicon carbide is also the most expensive of the ceramic options proposed.

Pros	**Cons**
High strength	High density
Resistant to wear and corrosion	Brittle
Extremely low water absorption	At times Expensive

3.7.2. Composites

Composites have become the dominant choice in aerospace and marine applications. Their popularity has risen to do property characteristics such as: high strength to weight ratio, high corrosion resistance, excellent fatigue resistance, and relatively low cost. Composites are in general made up from two or more materials which serve as the matrix or the reinforcement. The reinforcement is comprised of clusters of fibers or bundles of materials that are surrounded and bound by the matrix. The utility of composites is to generate a material that takes on superior properties to individual components. Composites are in high demand due to weight savings while maintaining relative stiffness and strength. For instance, composites have the potential to be five times the strength of steel while having one fifth of the weight. Composites are highly used for marine purposes due to corrosion and rust resistance. Most marine engines, bridges, hot tubs and surfboards are composed of fiberglass, which is a composite formed from glass fibers woven into a cloth then bonded together by plastic or resin. Common reinforcements include carbon, steel, glass, and graphite. Graphite is usually considered to be the cheapest reinforcement and is highly used in sporting equipment such as tennis racquets and golf clubs. Ultimately, the specific application should dictate the desired composite properties and thus the materials chosen for the matrix and reinforcement. Composites require high precision during manufacturing which could present difficulties for those who are inexperienced with them. Composite manufacturing is relatively cheap, but the individual material components can be costly based around material selection.

Pros	**Cons**
High strength	Can be difficult to manufacture
Light Weight	Still might not be light enough
Great in aquatic environments	Materials can be costly
Low thermal effects	

3.7.3. Polymers

Polymers make up many of our common day to day items such as water bottles or shampoo bottles and are colloquially referred to as plastics. Polymers applications besides plastics include polyesters and polyamides of which make up fabrics and nylons used in a wide array of applications. Given the low density and the relative strength to mass ratio this type of material plays a huge role for our project and in many other aerospace projects. Furthermore, polymers serve as the matrix to reinforcing material which means essentially that they fill in the space around the reinforcements . As such you will find that polymers also play a large role in composites given their overall malleability and strength. Now one should note that polymers are generally divided into three categories where the first two are thermosetting and thermoplastic polymers. Within the thermoplastic categorization there is the further subdivision of thermoplastic elastomers. In the sections to follow we will look at some of the general properties of each of these categories and in the end display a table of pros and cons of which express how polymers may be a benefit or detriment to the problem being examined by our team [[18]].

3.7.3.1 Thermoplastics

As the name implies this type of material displays what you would understand as plastic properties. When these are raised to higher temperatures the internal structure allows for easy movement thus one would find that by raising the temperature the material can be easily molded to the shape of interest. Following the molding the material is cooled down and in the cooling process much of the strength that engineers look for is found. For this reason this type of polymer is often times considered to serve as a substitute to metal components. As well as strength these thermoplastics are used to make nylon and other useful fabrics. This material fills in major requirements that the team is looking for in material selection. The reader should note that in general what is desirable is decent strength, lightweight, ability to handle water interaction, among other factors. These factors listed here are simply for the reader to keep in mind and will be described in much detail in the sections to follow. Now let us take a look at the subdivision of thermoplastics - elastomers.

3.7.3.2 Elastomers

Elastomers, as one might suspect, have properties very similar to rubber and given that they are a subdivision of thermoplastics they display very similar properties. Elastomers are often used in conjunction with different thermoplastics to make up the matrix of some composite. One large advantage to this material from a manufacturing standpoint is that this material is easily recyclable. Let's take a look at thermosetting polymers now.

3.7.3.3 Thermosetting

Recall that thermoplastics, at a molecular level, become very free to move when the temperature is raised. Thermosetting materials display just the opposite effect and as temperature increases the material tends to settle into itself further. Even upon cooling the rigidity and strength is maintained making this not easily usable for the construction of plastics. This material sees its commercial use a lot in adhesives since many adhesives would like to maintain their strength regardless of the temperature gradient experienced. Now that the general properties of these categories have been evaluated we will take a look at the general pros and cons of polymers as they relate to the requirements of the problem.

Pros	Cons
Relatively High strength	Often matrix material
Lightweight and Cheap	Potentially disagreeable with temperature gradients
Relatively easy manufacturing	
Maintains Integrity in water	
Can be made into a flexible, fabric-like material (Textiles)	

3.7.4. Metals

Metal alloys consist of a wide range of materials and properties, and therefore have seen use in a variety of applications. High strength to weight ratio is common throughout metal alloys, however their consistently high density and weight pose an issue. Within aerospace, aluminum is particularly popular due to being lightweight and inexpensive. Additionally, it is easily manufactured and a readily available. Suitable grades of aluminum and stainless steel also see applications in marine environments and are used to build boat hulls and various marine fittings. These material grades have increased resistance to corrosion from salt water effects. Different variations of aluminum metals have been appearing as well such as TiAl and Al-Li, where titanium and lithium have been introduced into the material respectively. The addition of titanium strengthens the alloy and increases the heat resistance while adding lithium decreases the density and weight while maintaining desirable mechanical properties. However these variations are more expensive and see less production, so finding vendors may pose a challenge. Overall, high strength metal alloys offer a viable solution if treated for use in marine conditions, however their high weight and density may lead to additional challenged in the design process.

Pros	Cons
High strength	High density
Can be treated to resist corrosion	Specific grades and variations can be costly

3.8. Deployment Mechanism

Successful deployment of the drifter is the first imperative step towards mission success. Therefore, a wing mounted release mechanism must be designed. It must autonomously deploy a single drifter at a time upon receiving a 3-12 [V] high signal. This mechanism must be very reliable as well as strive to meet our overall system goals of keeping the total weight below 2.7 kg. However, there is no cost requirements like with the drifters. It should be noted that for the scope of the project, a design for attaching the deployment mechanism to the undercarriage of the wing is not required; only the deployment mechanism itself is required.

3.8.1. Heated Release

Placing a 3-12 [V] power supply across a piece of nichrome wire with a tapered section creates a short circuit and heats the the wire to high temperatures. This circuit could be used to intentionally melt through a material to prompt deployment. Based on the given 3-12 [V] power supply availability, a thin nichrome wire can be heated to 500 - 900 [C] [[11]] which would quickly melt through most plastics. This mechanism provides a light weight and simple design solution for payload deployment. The majority of the weight will come from the mounting system which is necessary for any of the researched mechanisms. The wire and connectors to manage the heat will weigh under 10 [g] and be very inexpensive. However, this design would require heavy thermal management and design to be sure that nothing on the housing, drone, or drifter are damaged during deployment. In addition, melted hardware would need to be replaced after each deployment, adding a cost per unit deployed. Due to the nature of melting an object, the reliability and accuracy of deployment would be low. Below is a drawing of a possible deployment mechanism design which utilizes the heated release element in Figure 16 and a photo showing a heated nichrome wire in Figure 17.

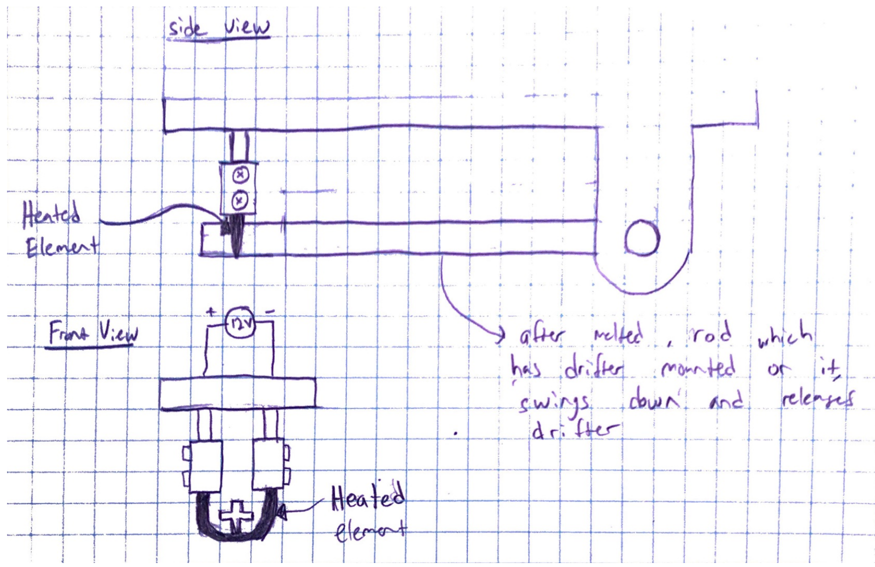


Figure 16: Sketch of one design which utilizes the heated deployment mechanism.

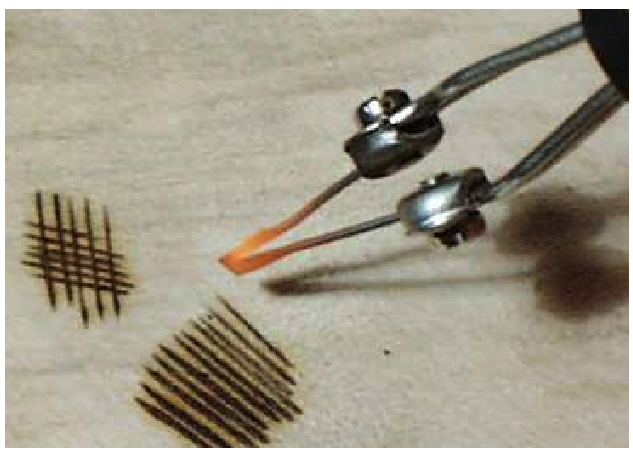


Figure 17: Example of heated element powered by 5V, 3A power supply. Red hot color signifies temperatures between 500 and 900C. [11]

Pros	**Cons**
Lightweight	Non-reusable component
Extremely Cheap	Thermal management
Minimal Electronics	Release time variation

3.8.2. Pyrotechnic Bolts

Pyrotechnic bolts are bolts that incorporate a pyrotechnic charge which immediately and remotely release two bound members. These bolts have been used extensively in aerospace applications to separate rocket stages and release massive payloads. In addition, these bolts have been successfully implemented to safely separate stages in model rockets. A pyrotechnic bolt could be used to secure the Drifter to the UAV. Upon detonation, the bolt would break apart and release the drifter. A spring could be placed between the head of the bolt and the support structure to ensure an instant and clean separation. For this application, the bolt would be made of plastic and use minimal black powder to ensure the UAV and drifter are not damaged. Pyrotechnic bolts provide a very inexpensive, lightweight, and simple design solution. The design will require almost no electronics as an off-the-shelf detonator can be connected directly to the supplied power. However, there are large safety and system damage concerns in manufacturing and testing pyrotechnic bolts. In addition, a new bolt would be needed for each deployment. Even though these bolts cost less than $4 per unit [12] to manufacture with off-the-shelf parts, this does add to the overall cost per drifter.

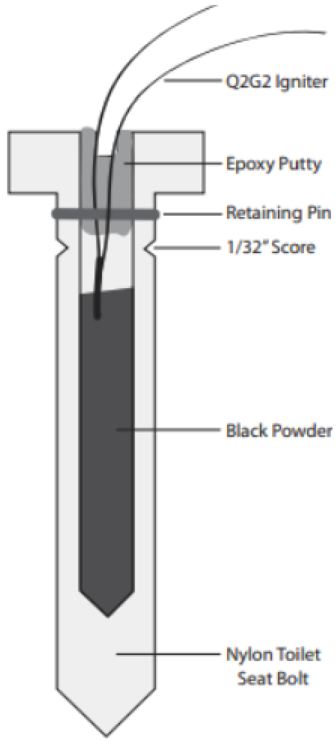


Figure 18: Small and simple pyrotechnic bolt design that has been implemented in model rockets. [12]

Pros	**Cons**
Lightweight	Non-reusable component
Cheap	Safety concerns
Simple Design	UAV damage concerns

3.8.3. Servo Release

A servomechanism, or servo for short, is an automatic device that is able to produce a torque about its gear train by a DC motor. Due to their incredible versatility in a wide arrange of applications, servos are widely available in all kinds of sizes. This would make it easy to find an ideal servo for the purpose of this project. As for its application, it will release the drifter by pulling a pin that holds the drifter and release mechanism together. See Figure 19 for more detail.

Figure 19: Servo release mechanism example [26]

As can be seen by Figure 19, the servo's gear train has an arm and push-pull rod attached to it. Surrounding the servo and extra components is a housing structure that attaches onto the wing of the UAV. On each side of the housing is a slot with a hole running through it. This slot is meant for each drifter to attach onto via a pin. They are located on opposite ends of the housing to allow for space between the drifters; if the slots were located adjacent to each other, then the drifters would be unable to be attached due to volume restrictions. The pins attaching the drifters to the housing are removed from place by the push-pull activated by the servo. At its initial position, the servo will be programmed to automatically rotate its gear train by approximately 45 degrees clockwise. This will cause the push-pull rod to move to the right, releasing the pin from the left side and thus releasing the drifter. At a later time, the servo will be programed to automatically rotate its gear train 90 degrees counterclockwise, or 45 degrees counterclockwise from its initial position. This will cause the push-pull rod to move to the left, releasing the pin from the right side and thus releasing the drifter. With this configuration, it is possible for the UAV to deploy four drifters during each flight. However, this design will require relatively more programming and electronic interface than the other designs. Additionally, the servos would require a relatively greater amount of housing than the other designs.

Pros	Cons
Many available options	Requires programming
Relatively cheap	Requires components other than housing
Can release two drifters	Relatively heavier

3.8.4. Muscle Wire Release

Muscle Wire is an extremely thin wire made from Nitinol (a nickel-titanium alloy) that is known for its ability to contract when an electric current is applied [2]. As a malleable wire, it can be formed to any shape at will. For the purpose of this project, an expanded spring would be most beneficial. See Fig. 26 for more detail.

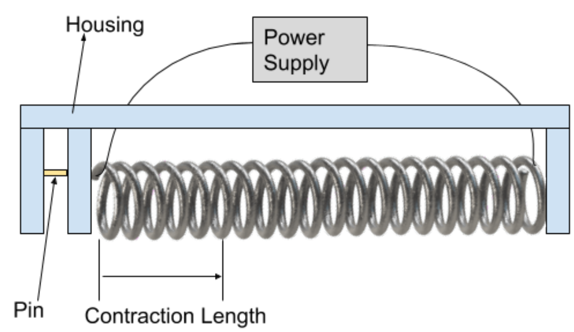


Figure 20: Servo release mechanism model

The spring is expanded in its neutral state as will compress under high temperature. It will release the drifter by pulling a pin that holds the drifter and deployment mechanism together, similar to servo release mechanism. The muscle wire will pull the pin by having an electric current run through it in order to activate its austenite form. However, it is difficult to control the extent of how much it contracts through variable temperatures, so it would not be possible for this release mechanism to deploy two drifters, only one. Therefore, two different release mechanisms will have to be manufactured. Additionally, because the UAV will be flying over the ocean, it is possible that sea mist, as well as the airflow, will affect the temperature gradient of the muscle wire, resulting in an incomplete contraction. This could lead to a drifter release failure. This could be remedied by adding more protective housing around the mechanism or wrapping insulation around the wire, both options adding more mass to the deployment mechanism.

Pros	Cons
High strength to weight	Variant to temperature
Incredibly lightweight	Can easily deform
Simple design	Can only release one drifter

3.8.5. Electric Linear Actuator

The electric linear actuator is one of the simple devices that generate linear motion. Basically, this device converts rotary motion created by an electric motor to linear motion. The electric linear actuators have a built-in electric motor, hence there is no complexity involved in building one. The electric motor transfers motion to the cylinder inside the device that linearly moves inward and outward. Within this project, the electric linear actuator can be used as a deployment mechanism that releases the payload by the linear motion of the cylinder. A picture of the device is shown in the following figure.

Figure 21: Electric linear actuator [25]

Because of its square-shaped, this device can be easily mounted on a wing. The electric actuator moves its cylinder outwards, and the cylinder pushes the first release pin. Then, the payload attached to the first release pin deploys. Once the first release pin is dropped by the cylinder of the electric actuator, the second release pin replaces the first one. This procedure is roughly summarized by the figure below.

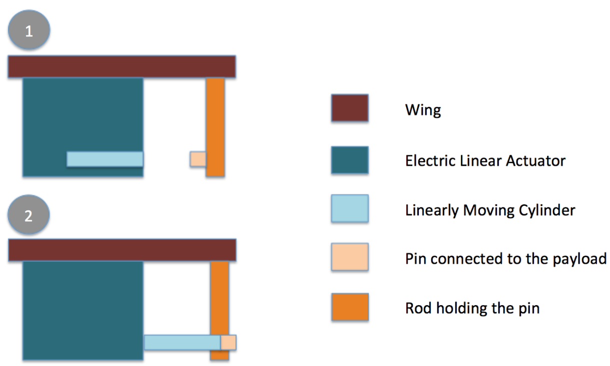


Figure 22: Side View of the Deployment Procedure

This will allow deploying two drifters using only one electric actuator. Hence, it will be a more cost and weight effective deployment mechanism. Each of the electric linear actuator weighs 15 [g], costs $ 65, and produce 15 [N] of side force. [25] However, there is some complexity involved with this design. The electric actuator needs a power circuit in order to run the electric motor inside the device. Also, this device needs to be programmed to generate the linear motion of the cylinder. Another critical factor that needs to be considered is the drag. The device has to still function while moving at a high speed. Basically, the linear motion of the cylinder has to overcome the drag when it's moving linearly outward.

Pros	**Cons**
Can deploy 2 drifters	Requires programming to operate the system
Lightweight	Requires power circuit to run the system
Inexpensive	Not very reliable against drag

3.8.6. Servoless Release

The servoless release mechanism is a device that enables the pilot of a UAV to drop a single payload during flight. This device is ready to use and does not require any manufacturing. Also, it does not involve any programming to drop the payload. The payload can be released just by a command from the pilot. Because of its simplicity of use and easy installation, the servoless release mechanism is mostly used in remote-controlled airplanes. It has never been used for a mission accomplished by a UAV. A picture of the servoless release mechanism is shown below.

Figure 23: Servoless release mechanism [27]

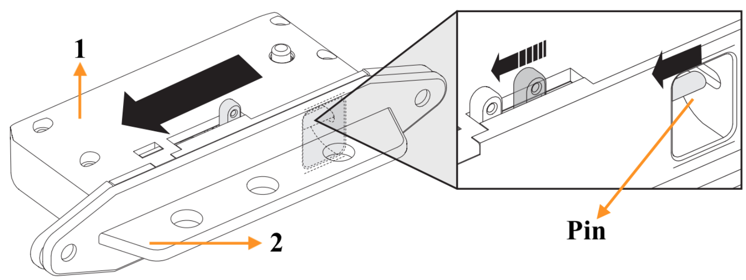


Figure 24: Servoless release mechanism model [28]

First, the device needs to be connected to the receiver. The bottom part, mounting plate, (labeled as 2 in Fig. 24) of the device will split from the top part of the device (labeled as 1 in Fig. 24), once the release switch is used on the transmitter. This deployment occurs by the release of the pin as shown in Fig. 24. Once the payload is dropped from the UAV, the mounting plate of the device must be replaced because that part will also be deployed along with the payload. The servoless release mechanism can only deploy one payload at a time. Hence, for four drifters, four separate servoless release mechanism are needed. This means quadrupling the cost and weight of the deployment mechanism, and each of the servoless release mechanism weighs 18 [g] and costs $ 25. [27] Another downside of this device is the fact that this device is mainly made for remote-controlled airplanes and has no example of its application on a UAV.

Pros	**Cons**
Easy installation on a wing	Not very reliable
Simple to operate	Can only drop a single payload
Does not require a housing	Need a replacement part after each deployment

4. Trade Study Process and Results

4.1. Configurations

4.1.1. Deployment

The deployment configurations were grouped into the following five categories: parachute, monocopter, high drag air resistor, impactor, and energy absorber. The categories were then evaluated based on their complexity, flexibility, reliability and heritage, and mass.

4.1.1.1 Metrics and Weights

Reliability - Weight: 40%

Reliability was chosen as the highest weighted metric at 40%. The chief requirement of the deployment configuration is to ensure that the drifter will survive its fall from the UAV., in order to allow for the opportunity for mission success.

Heritage and previous research were taken into consideration when establishing weighting. If an option had previous, proven results, it received a higher score. The reliability metric breakdown is shown in Table 3.

Table 3: Levels of Reliability Metric

Reliability	1	2	3	4	5
	Never been used before	Experimental solution with no real life trials	Non-conventional solution	Proven capabilities	Industry standard solution

Flexibility - Weight: 30%

Flexibility was selected as the second most important metric at 30%. The flexibility of the deployment configuration was defined as an option's capacity to allow or restrict the drogue or flotation device design space. For instance, if a deployment configuration was unable to significantly decrease the descent velocity of the drifter, stronger materials would be required and external protrusions from the drifter may not be possible. This would result in a lower score. The flexibility weighting metrics are shown in Table 4.

Table 4: Levels of Flexibility Metric

Flexibility	1	2	3	4	5
	Limits drogue and float designs due to material constraints	Limits float configuration	Limits drogue design due to material constraints	Limits drogue configuration	No limitations on drogue or float design

Complexity - Weight: 20%

Complexity was ranked as the third most important metric at 20%. The less steps and components required to decrease descent velocity, the higher score the option earned. A breakdown of the complexity metric is shown in Table 5.

Table 5: Levels of Complexity Metric

Complexity	1	2	3	4	5
	Requires active, moving components and constant control.	Additional structures required. Activation required. Deactivation required Passive operation.	Additional structures required. Activation required. Passive operation.	One additional structure required. No deployment required. Passive operation.	No additional components needed

Mass - Weight: 10%

Finally, although mass plays a critical part in the overall design of the drifter, it was weighted at 10% for the deployment configuration. This was due to the expectation that all deployment configurations would be similar in their masses, while simultaneously not significantly contributing to the overall mass of the drifter. Therefore, by setting a relatively low weight to the mass metric, no option would appear to be considerably advantageous by being slightly lighter. Table 6 shows the weighting scale for the mass metric.

Table 6: Levels of Mass Metric

Mass	1	2	3	4	5
	> 50 [g]	30-40 [g]	20-30 [g]	10-20 [g]	< 10 [g]

4.1.1.2 Results

The results of the trade study for the deployment configuration is shown in Fig. 25. The parachute scores well in the weight attribute of the trade study. Unlike the other categories, the parachute was hard to weigh based on the actual weigh metrics. Since the parachute in the worst case scenario will add rough 30 grams, it would score either a 2 or 3, however, the difference in decent velocity is so great (approximately 77 [m/s]) that a much lighter material can be used. For this reasoning, the parachute scored 4, rather than a 2-3 as prescribed by the weight metric. The parachute scored very high in the flexibility category due to the fact that it can enable the design to incorporate a much larger material selection and renewable energy selection (in the case of fragile PV cells). Where the parachute did not score well was in the complexity category as the parachute has the chance of getting tangled or not opening. The need for the parachute to also adds the need for the parachute to have a release mechanism once in the water as it will effectively anchor the drifter once submerged underwater. Lastly, the reliability of the parachute was moderate as the only other UAV deployable drift incorporates a parachute, however, the parachutes complexity adds unreliable characteristics. The impactor came in a close second due to its simplicity in nature. However, if this option were to be chosen, it may restrict the design options of other subsystems, as they would need to be able to withstand a significant impact. Similarly, the high drag configuration and crumpling body type scored

		Parachute		Monocopter		High Drag		Impactor		Crumpling Body Type	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Reliablity	0.4	3.00	1.2	1.00	0.4	3.00	1.2	3.00	1.2	4.00	1.6
Flexibility	0.3	5.00	1.5	3.00	0.9	2.00	0.6	2.00	0.6	1.00	0.3
Complexity	0.2	2.00	0.4	4.00	0.8	4.00	0.8	5.00	1	3.00	0.6
Mass	0.1	4.00	0.4	2.00	0.2	2.00	0.2	3.00	0.3	3.00	0.3
Totals	1		3.5		2.3		2.8		3.1		2.8

Figure 25: Deployment configuration trade study.

4.1.2. Drogue

The three drogue configuration options are evaluated based on flexibility, complexity, durability, and predictability.

4.1.2.1 Metrics and Weights

Flexibility - Weight: 40%

Naturally, the mass and cost requirements (FR7 & FR8) will drive the design of the drogue. Those metrics will more directly relate to the material chosen for the drogue, but the material options for building the drogue might be limited by which drogue configuration we employ. In addition, our selection might impact the deployment of the drifter further tightening requirements on other systems. Given the broad impact of the drogue configuration on the final design, flexibility has been chosen as the most important metric.

Table 7: Levels of Flexibility Metric

Flexibility	1	2	3	4	5
	Predetermines drogue configuration and material	Restricts drogue material options	Restricts drogue and deployment configuration. Few to no restrictions on material	Restricts drogue configuration. Few to no restrictions on deployment or material.	Few to no restrictions on deployment, drogue configuration or material

Complexity - Weight: 30%

The complexity of each drogue option will be determined by how many mechanisms or arrangements that configuration will likely require. The more involved the drogue design is, the larger the margin for error will be.

Table 8: Levels of Complexity Metric

Complexity	1	2	3	4	5
	Highly transient drift configuration. Requires pre-deployment housing as well as deployment mechanism.	Multiple configurations. Requires pre-deployment housing as well as deployment mechanism.	Multiple configurations. Requires deployment mechanism.	Single configuration. May require deployment mechanism	Single rigid structure. No deployment mechanisms necessary

Heritage - Weight: 15%

The heritage of each design consideration is a measure of how widely used for Lagrangian drifters. Given the few examples of existing Lagrangian drifters, it may be advantageous to pick a design that has be proven.

Table 9: Levels of Heritage Metric

Heritage	1	2	3	4	5
	Non conventional solution with no or few examples in similar applications.	Non conventional drogue configuration for a Lagrangian drifter. Several examples in a similar application.	1 or 2 examples on Lagrangian drifters	3 or 4 examples on Lagrangian drifters	More than four examples on Lagrangian drifters

Predictability - Weight: 15%

Before any drogue is constructed, we must first verify its performance with respect to FR2.0 using some method of approximation. Although not crucial to the overall success of the project, a better or simpler model will enable us to choose a more thoughtful baseline design as well as reduce the necessity of iteration.

Table 10: Levels of Predictability Metric

Predictability	1	2	3	4	5
	No sufficient modeling technique. Will require experimental verification of performance	Will require high fidelity CFD analysis	Will require time averaged (RANS) and/or low fidelity CFD analysis	Well modeled with simple aerodynamic shapes. Some transient considerations	Well modeled with simple aerodynamic shapes. No transient considerations

4.1.2.2 Results

The results of the drogue trade study are tabulated below.

		Parachute		Collapsible		Rigid Body	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Flexibiilty	0.4	3.00	1.2	4.00	1.6	2.00	0.8
Complexity	0.3	1.00	0.3	3.00	0.9	5.00	1.5
Heritage	0.15	2.00	0.3	4.00	0.6	3.00	0.45
Predictability	0.15	1.00	0.15	4.00	0.6	4.00	0.6
Totals	1		1.95		3.7		3.35

Figure 26: Drogue Configuration Trade Study Results

Unsurprisingly, the parachute drogue was the least applicable of the design options. While its somewhat simplistic design afforded it some flexibility, it introduces an array of design problems including concerns about how to mitigate the risk of getting tangled at different stages of the mission. These concerns are reflected in the complexity score. The parachute drogue would also have a highly transient drift configuration as they are designed for high speed implementation, making a consistent model difficult to develop or verify. The collapsible drogue has the highest overall score. The flexibility and heritage of this design were the main advantages. Having a pre-deployment configuration will make deployment easier to manage, and there are three different drifters (with two unique designs) that employ some sort of collapsible drogue. Finally, the rigid body drogue has the second highest total score. The simplicity of this design was offset by its lack of flexibility. The nature of the rigid body drogue would preclude certain materials due to the stresses experiences during aerial transit and deployment. A polyester structure, like that of the Microstar drogue, might fail while fixed to the UAV without additional support or a more aerodynamic configuration (ie. collapsed state).

The predictability of the three options was evaluated somewhat heuristically. The actual modeling process will depend on the specific geometry of the drogue, and a wind tunnel test will almost certainly be needed to verify hydrodynamic performance. However, assuming that our eventual drogue design follows the conventions established from existing drogue designs (see § 3.1.1.4), we can assume any drogue with a reasonably rigid float configuration is well modeled by simple aerodynamic shapes with some considerations for different orientations.

4.1.3. Deployment Mechanism

4.1.3.1 Metrics and Weights

Each design option for the deployment mechanism was evaluated in five categories: mass, cost, mechanical complexity, electronics, and risk requirements.

Mass - Weight: 25%

The mass of the deployment was estimated based off of the hardware required to build four deployment mechanisms, or two if the design options allows for it. This estimate did not include any of the housing or mounting materials etc. Mass was given a relatively high metric of 25% because although there is not as critical of a mass requirement for the deployment mechanism as the drifter, 700 [g] for the former and 500 [g] for the latter, any mass not used for the deployment mechanism can be used for the drifter. This is valuable for mission success as the 500 [g] mass limit of the drifter is one of the mission's most challenging requirements. The levels of mass were defined to be:

Table 11: Levels of Mass Metric

Mass	1	2	3	4	5
	<80 [g]	<60 [g]	<40 [g]	<20 [g]	<10 [g]

Cost - Weight: 5%

The cost of the deployment mechanism is determined as the overall cost for components, neglecting housing, for 1000 deployments. Cost has the lowest metric weight of 5% because while cost is important it was determined that the other metrics would contribute more towards the success of the project. A deployment mechanism with a low mass but high cost would be more valuable to the project success than a deployment mechanism with a high mass but low cost. Additionally, the deployment mechanism does not have a price per unit limit like the drifter. The levels of cost were defined to be:

Table 12: Levels of Cost Metric

Cost	1	2	3	4	5
	<$1000	<$100	<$60	<$30	<$15

Mechanical Complexity - Weight: 30%

The mechanical complexity is one of the major contributors to the design of the deployment mechanism. It is calculated based on whether the deployment mechanism requires custom-made components if it does whether they can be outsourced for production or can be manufactured on site. The mechanical complexity weighs 30% because it is very critical to have a deployment mechanism that successfully drops the payload at the desired moment. Ideally, it is known that having to manufacture fewer parts will reduce the chance of mission failure. The levels of mechanical complexity defined to be:

Table 13: Levels of Mechanical Complexity Metric

Mechanical Complexity	1	2	3	4	5
	All custom parts that must be outsourced for production	All custom parts that can be manufactured on site	Custom housing and parts with off shelf components	Only housing design	No custom mechanical components

Electronics - Weight: 10%

The electronics metric is determined based on the amount of electronics components required for the deployment mechanism, whether these components can be purchased or must be custom made, and whether the deployment mechanism requires software/interfacing. The electronics weights 10% because it brings an extra level of complexity to the deployment mechanism. Also, if the system requires electronics, it means that more power will need to be consumed from the UAV. If the system does not require any electronics, all of the available power can be used for the power system configuration section. The levels of electronics defined to be:

Table 14: Levels of Electronics Metric

Electronics	1	2	3	4	5
	Required two or more electronic components and software/interfacing	Requires two off-the-shelf electronic components with software/interfacing	Requires one off-the-shelf electronic component with software/interfacing	Requires one off-the-shelf component with no software/interfacing	Requires no additional electronics (i.e. only a high signal)

Risk - Weight: 30%

While most of the deployment mechanisms should perform according to the requirements under controlled test conditions, this may not be the case under the actual environment the deployment mechanism is expected to perform in. Additionally, some deployment mechanisms may be more susceptible to worse than nominal conditions than other design options. For example, while the muscle wire spring release offers an option that is lightweight and inexpensive, its functionality is completely dependent on temperature. If an uneven temperature gradient occurs throughout the spring, via sea mist or airflow, then the spring may not be able to fully contract and release the pin holding the drifter. This would result in a mission failure. Mission failure can also occur if sever damage to the UAV, deployment mechanism, or drifter occur before completion of the mission. With the pyrotechnic bolt and heated release mechanism, due to the explosive and high temperature nature that the mechanisms function under, there is serious risk of damage to all of the physical components of the mission. Therefore, risk is defined as the likelihood a deployment mechanism will result in a mission failure via failed deployment or severe damage to mission critical components due to under-performance in unideal conditions. This metric was weighted heavily relative to the others because such risks can occur and result in a mission failure. Each method was scored based on the levels of risk, defined to be:

Table 15: Levels of Risk Metric

Risk	1	2	3	4	5
	Extremely high risk	High risk	Medium risk	Low risk	Negligible risk

4.1.3.2 Results

The results of the deployment mechanism trade study are presented in Fig. 27.

		Servo Release Mechanism		Muscle Wire Spring Mechanism		Servoless Release Mechanism		Pyrotechnic Bolt Mechanism		Electric Linear Actuator		Heated Release Mechanism	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Mass	0.3	4.00	1.2	5.00	1.5	4.00	1.2	4.00	1.2	3.00	0.9	5.00	1.5
Cost	0.1	3.00	0.3	4.00	0.4	3.00	0.3	0.00	0	3.00	0.3	0.00	0
Manufacturabilty	0.2	3.00	0.6	4.00	0.8	5.00	1	3.00	0.6	4.00	0.8	4.00	0.8
Electronics	0.1	3.00	0.3	5.00	0.5	5.00	0.5	5.00	0.5	4.00	0.4	4.00	0.4
Reliability	0.3	5.00	1.5	3.00	0.9	3.00	0.9	3.00	0.9	4.00	1.2	2.00	0.6
Totals	1		3.9		4.1		3.9		3.2		3.6		3.3

Figure 27: Deployment Mechanism Trade Study Results

4.2. Materials

4.2.1. Buoy

4.2.1.1 Metrics and Weights

Weight - Weight: 45%

A crucial aspect of the design is delivering a buoy approximately 0.5 [kg] in mass. This mass design could be greater or lower depending on the mass of a deployment mechanism. Because of the miniaturization process, weight of the material is a large factor in choosing a material that would work for the design of the drifter. The weight needs to be coupled with the strength of each material, as choosing a light material that can not withstand impact forces would invalidate the material selection. The below metrics are in reference to a rough estimaate on material needs.

Table 16: Levels of Weight Metric

Weight	1	2	3	4	5
	>0.50 [kg]	0.45 - 0.50 [kg]	0.35 - 0.45 [kg]	0.25 - 0.35 [kg]	<0.25 [kg]

Strength - Weight: 20%

The strength of the material is crucial to the survival of the drifter and determines whether or not the mission will fail or succeed at any given stage. This metric encompasses the ability to survive impact with the water while ensuring all internal components remain operational, along with withstanding shearing forces applied through the combination of surface currents and wind. The high weight reflects the importance of the specific mechanical properties. Given that strength properties can range so much for a given material type it seemed necessary to get a simple calculation to let us know as to what ballpark we are looking at when the configuration impacts the water. The value desired is the stress experienced by the material at impact. We will now go through the evaluation performed as well as the assumptions made in the process. Using Newton's Second Law the differential equation found that models the motion in the y-direction is

$$y'' + \beta y'^2 = g \tag{1}$$

Although this is a second order, nonlinear, non-homogeneous differential equation we only care about the terminal velocity in are scenario so we simplify to yield

$$v_T = \sqrt{\frac{g}{\beta}} \tag{2}$$

where β holds constants used to evaluate the force of drag

$$\beta = \frac{C_d \rho A}{2m} \tag{3}$$

Now in the worst case scenario, which is what we are evaluating, the body comes to a complete stop once it hits the water and as such Newton's Second is simplified to the following impulse equation

$$F = \frac{m}{t}\sqrt{\frac{g}{\beta}} \tag{4}$$

As specified before we are ultimately interested in the stress experienced by the object so using the last equation

$$\sigma_{\theta\theta} = \frac{mD}{2tt_H}\sqrt{\frac{g}{\beta}} \tag{5}$$

where t_H is the thickness of the object, t is the time lapse of the impulse, D is the diameter, and g is simply our gravitational constant. Now $\sigma_{\theta\theta}$ implies a hoop stress and from this one can infer that a sphere was being used. Being that this is an evaluation of material and not on configuration we found it best to not complicate the design. Many buoy designs on past drifters have had such a shape and as such we found it to be a valid approximation without assuming too many details of the design aspect. All area calculation were then performed for a circular cross section. The last assumption one should note is that the relationship for hoop stress that we have used assumes thin walled vessels. As such we made sure that the thickness of the wall was at least one fourth the size of the radius of the body. Using reasonable values for the presented scenario it was found that the stress experienced is between 1 and 10 [kPa]. Again the reader should note that this is an estimate and further analysis will be done in the future, however, we now have a good understanding of the maximum stresses are material choices will need to withstand as will as valid factors of safety. When looking at many material types and the different stresses that can be managed this 10 [kPa] is very reasonable. Most materials with engineering design in mind can withstand tresses in the [MPa] range before structural decomposition occurs. Since this is such a large difference the factors of safety would be very high it is unjustified to use such factors in the metric of our study. As such 5 is simply that it can withstand the fall based off the calculations done and 1 is that it cannot withstand this fall. Note that the general strength of the material is important and that durability played a factor in understanding this as well. While the body moves through the water there will be stresses and strains constantly acting on the material. Since strength plays a critical part in the project the weight is still justifiably 20%.

Table 17: Levels of Strength Metric

Strength	1	2	3	4	5
	Will not structurally survive impact force or oceanic forces based on model	N/A	N/A	N/A	Will structurally survive impact force or oceanic forces based upon model

Material Interaction with Water - Weight: 15%

In order to remain functional for a 3 month lifespan, the material selection for the drifter must have low water absorption and resist the corrosive of salt water.

Table 18: Levels of Water Durability Metric

Durability	1	2	3	4	5
	Will not maintain integrity in water for 3 months	No commercial use in aquatic environments	Evidence of commercial use in aquatic environments	Used in aquatic environments	Used extensively in aquatic environments

Cost - Weight : 10%

A functional requirement given by the customer is to keep the cost of manufacturing each drifter under \$1000. This includes manufacturing and cost of data budget. The material volume needed for each drifter is small due the overall mass restriction. In factoring the cost metric, the team took in to account the amount of material needed for each drifter buoy. The cost for such a small amount of material justifies the team selection for a weighing of 10%.

Table 19: Levels of Cost Metric

Cost	1	2	3	4	5
	>\$400	\$300 - \$400	\$200 - \$300	\$100 - \$200	<\$100

Ease of Manufacturing - Weight: 10%

Table 20: Levels of Manufacturing Ease Metric

Manufacturing Ease	1	2	3	4	5
	Unable to build	Send away to manufacture	Partly manufacture ourselves, partly send off	Manufacture ourselves with modest effort	Manufacture ourselves with minimal effort

4.2.1.2 Results

		Polymers		Ceramics		Metals		Composites		Textiles	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	0.1	5.00	0.5	5.00	0.5	4.00	0.4	4.00	0.4	5.00	0.5
Weight	0.45	5.00	2.25	3.00	1.35	3.00	1.35	4.00	1.8	5.00	2.25
Manufacturing Ease	0.1	4.00	0.4	4.00	0.4	3.00	0.3	3.00	0.3	4.00	0.4
Strength	0.2	5.00	1	5.00	1	5.00	1	5.00	1	1.00	0.2
Water Durability	0.15	4.00	0.6	2.00	0.3	3.00	0.45	5.00	0.75	4.00	0.6
Totals	1		4.75		3.55		3.5		4.25		3.95

Figure 28: Buoy Material Trade Study

4.2.2. Drogue

4.2.2.1 Metrics and Weights

Weight - Weight: 40%

A major functional requirement is that the weight of 4 drifters and 2 deployment mechanisms shall not exceed 2.7 [kg]. Keeping the drogue as light as possible will be add more flexibility in the buoy design.

Table 21: Levels of Weight Metric

Weight	1	2	3	4	5
	>0.50 [kg]	0.45 - 0.50 [kg]	0.35 - 0.45 [kg]	0.25 - 0.35 [kg]	<0.25 [kg]

Strength / Water Durability - Weight: 30%

The team anticipates the main forces acting on the drogue to be the forces coming from the current flow. This section purely measures the capability of each material withing the potential current flow. This metric focuses on material strength and likelihood of a crack or tear in the material to propagate.

Table 22: Levels of Strength/Durability Metric

Strength and Durability	1	2	3	4	5
	Material will degrade to inoperable before 3 months	Material can withstand ocean forces, crack will propagate and result in structure failure	Material can withstand ocean forces, crack will propagate and not result in structure failure	Material can withstand ocean forces and crack will not propagate	Material can withstand ocean forces and maintain full structural integrity

Design Flexibility - Weight: 20%

This metric refers to the material restriction on design. Different drogue types were examines, including rigid and collapsible. Certain materials will limit the design scope to only rigid. This will potentially binding in future design consideration. This metric addresses how each material restricts the overall design consideration.

Cost- Weight: 10%

The cost of manufacturing a drifter shall be under $1000. This is a functional requirement given by the customer. Therefore, cost will need to be considered when examining materials for the drogue.

Table 23: Levels of Cost Metric

Cost	1	2	3	4	5
	>$400	$300 - $400	$200 - $300	$100 - $200	<$100

4.2.2.2 *Results*

		Polymers		Ceramics		Metals		Composites		Textiles	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	0.1	5.00	0.5	5.00	0.5	4.00	0.4	4.00	0.4	5.00	0.5
Weight	0.4	5.00	2	3.00	1.2	3.00	1.2	3.00	1.2	5.00	2
Strength/ Durability	0.2	3.00	0.6	2.00	0.4	3.00	0.6	4.00	0.8	3.00	0.6
Design Flexibility	0.3	3.00	0.9	1.00	0.3	3.00	0.9	3.00	0.9	5.00	1.5
Totals	1		4		2.4		3.1		3.3		4.6

Figure 29: Drogue Material Trade Study

4.3. Electronics

4.3.1. *Power Generation*

We evaluated 3 options for their ability to power the system. We considered but summarily rejected many more 'exotic' options such as thermal power generation of the temperature difference between the surface the the 1 [m] depth temperatures, nuclear thermal, and wind power. Reasons for rejection include extreme complexity, no radiation risk, or contradicting design goals (capturing wind vs. avoiding wind).

4.3.1.1 Metrics and Weights

Weight - Weight: 30%

Weight was the most important criteria for judging power generation options against each other and has been weighted accordingly.

Table 24: Levels of Weight Metric

Weight	1	2	3	4	5
	>150 [g]	150-100 [g]	100-66 [g]	66-33 [g]	<33 [g]

Power Flux - Weight: 30%

Power flux is the second critical variable for the power generation section. This is how much instantaneous power is gained or lost.

Table 25: Levels of Power Flux Metric

Power Flux	1	2	3	4	5
	¡ .1 [W]	.5 [W] - .1 [W]	1 [W] - .5 [W]	¿1 [W]	Less than .01% day power loss

Durability - Weight: 20%

The rigidity of the power system will affect the decision of descent: free fall or controlled.

Table 26: Levels of Durability Metric

Durability	1	2	3	4	5
	Would break if dropped	Fragile	Moderately durable	Durable but effected by water	Very durable

Complexity - Weight: 20%

The complexity of the system to implement is another design factor to consider. Some systems have more moving parts and would cause a failure risk.

Table 27: Levels of Complexity Metric

Complexity	1	2	3	4	5
	Many moving parts and development	Large requirements or moving parts	Requires adaptation or few moving parts	Slight adaptation or one moving part	Plug and Play

4.3.1.2 Results

		Battery		Solar Panel		Wave Generator	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Weight	0.3	1.00	0.3	5.00	1.5	2.00	0.6
Power	0.3	5.00	1.5	3.00	0.9	1.00	0.3
Durability	0.2	5.00	1	1.00	0.2	4.00	0.8
Complexity	0.2	5.00	1	4.00	0.8	4.00	0.8
Totals	1		3.8		3.4		2.5

Figure 30: Battery Trade Study

The result shows that taking along enough power to run the drifter for three months is desirable. However this may not be possible and will require very detailed analysis to determine. If it is not possible the solar panel is the best option for generating power in-site.

4.3.2. Battery

That battery options were evaluated in three categories: weight, cost, voltage and rechargeable.

4.3.2.1 Metrics and Weights

Weight - Weight: 50%

Mass was the most important criteria for judging batteries against each other and has been weighted accordingly.

Table 28: Levels of Mass Metrics

Mass	1	2	3	4	5
	>50 [g]	50-40 [g]	40-30 [g]	30-15 [g]	<15 [g]

Cost - Weight: 30%

Cost is the second critical variable. To keep minimized, as if we require 10 or 20 of these batteries the cost will add up quickly. It was weighted at 30% of the total.

Table 29: Levels of Cost Metric

Cost	1	2	3	4	5
	Over $20	$20-$15	$15-$10	$10-$5	Under $5

Voltage - Weight: 20%

The voltage the battery outputs is our final weighted critical value. The voltage influences the overall design choice as if it is too high or low it will require wasteful and massive power converters.

Table 30: Levels of Voltage Metric

Voltage	1	2	3	4	5
	>7 [V]	3.5 [V] +/- 2 [V]	3.5 [V] +/- 1.5 [V]	3.5[V] +/- 1 [V]	3.5[V] +/- .5 [V]

Rechargeable - Weight: 0%

Rechargeable is a special category worth zero points, but needs to be known for a major design decision. If the power budget dictates that we will not be able to take along all the power we need, we will need to use in situ power generation. If we decide to take along a solar panel, for instance, then we will need rechargeable batteries.

4.3.2.2 Results

		Li-Po		Li-Po Coin		Alkaline		NiMh	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Weight	0.5	2.50	1.25	5.00	2.5	4.50	2.25	2.50	1.25
Cost	0.3	3.00	0.9	4.00	1.2	5.00	1.5	4.00	1.2
Voltage	0.2	5.00	1	5.00	1	4.00	0.8	3.00	0.6
Rechargeable	0	Y	0	N	0	N	0	Y	0
Totals	1		3.15		4.7		4.55		3.05

Figure 31: Battery Trade Study

The result is that the Lithium Coin cell is the best option gram for gram. It has very low weight and cost. However it is not rechargeable. If recharging is required, then the best option is the non-coin lithium battery, as per the weighting table.

4.3.3. Satellite Communication Module

The two communication transmitters are evaluated based on cost, weight, upload rate, and Transmission mode power consumption.

4.3.3.1 Metrics and Weights

Cost - Weight: 40%

In order to minimize the total cost of the each drifter, cost of electronics devices such as communication transmitter, must be minimized. Cost of Communication transmitter depends on the cost of the modem and the data service for three months period. This metric focuses on minimizing the cost of the modem only.

Table 31: Levels of Cost Metric

	1	2	3	4	5
Cost	>$600	>$400	>$300	>$250	<$ 250

Weight - Weight: 10%

The total weight of each drifter must be lower or equal to 0.5 [kg], this means that weight of electric devices must also be minimized. The following metric focuses on minimizing the weight of communication transmitter.

Table 32: Levels of Weight Metric

	1	2	3	4	5
Weight	>100 [g]	>85 [g]	>70 [g]	>65 [g]	<65 [g]

Upload Rate - Weight: 40%

Upload rate is one of the important feature in communication transmission, since BEACON drifter needs to transmit 2304 bytes of data to a server. Therefore, increasing the upload rate increases the cost of the transmitter, which could decrease the amount of power needed during the three months period.

Table 33: Levels of Upload Rate Metric

	1	**2**	**3**	**4**	**5**
Upload Rate	low data rate and 30 minutes of latency	N/A	Send position data on several messages with 10 seconds of latency	N/A	Send the entire day position package at once in 1 seconds

Transmission Mode Power Consumption - Weight: 10%

Most communication transmitter have at least three power saving modes. However, transmission mode draws a large amount of power to send data to satellites in orbit.

Table 34: Levels of Power Consumption Metric

	1	**2**	**3**	**4**	**5**
Power Consumption	>700 [mA]	>650 [mA]	>600 [mA]	>550 [mA]	<500 [mA]

4.3.3.2 Results

		Iridium RockBlockl mk2		Globalstar - GSP 1720		Iridium 9603N SBD		STX3 Globalstar	
Attribute	**Weighting**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**
Cost	0.4	4.00	1.6	2.00	0.5	1.00	0.4	1.00	0.4
Weight	0.1	4.00	0.4	5.00	0.5	5.00	0.5	5.00	0.5
Upload Rate	0.4	3.00	1.2	5.00	2	3.00	1.2	1.00	0.4
Transmission mode Power Consumption	0.1	3.00	0.3	1.00	0.1	5.00	0.5	4.00	0.4
	1		3.5		3.1		2.6		1.7

Figure 32: Communication Transmitter Trade Study

4.3.4. Interface Board Processors

The primary function of interface board processors on BEACON dirfter is to receive and store position data, process these data every 5 minutes , and send them to a transmitter via a serial interface port every 24 hours. The three interface board processors are evaluated based on power consumption, storage space, power modes, and supporting input/output devices

4.3.4.1 Metrics and Weights

Power Consumption - Weight: 40%

Power consumption in interface board processors depends mostly on the processor chip and storage space. The faster the processor chip is, the more it needs to draw current. Since BEACON drifter must operate for three months period, it is better to focus on interface board processors that consume less energy.

Table 35: Levels of Power Consumption Metric

	1	2	3	4	5
Power Consumption	>1 [Amp]	>0.8 [Amp]	>0.5 [Amp]	>0.3 [Amp]	<0.1 [Amp]

Storage Space - Weight : 20%

The storage space refers to the amount of memory space of the interface board processors. 288 position data must be transmitted to a server every day, in total of 2304 bytes at minimum. Thus, interface board processors must at least have 2304 bytes of memory storage. Position data will be overwritten in that case. Higher memory space is preferable and could be retrievable whenever needed.

Table 36: Levels of Storage Space Metric

	1	2	3	4	5
Storage Space	Need to overwrite position data every 5 minutes	Need to overwrite position data every hour Need to overwrite position data every day	Need to overwrite position data every 1 month	Need to overwrite position data every 3 months	Doesn't need to overwrite data

Power Modes - Weight : 30%

Power Saving modes consumes a small amount of power on saving mode. Saving mode keeps the interface board processor ON, but waits for a signal from peripheral devices. BACON drifter only needs to receive position data once every 5 minutes. Thus, interface board processors need to function for 12 minutes every day to store position data.

Table 37: Levels of Power Modes Metric

	1	2	3	4	5
Power Modes	No power saving modes			three	Several power saving mode

Supporting I/O Devices - Weight : 10%

This last category refers to the number of input and output ports that are available to use for the microcontroller. Having at least four input and output ports is essentially great for ease of use when connectors are wires and other devices in and out of the microcontroller. The less I/O ports we have the more trouble we have to go through to work around it and find a way to connect it all.

Table 38: Levels of Supporting Devices Metric

	1	2	3	4	5
Supporting I/O Devices	No I/O serial interface ports	N/A	N/A	N/A	two I/O serial interface ports

4.3.4.2 Results

		Arduino Trinket Pro		raspberry Pi zero		ADSP-21065L dsp	
Attribute	Weighting	Score Li	Weighted Score	Score Alkaline	Weighted Score	Score Alkaline	Weighted Score
Power Consumption	0.4	5.00	2	1.00	0.4	1.00	0.4
Storage Space	0.2	3.00	0.6	5.00	1	4.00	0.8
Power modes	0.3	5.00	1.5	1.00	0.3	1.00	0.3
Supporting devices	0.1	3.00	0.3	3.00	0.3	3.00	0.3
Totals	1		4.4		2		1.8

Figure 33: Microcontroller Trade Study

4.3.5. GNSS

4.3.5.1 Metrics and Weights

Power Consumption - Weight: 40%

The metric of power consumption refers to how much power is being processed or utilized. This section encompasses full power which represents the amount of power and max voltage and max current. This power consumption also includes searching, tracking, navigation, and idle power. The reason why this metric is important is because one of main requirements is to have the drifter last for 3 months and therefore having insight on the power usage is crucial.

Power Consumption	1	2	3	4	5
	>0.9 [W]	0.6 ∼ 0.9 [W]	0.14 ∼ 0.5 [W]	0.121 ∼ 0.13 [W]	<0.12 [W]

Weight (Mass) - Weight: 30%

The weight category is definitely critical as it is one of main requirements that we must not go over. In simple terms, this means that the weight is essentially how massive the GNSS module is by itself. The GNSS should fit within the team's mass requirements.

Weight	1	2	3	4	5
	>0.01 [kg]	0.01 ∼ 0.02 [kg]	0.006 ∼ 0.009 [kg]	0.002 ∼ 0.005 [kg]	<0.002 [kg]

Volume Capacity - Weight: 10%

This category refers to the amount of volume that the GNSS module make take in the drifter. Indeed, a drifter is a compact object with all of its components organized appropriately inside.

Volume	1	2	3	4	5
	>501 [mm^3]	251 ∼ 500 [mm^3]	181 ∼ 250 [mm^3]	160 ∼ 180 [mm^3]	<160 [mm^3]

Cost - Weight: 20%

The amount of cost is important as all of the GNSS modules have a wide range of stock prices available and we are on a price budget.

Cost	1	2	3	4	5
	>$71	$61 ∼ $70	$51 ∼ $60	$41 ∼ $50	<$40

4.3.5.2 Results

		Adafruit Ultimate		WI-GPS-XX		Venus638FLP		Copernicus II	
Attribute	Weighting	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Power Cosumption	0.4	4.00	1.6	1.00	0.4	5.00	2	4.00	1.6
Weight	0.3	3.00	0.9	1.00	0.3	4.00	1.2	5.00	1.5
Volume Capacity	0.1	3.00	0.3	1.00	0.1	5.00	0.5	3.00	0.3
Cost	0.2	5.00	1	1.00	0.2	4.00	0.8	1.00	0.2
Totals	1		3.8		1		4.5		3.6

Figure 34: GNSS Trade Study

5. Selection of Baseline Design

5.1. Configuration

5.1.1. Drogue Configuration Selection

From the results of the drogue configuration trade study, we have selected a collapsible drogue for our baseline design. This arrangement affords the most flexibility in terms of deployment options as well as materials. This will require us to design an automated deployment mechanism for our drogue.

5.1.2. Drogue-Float Interface Selection

Given the requirements of weight, it was found without the need of a trade study that the configuration of the drifter would consist of a float and drogue. The drogue portion of the configuration is standard for drifters in order to follow ocean currents. The need for a float to drogue configuration is due to the the amount of power it would take to transmit GNSS data from under-water (no float), which would require a larger power source. Since weight is already restricted, it was found that a float was needed in order to transmit from above water by incorporating a float.

5.1.3. Deployment Configuration Selection

The parachute outperformed all other other configurations with respect to the metrics outlined to be most important for the deployment configuration selection. Namely, the parachute out-shined the other configurations with respect to reliability, complexity, mass, and flexibility. Overall the parachute allowed for design flexibility as the material and renewable energy resources it enabled, while also saving mass, made it the best choice.

5.2. Material Selection

5.2.1. Buoy Material

Based on the requirements outlined in the trade study, the BEACAN drifter will employ polymer materials for use in constructing the buoy. These materials offer the strength and durability properties necessary to survive both the initial impact and the aquatic environment. Additionally, they are lighter and cheaper than many other options explored. Focusing on polymers in the buoy design leads to greater freedom associated with designing and implementing this section of the drifter.

5.2.2. Drogue Material

Through the trade study, textile materials were chosen for fabrication of the drogue material. The metrics for the drogue material trade study aligned closely with the metrics used for the buoy trade study. Most emphasis was placed on the weight of the material. Textiles offer the greatest flexibility and are the lightest option among all the materials considered.

5.3. Deployment Mechanism

Servo release mechanism: Based on the trade study conducted for the deployment mechanisms and on the existing knowledge, the servo release mechanism was selected. It was one of the design options with the least amount of risk as servos are made with their own housing, and the manufacturer will usually produce the arms and rods that fit with the servo. They are also incredibly popular with hobbyists and therefore come in a large variety of sizes and strengths, making it easy to find an ideal servo for our project's purpose. Lastly, it is one of the few design options that is able to deploy two drifter per mechanism, as opposed to being only able to deploy one drifter per mechanism.

5.4. Electronics and Communication

5.4.0.1 Power

The baseline design for power systems came from the trade studies and the weight tables. For power generation, taking along enough power was found to be the best option for simplicity, reliability and robustness. More detailed study will be needed to determine if we are able to close the power budget without renewables, but to chose a baseline design we are confident taking alone batteries is preferable.

Having chose batteries, the next step is picking a baseline for battery chemistry. From the data and discussions above, the best choice for non-renewable batteries is the lithium coin batteries. They are chosen because of the high energy density and the lowest weight per amp-hour of the battery chemistry's we evaluated. Also for the extreme ease of use and the desirable native voltage output (3 [V]).

5.4.0.2 Satellite Communication Module

Based on the trade study, Iridium RockBlock was chosen to transmit position data to a specific server at 804 [km] away. Selecting Iridium module means that position data will not be sent in one data package, but in 7 messages with 10 seconds of latency. BEACON drifter will not need an external antenna, since Iridium RockBlock has a built-in antenna mounted on the board. In addition, Iridium offers special sales on data service and modem for +100 devices. This will drop the cost of each message below $1 . In addition, Iridium RockBlock is compatible with Arduino language.

5.4.0.3 GNSS

The GNSS component of the electronics section was a necessity to acquire useful data for our Drifter. The GNSS module that was selected for the drifter is the Venus638FLP. To begin with under close analysis of the trade study table in figure 34 shows shows that Venus comes out on top in nearly all of the weighted categories. It has really good low power consumption with the ability to go into sleep mode. If there was not a sleep mode option then we had to undergo a alternate path of switching on the GNSS module off and on autonomously. It is good to have both options. Next it is extremely light weight coming in only at 0.0045 [kg]. The cost is unbeatable even though it comes close to the Adafruit. It has the fastest cold start up time to instantly acquire data. The accuracy is well within our accuracy. Lastestly, it has the universal UART port.

5.4.0.4 Interface Board Processor

Arduino Trinket Pro was chosen to BEACON drifter's interface board processor based on the results of the trade study. It has a good memory space, as well as several serial interface ports. In addition, It also compatible with the chosen communication transmitter and GNSS. Arduino Trinket has several power saving modes which will helps save a great amount of power for 3 months period. It can also store position data for 12 days without the need to overwrite data.

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