PTO/SB/16 (01-22)
Approved for use through 05/31/2024. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 Remove

Given Name	Middle Name	Family Name	City	State	Country
Ian		Gannon	Portsmouth	RI	US

Inventor 2 Remove

Given Name	Middle Name	Family Name	City	State	Country
Alan		Zhang	Scarsdale	NY	US

Inventor 3 Remove

Given Name	Middle Name	Family Name	City	State	Country
Alexander		Bruch	New York	NY	US

Inventor 4 Remove

Given Name	Middle Name	Family Name	City	State	Country
Jonas		Kendra	Cranston	RI	US

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Title of Invention	ADVANCED DRONE DELIVERY AND RECOVERY METHOD
Attorney Docket Number (if applicable)	104916-100

Correspondence Address

Direct all correspondence to (select one):

◉ The address corresponding to Customer Number	○ Firm or Individual Name
Customer Number	140282

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

◉ No.

○ Yes, the invention was made by an agency of the United States Government. The U.S. Government agency name is:

○ Yes, the invention was under a contract with an agency of the United States Government. The name of the U.S. Government agency and Government contract number are:

PTO/SB/16 (01-22)
Approved for use through 05/31/2024. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

PTO/SB/16 (01-22)
Approved for use through 05/31/2024. OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

Entity Status
Applicant asserts small entity status under 37 CFR 1.27 or applicant certifies micro entity status under 37 CFR 1.29

- ◉ Applicant asserts small entity status under 37 CFR 1.27
- ○ Applicant certifies micro entity status under 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
- ○ No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Stephen N. Kulhanek/			Date (YYYY-MM-DD)	2023-12-19
First Name	Stephen	Last Name	Kulhanek	Registration Number (If appropriate)	76,240

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or paten. Accordingly, pursuant to the requirements of the Act, please be advised that : (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, t o a n other federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

ADVANCED DRONE DELIVERY AND RECOVERY METHOD

SUMMARY OF THE DISCLOSED SUBJECT MATTER

Embodiments of the present technology are directed to devices, systems, and methods of launching and recovering drones from submarines. In some embodiments, the system includes a drone, a delivery system, and a recovery system. The delivery system includes a canister launcher that is configured to launch the drone from a submarine underwater. In some embodiments, the launcher utilizes pressurizing film to launch the drone. The drone is stored in the canister launcher with wings in a folded position and, after being launched through the water and into the air, is configured for flight with the wings in an extended position. In some embodiments, the system includes artificial intelligence and control systems that are configured to control the drone during flight and recovery operations. The recovery system includes landing rails that are positioned on the submarine. In some embodiments, the landing rails include magnetic electric eddy currents that are configured to reduce the drone's landing speed without making direct, physical contact with the drone, thereby reducing and/or eliminating wear on the drone and the landing rails.

SUMMARY OF ADDITIONAL DISCLOSURE MATERIALS

1. Detailed Description of the Disclosed Subject Matter (24 pages)

Introduction

Problem Statement: The introduction of the aircraft carrier provided air superiority seemingly anywhere in the world. Submarines offer the ability to carry out clandestine operations while staying hidden from adversaries. Submarines are cheaper than aircraft both to manufacture and to operate by a magnitude of 12.04 billion dollars [redacted]. Underwater missions are also limited by the amount of consumable supply to the submarine.

The Navy is directly impacted from this problem as more sailors are [redacted] for Surface Warfare designations, but ultimately the problem lies on the American taxpayers as the funding from the Navy stems from taxpayer money.

By having a submarine that can be resupplied at any point and time while also having the ability to provide auxiliary air support, it could serve to benefit future naval operations and save American taxpayers money.

Background

In fully understanding the problem definition, our group began by researching what existing technologies are and how they can be improved. Instead of performing a “day in the life” analysis, we decided to instead look at a submarine mission and see where there are areas for improvement.

<u>A Day in the Life - Average Mission:</u>
Stock up on supplies at shore
Travel to dangerous territories
Listen to enemies and transmit data to home
Travel back to shore and report

This day in the life gave [redacted] information into the limits of submarine surveillance, in that the main form of surveillance is auditory. Submarines can listen to radio signals, but they are not able to perform visual surveillance as they are underwater. Submarines also [redacted] to restock food and necessities on shore or by a larger ship, making it difficult to be in dangerous territories for long. To understand why submarines are unable to stay in mission [redacted] zones for extended periods of time, a 5 why analysis was performed.

<u>5 Why:</u>
Why can’t submarines stay in [redacted] areas often?
- Because they [redacted] to resurface

Why do they [redacted] to resurface?
- To obtain food and resources

Why can’t they obtain resources in the [redacted] areas?
- Because sailing a boat into these areas is too dangerous

Why does the food [redacted] to be sent by boat?
- Because there is no existing technology that allows submarines to both send and receive objects

Why does this not exist?
- Because innovators haven't thought about it yet.

This analysis led the group to the conclusion that some form of delivery system is an [redacted] innovation for the future of submarines, and there is no reason why it shouldn’t exist. [redacted]

Current Designs In Use

The Multiple All Up Round Canister (MAC) is a system on vertical payload tubes on current US submarines. [redacted] MAC support modules below the payloads, the payloads themselves, and a protective film on the top. The film serves to create a barrier between the sea and the payload, the cavity fills with positive pressure and the film breaks causing the payload to start rising and begin its delivery. Pictures of the top of the MAC can be seen below. [redacted]

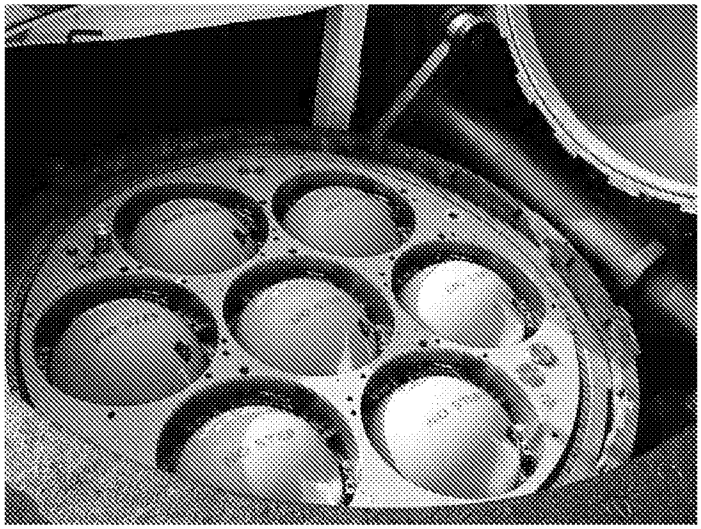

Figure 1: Existing submarine launching canisters

Figure 2: Submarine launching canister in action

Analytical Development

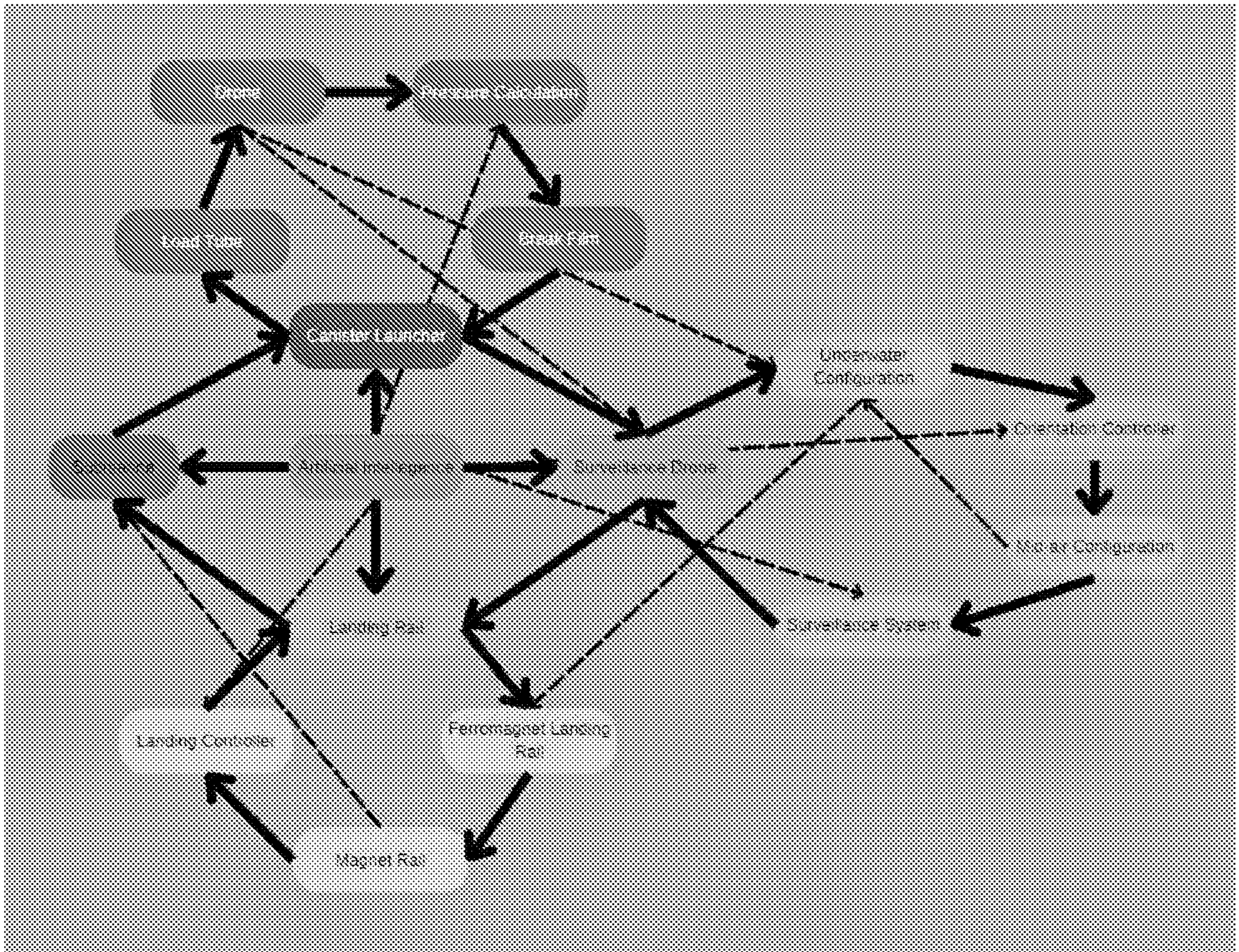

Figure 3: System Level Solution

This project can be broken into the system level solution seen above. At its highest level, there is a submarine that uses a canister launcher to launch a drone that will do surveillance and then dock back on the submarine. The canister launcher uses existing technology of pressurizing a film to launch an object from the submarine. The surveillance drone will be in a prone position where the wings are folded in so that it can travel through the water smoothly. Once the drone reaches the air, the artificial intelligence combined with integrated control systems will orient the drone in the air and allow it to travel to its destination rapidly. Once the surveillance mission is complete, the drone will be able to dock back on the submarine using landing rails. The artificial intelligence and integrated control systems will be integral in orienting the drone correctly and catching it properly. Magnetic electric eddy currents will be able to slow down the drone without any contact, thus eliminating wear.

Product Specifications

Customer [redacted]	Interpreted [redacted]	Specification
Drone Fits in Launch Canister	Minimize Compacted Drone Volume	Compacts to <2.5m
Compact Recovery System	Minimize length	<50m system
Drone has wide surveillance capability	Maximize sensor housing capability	>100 sensors
Large Drone Range	Maximize mileage	>1000 mi

Table 5: Product specifications

Product specifications are included, with a focus on physical size and component [redacted] for the launch/recovery system, along with the accompanying drone. Of these, they are designed to be easily implemented to existing, standard sizes of submarine, while maintaining above average performance characteristics.

Performance Specifications

Customer [redacted]	Interpreted [redacted]	Specification
Operate in deep sea	Survive depth >10km	>100 atm Pressure
Large Drone Range	Maximize mileage	>5,000 Amp Hours
Long Lasting	Maximize Component Lifespan	>1000 uses to failure
Smooth Stop/recovery of drone	Minimize Instantaneous Forces	<100kN
Drone orients on launch	Minimize time to stable control	<1s orientation
Fast Operation	Minimize Setup Time	<1 minute to launch

Table 6: Performance specifications

Performance Specifications have also been included, with a focus on operating conditions, lifespan, and control [redacted]. Of these, we expect that the hardest to meet will be the 100 atm of pressure. To validate these, simulations

100 questions were written to ensure that the group has a strong understanding of the project and what still [redacted] to be understood. These are seen in Appendix A and helped the group understand that the technology to solve this problem exists, but a solution has not been made yet. It is the groups job to innovate and use engineering to solve this problem.

System Overview: Launching

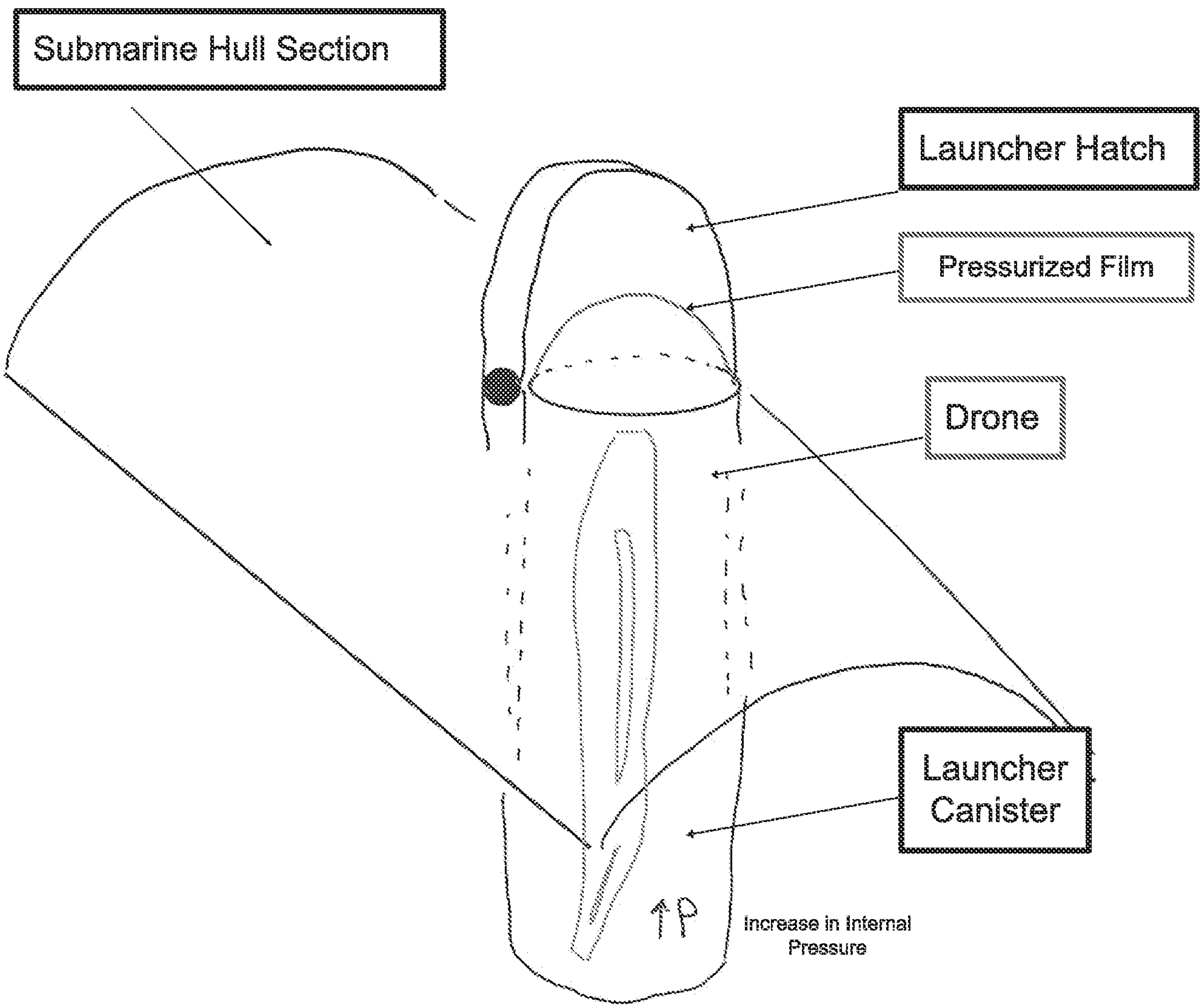

Figure 4: Launching sketch

System Overview: Folding Wings

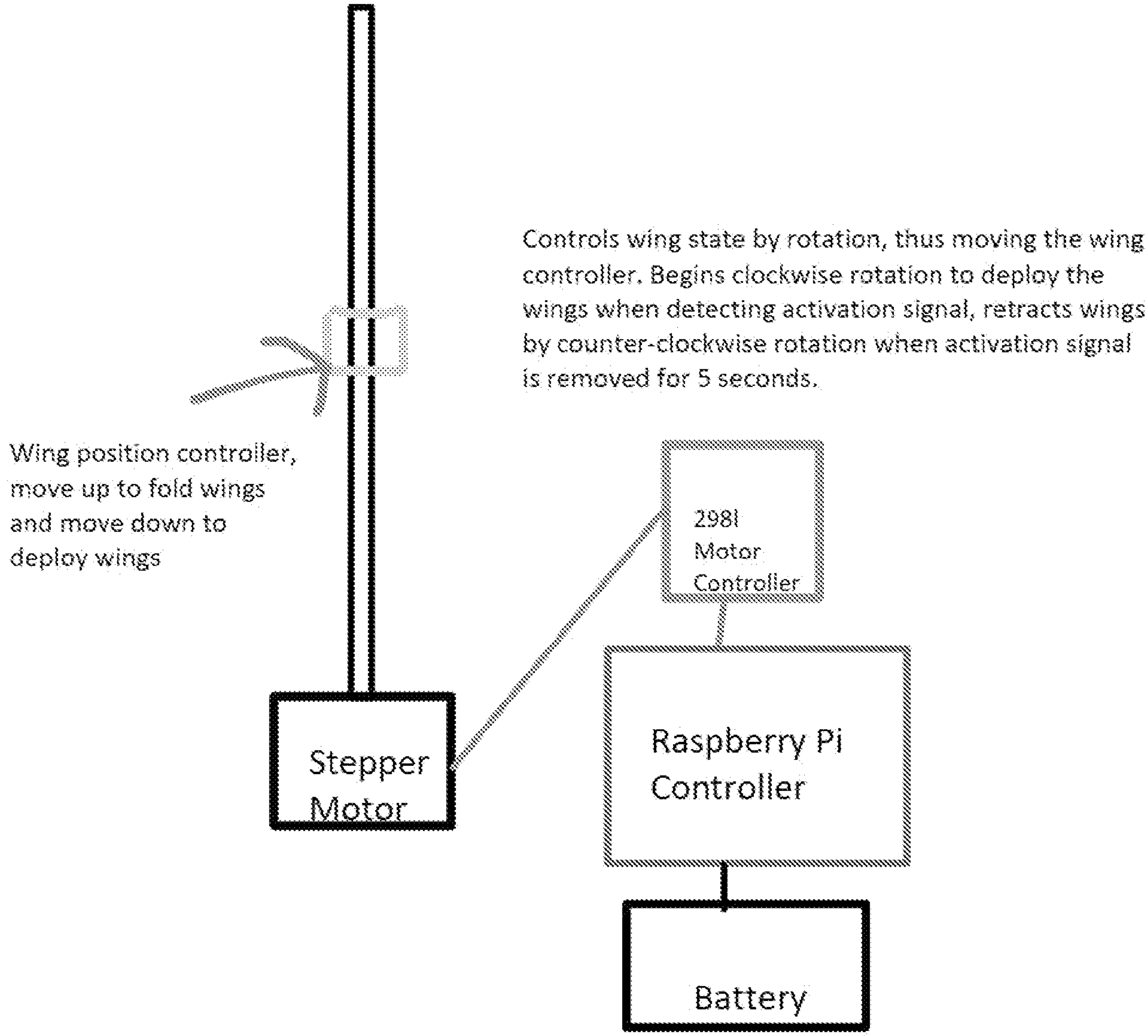

Figure 5: Circuit prototype block diagram

System Overview: Recovery

An [redacted] aspect of the efficacy of the system solution is ensuring that the drone can safely land, and in turn, be recovered for future operations. Along with being compact, an ideal solution prevents any undue servicing [redacted]. Upon landing, the drone will return, guided towards the launcher hatch by the landing rail, where it will slow down quickly, before being lifted and returned to the launcher, as seen in the diagram below.

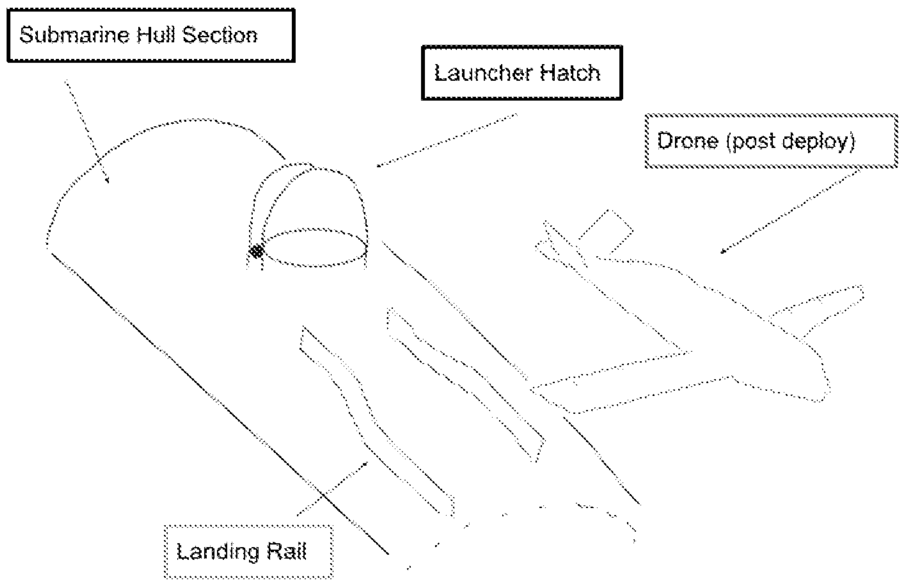

Figure 6: Recovery system overview

To allow for successful landing, inspiration was taken both from helicopter landing rails and Lenz's law. A copper tube will be utilized as a landing rail, and the drone will house strong magnets, mounted much like a helicopter's landing skids. Much of the speed reduction from flying to stationary can be done frictionless, utilizing the concept of Lenz's law. A resisting electromagnetic force will be applied to the landing skid (or rail), resisting its motion through the landing guide(receiving) rail. This resistive force is a function of velocity, meaning it will behave similarly to a damper. The benefit of using this solution is that there is no mechanical collision, meaning no wear, and no servicing of involved components will be [redacted], as long as the applied load is in the elastic region for the landing rail and drone. Once near its stopping speed, a further breaking mechanism may be applied, but a small amount of friction towards the end of the rail should be sufficient. A diagram depicting the realized forces is pictured below.

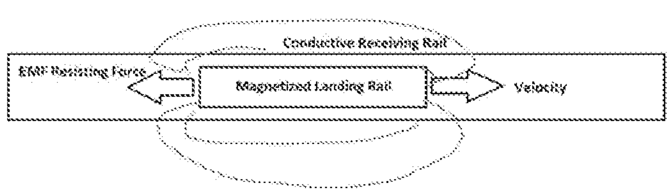

Figure 7: Landing rail diagram

In addition to the theoretical solution, the landing guide rail was created in CAD and can be seen below.

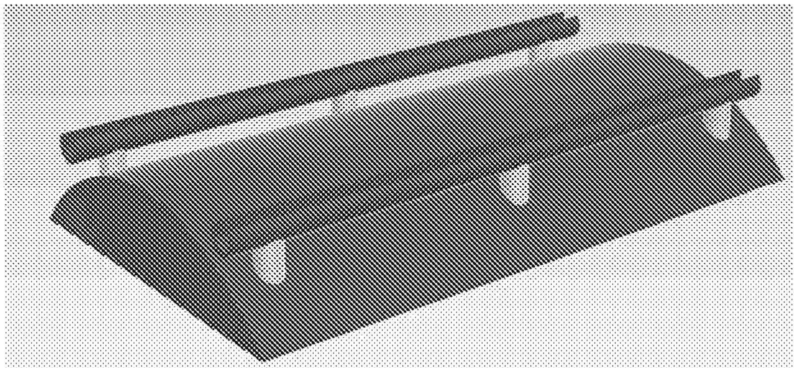

Figure 8: Landing rail CAD

Table 1: FMEA Chart (Split for legibility)

System	Potential Failure Mode	Failure Effects	Severity	Potential Causes	Occurrence
Return System	Power Failure	Structural damage to landing rails	4	Wire damage/corrosion	3
Return System	Structural damage on return rail	Drone crash	7	Rail system fails to catch drone	4
Return System	Structural damage on return rail	Data loss	6	Exposed to ocean environment too long	6
Return System	Drone stuck outside containment	Corrosion/damage to drone	5	Failure of return hydraulics	2
Launch System	Not enough pressure to launch	Drone fails to launch	2	Submarine is too deep	3
Launch System	Drone launches prematurely	Seal and Drone damage	7	Safe launch control algorithm failure	1
Launch System	Drone launches at wrong angle	Drone could get lost at sea	9	External forces or drone sensor failure	1
Drone System	Battery Fail	Drone gets lost	5	Poor manufacturing	3
Drone System	Controller Fail	Drone crash	7	Insufficient computing power	3
Drone System	Mechanical Fail	Emergency landing	5	Material cracks	2
Drone System	Sensor Fail	No obtained data	2	Underwater short circuit	2

System	Current Controls	Detectability	RPN	Remedy
Return System	Wiring housed internal to submarine, tested before landing	8	96	Utilize permanent magnet system instead of electromagnet
Return System	Visual inspection for damage on shore, between departures	3	84	Sensor/camera on-board to monitor gear status
Return System	High-strength material guide rail	4	144	Utilize anti-corrosion paint/coating to improve lifespan
Return System	Designed for long lifespan, anti-corrosion materials	7	70	Standard part inspection, from 1st percentile design lifespan
Launch System	Depth Sensor and safe launch protocols	3	18	Have multiple failsafe within launch protocol
Launch System	Feedback loops	2	14	Have multiple failsafe within launch protocol
Launch System	gyroscopic sensor	3	27	Refrain from launching in rough seas.
Drone System	All batteries are stress tested beforehand	5	75	Redundant batteries
Drone System	Powerful computers are dedicated to single systems	3	63	Multiple computers on different networks
Drone System	Military grade materials	8	80	Inspection after each flight
Drone System	Waterproof shell	7	28	Redundant seal re-made after each flight

Table 7: FMEA risk analysis

Experimental Development

Canister Launcher:

Success for the canister launcher means providing the drone with sufficient transport to the surface of the water. This is done similar to the industry style of transporting payloads to the surface by creating positive pressure within the canister enclosure, and allowing the air to help transport the drone in this case to the surface. Some equations that will be helpful to calculate exactly how much force is aiding in the drone ascent are listed below:

$$F_b = -\rho g V$$

Equation 1: Buoyant Force Formula

$$F_D = 6\pi r \eta v$$

Equation 2: Force due to Drag (Assuming Stoke's Law is true)

$$F = mg$$

Equation 3: Force due to Gravity

Overall the system [redacted] to overcome several other challenges in the real world such as changes in fluid temperature, salinity, and pressure, which will all affect the properties of the fluid (salt water) that the drone, and submarine system will be exposed to. For the purposes of this design, a simplistic approach will be used as a baseline to prototype.

Guard rail / recovery system:

To successfully recover a UAV, the team is [redacted] to develop a system that incorporates UAV technology with submarine technology, interfacing the two in a way that allows one to dock on the other. To do this, a structurally stable rail system with a spring-damper system [redacted] be created to stop the UAV at a controlled point, with some level of tolerance in relative initial velocity. In the end, a balance of the five following equations [redacted] be struck to balance and meet various input [redacted].

$$m\ddot{x} + c\dot{x} + kx = 0$$

Equation 4: Non-excited Vibration Equation

$$\omega_0 = \sqrt{\frac{k}{m}}$$

Equation 5: Natural Frequency equation, Wn

$$\omega_d = \omega_n\sqrt{1-\zeta^2}$$

Equation 6: Oscillation frequency of damped system

$$T_s = \frac{4}{\zeta\omega_n}$$

Equation 7: Settling time for stopping UAV

$$PO = \left[e^{\left(-\pi\zeta/\sqrt{1-\zeta^2}\right)} \right] \cdot 100\%$$

Equation 8: Positional Overshoot

Overall, the system [redacted] solve several problems: The UAV and rail/submarine [redacted] be able to withstand all forces without deformation, the process [redacted] be safe and repeatable, and the system should be fairly quick. To achieve this, a balance will be made between deceleration, positional overshoot, total system length, and system settling time.
A cost-benefit analysis will be completed, judging the effects of each component, and determining feasibility.

Surveillance Drone:

For this drone the NACA 5012 airfoil was selected for the wings.

$$F_L = \frac{C_L \rho V^2 A_P}{2}$$

Equation 9: Airfoil Lift

$$C_D = C_{D\infty} + \frac{C_L^2}{\pi AR}$$

Equation 10: Coefficient of Drag

$$M = \frac{C_M \rho V^2 A_p c}{2}$$

Equation 11: Aerodynamic Moment

The equations above show the [redacted] forces when understanding the flight of this drone. In the prototype a NACA 5012 airfoil was used, but the prototype was not intended to fly. These forces [redacted] be evaluated with an aerodynamic analysis on the drone when validating if it will fly based on the weight and speed. It is also [redacted] to do research into whether different wing angles are beneficial for different aerial maneuvers, but the group does not possess the resources for that yet.

Prototype

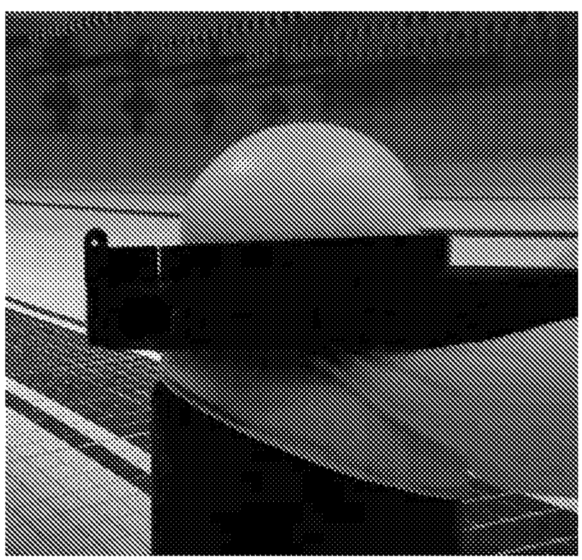

Figure 9: Pressurized canister prototype underwater test

Figure 10: Open canister prototype

The prototype of the canister launcher validates multiple system level [redacted], mainly the ability to house the drone (a scaled down mock up), and the ability to provide positive pressure in its enclosure that can help the drone reach the surface. The prototype is designed to be pumped with external pressure via an air pump until a seal breaks at a certain pressure. During testing of this prototype underwater (~1 m), the seal was being sheared around the lip of the canister leading to suboptimal max pressures. In conjunction with the seal breaking, air was leaving the system at the bottom fitting also leading to minimal max pressures. In a second prototype, this could be improved upon by changing the type of insert the seal has, therefore improving the interface between the canister and the surrounding environment (sea). Similarly, the original design for this prototype included a pneumatically powered linear actuator driven by the same input pressure. This idea was scrapped due to time constraints and simplicity of design during testing. In a second iteration of prototyping, much like the seal and bottom fitting, more emphasis on air and subsequently sea tightness would [redacted] to be considered.

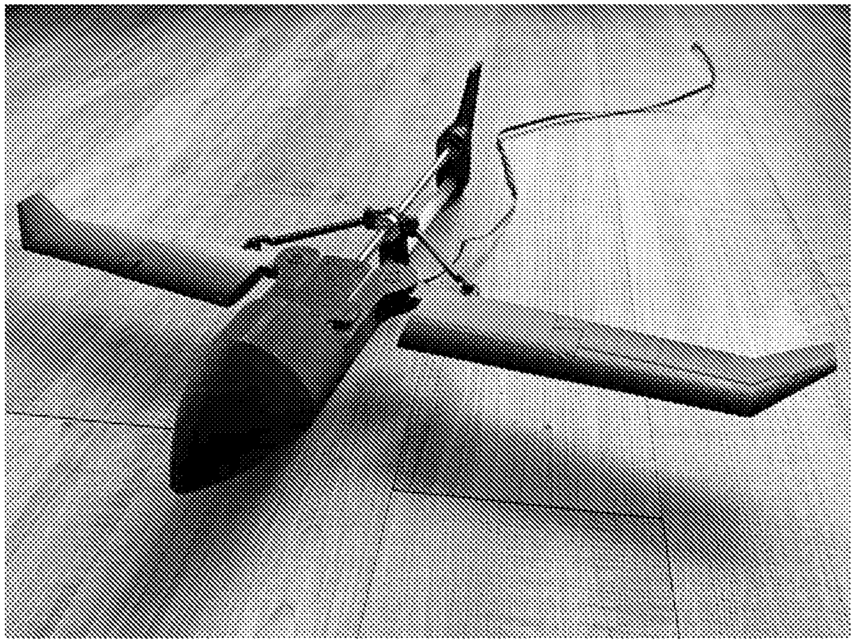

Figure 11: Open drone prototype

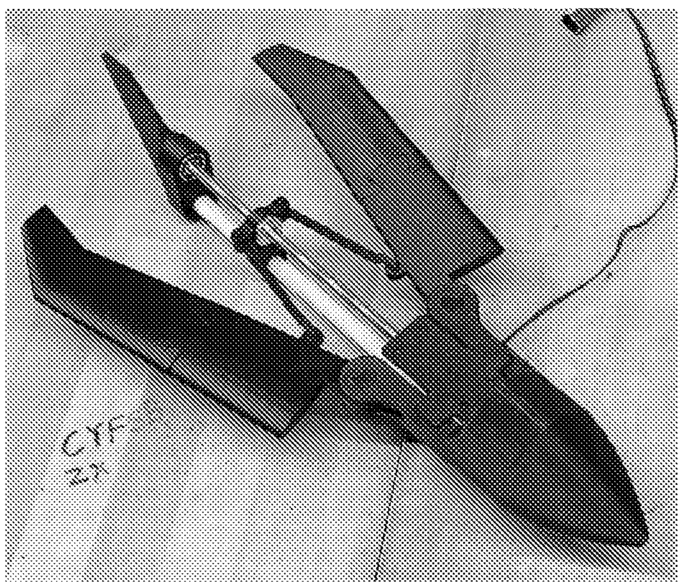

Figure 12: Folded drone prototype

The prototype for the drone validated multiple system level [redacted], including sensor response time, deploy time, and the foldability of the wings. This drone was programmed to start in the folded position and deploy once there was a signal.Upon removal of activation signal for 5 continuous seconds after full deployment, the drone folds up again. The reaction time from first receiving a signal to the motor receiving full power is measured with an oscilloscope, and this time is 11ms, well within an acceptable range.

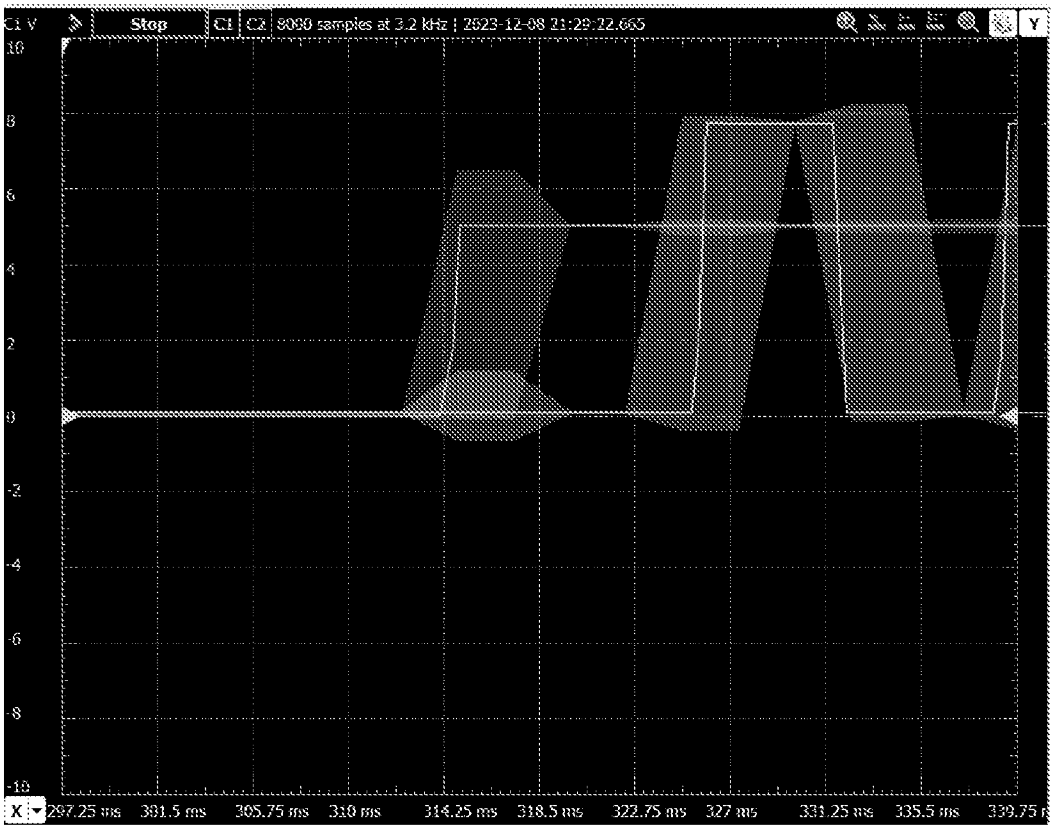

Figure 13: Measured refresh time

At a reasonable speed, this drone took 2.3 seconds to fully deploy the wings. At a larger scale this may slow down and a full FEA analysis will [redacted] to be performed once the body shape has been finalized. We also verified that this drone can reasonably fold from a 7.9 inch wingspan to 4.6 inch diameter, which is a 42% size reduction. This can be improved with thinner wings and a different actuator mechanism that allows for the wings to arrive at a parallel position when folded.

Finally, after coming up with a conceptual solution for a landing/recovery system, a prototype was designed and constructed. To do this, Neodymium magnets were used due to their strong magnetism, and a copper tube was purchased to allow for the electromagnetic damping force. Pictured below are the magnet and tube.

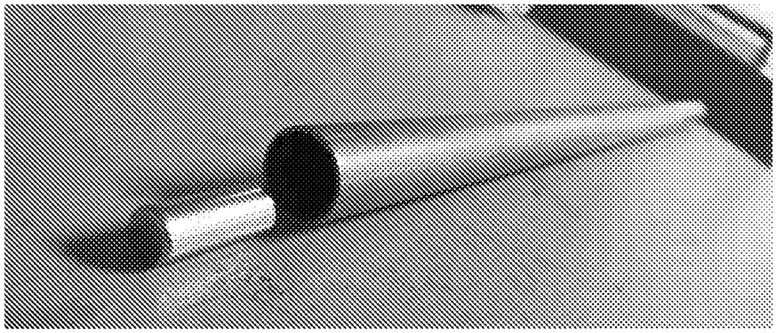

Figure 14: Landing gear prototype components

To more accurately model the full landing gear, a sort of landing skid, similar to the one intended to be on the drone was constructed, utilizing a magnet on each end to increase electromagnetic force.

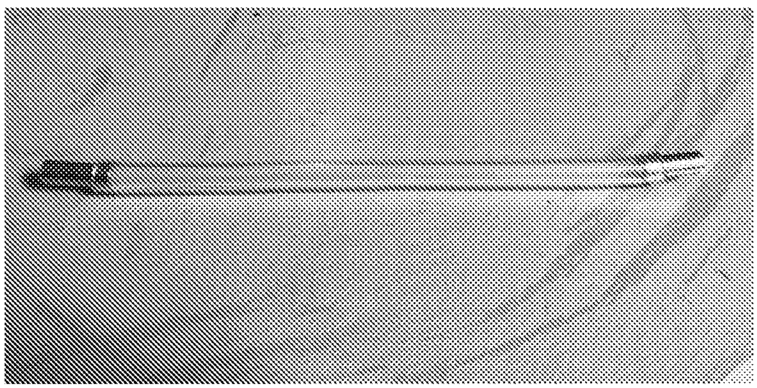

Figure 15: Drone landing skids.

Finally, shown below is a table of experimental results comparing the efficacy of various magnet configurations.

Magnets Config:	Avg. fall time, in seconds; less is better
0x (control)	~0.75s
1x	~3s
2x (attached)	~2s
3x (attached)	~1.5s
3x (separated, in rail design)	~4s*
2x (separated, in rail design)	~4s*

Table 8: Magnet config vs. falling time

It is worth noting that performance was practically identical in each case when referencing the rail design, however this comes with a caveat. In each case, the tubing used to create the rail had a significant amount of friction with the outside of the tube, defeating the point of the design. While the increased weight made the time to fall significantly worse, (smaller value, approaching the control value), this was not as easily evident due to the sides of the built rail getting caught in the tube. To that end, it is extremely [redacted] to ensure good tolerancing for use in real life, lest the system "self tolerance", or grind itself down until it behaves properly-something that definitely isn't desired in a product like ours.

Future Work

The next step in this project is to develop a higher quality launching mechanism and mathematically characterize the launching and landing. By understanding the forces at play in the launching and landing we will be able to develop a higher quality model that is closer to functioning. The next launching mechanism should have a waterproof drone that can be launched, even if at a small scale. Simulations and calculations of the frictionless landing mechanism should also be created to understand exactly how to manufacture the guide rails and what kind of slowing force is exerted on the drone. While frictionless landing improves performance, there is also still wear due to a fluctuating load.

[redacted]

[redacted]

Conclusion

In conclusion, the work done [redacted] has demonstrated that this project is very feasible. The mindful reflection and all the ideation tools have laid out exactly what [redacted] to be done to succeed with this project and the prototypes have verified the design. While it may take a while to complete all the future work, manufacturing of early prototypes can be done simultaneously which can cut down on time. This is definitely not a project that can be completed rapidly, as it [redacted] lots of prototyping and analysis, but with a strong understanding of the problem and existing technologies we have a solid understanding of how to go about doing it.

[redacted]

Appendix A:

<u>100 Questions:</u>

What does ADDRM stand for?

Advanced Drone Delivery and Recovery Method

1: Cost

1. How much does a prototype cost?
   a. A full-size prototype will cost hundreds of thousands of dollars. However, a proof of concept prototype should be possible with roughly $100-200.
2. How many prototypes [redacted] to be created to test all system level solutions?
   a. At least minimum 3 prototypes will largely test the broad system level solution but many are [redacted] before a working product is produced.
3. How much does it cost to integrate this solution into existing technology?
   a. This will cost tens of thousands to retrofit into existing submarines
4. What will be the impact of the solution on the current market?
   a. The development will change a shift in technology, and reduce dependence on aircraft carriers
5. What is the cost of maintaining this solution?
   a. Tens of thousands per year for the launcher, and tens-hundreds for the drone. Although, this is significantly lower than other alternatives
6. What is the cost of updating this solution as new technologies emerge?
   a. Improving technology will likely take hundreds of millions of dollars
7. What is the most costly system level solution?
   a. Developing a drone that can fold, while still maintaining capability is the most [redacted] aspect (<2.5M diameter in launcher)
8. Can testing certain system level solutions be combined to reduce cost?
   a. No, this cannot be done.
9. How much does it cost if a system fails?
   a. The drone will most likely cost millions, which will all be lost if a system fails and it crashes.
10. What is the cost of prototyping within the scope of this class?
    a. The prototypes should cost less than a couple hundred dollars.

2: Knowledge

1. How much does our group already know about the project?
   a. Our group knows roughly half of what is [redacted] to complete the project.
2. What is left to learn?
   a. The group [redacted] learn more through patent research, and hydraulics research.
3. How much experience does our group have in this field?
   a. Our group has above average experience, as one member has worked in a submarine manufacturing company.
4. Do we have access to industry professionals?
   a. Yes, professionals from Electric Boat can be accessed if [redacted].
5. At what stage in the process are industry professionals [redacted] to critique the design?

   a. Near the end of the semester/after a full concept is created & proof of concept demonstrated, it can be critiqued by professionals.
6. What are the system level [redacted] to stop the iterative design?
   a. Seen in product specifications.
7. At what stage in the prototype is our group's knowledge limit met?
   a. We will not get to that stage in this class, if this were a full time project, we would learn as we worked, but having industry professionals would be [redacted] in ensuring that the design isn't flawed in any way.
8. What are the different levels of industry professionals that are [redacted]?
   a. Everyone from submarine engineers to submarine pilots are [redacted] in this project.

3: AI Integration
1. What system level solutions are controlled by AI?
   a. Landing mechanism, UAV sensor control, and launch controls are all done by AI
2. What are the current limitations of AI?
   a. AI will [redacted] to be extensively taught about different, niche failure modes before it can be effective.
3. How will future changes in AI affect this project?
   a. Faster learning AI can be used to learn from situations more quickly
4. Will AI be beneficial to implement, or is it more risky than it is worth?
   a. For prototyping, it is not worth developing AI
5. How quickly will our technology become outdated?
   a. Technology will likely be replaced within 1-2 decades
6. Is there a benefit to user control over ai control?
   a. In the future AI will be able to make objectively better decisions because it will understand the complex statistics behind every problem.
7. Will the AI be able to make decisions on its own without human acceptance?
   a. In the future, AI will be able to make better decisions than humans, and therefore a point will be reached where the AI will be able to send commands on its own.
8. How will the drone function if the AI isn't working?
   a. This drone [redacted] AI for the precise launching and landing mechanisms, and therefore it will not work if AI is not working.

4: Safety
1. What will happen to users of the product if it fails?
   a. No one should be harmed, as it is operated with no users inside
2. What system level solutions are most likely to fail?
   a. Corrosion and cracking will likely cause our product to fail lifespan [redacted]
3. What is an acceptable factor of safety?
   a. 3.0 is a minimum factor of safety
4. How can errors be mitigated?
   a. This can be seen in FMEA
5. How regularly should our device be inspected?
   a. Inspection should occur based on first percentile failure in simulation
6. What procedures should be written regarding safe operation?

    a. List of all inspection criteria and operation steps, as well as a list of potential failure causes/mitigations should be written
7. Are there any errors that are low probability but high impact?
    a. Yes: Seen in FMEA
8. Are there any errors that are high probability but low impact?
    a. Not really: Seen in FMEA
9. Will our system function under fire/attack?
    a. This will depend on future simulations, however this is unlikely
10. What safety features mitigate damage due to explosives/attack?
    a. None are included yet, but this would [redacted] of structural design improvements/increasing factor of safety

5: Competitors
1. Do any current solutions to this problem exist?
    a. No
2. [redacted]
3. Who is currently making a solution to this problem?
    a. No one is creating a solution that meets all of our problems
4. Can this be patented?
    a. Yes
5. If patented, what competing solutions can still be created?
    a. This depends on how direct patent claims are. Likely, similar designs could be created, with slightly differing claims.
6. How much man-time is [redacted] to produce 1 device?
    a. This is unknown, but can be determined as design for manufacturing is further considered. Likely, around 250 hours
7. How much robotics/machine time is [redacted] to produce 1 device?
    a. Currently unknown, similarly can be tested in simulations in MasterCAM for CNC tooling time.
8. Is it possible that other companies develop this before we do?
    a. At this time no other company is doing work on this system and therefore it is unlikely that someone will reach a solution before we do.
9. Is it beneficial to team up with the biggest competitor?
    a. Currently there is no top runner in terms of competitors and therefore it is not beneficial to combine resources at this point.

7: Surveillance
1. Can the system be shrouded to prevent detection?
    a. Yes, although specific technology research will be [redacted] to determine if implementation is feasible.
2. Will sensor systems increase detectability?
    a. Balance will have to be struck between outgoing signal strength, stealth technology, and information gain
3. Does this solution [redacted] to be protected from other countries?

    a. Yes, this is dangerous technology that can be abused in the wrong hands.
4. How many sensors will be included on the drone?
    a. Because the drone is unmanned, it will [redacted] a multitude of sensors to ensure that it can accurately launch and land.
5. What is the most [redacted] sensor on the drone?
    a. No single sensor is most [redacted] because all [redacted] to be used in tangent to give the drone the information it [redacted] to understand its position, velocity, acceleration, and surroundings.
6. What happens when a sensor fails?
    a. Redundant sensors will be built into the drone to ensure that if one sensor breaks there is still a working sensor.
7. What is the primary surveillance mechanism of the drone?
    a. This drone will primarily intercept radio waves while taking high quality photos and videos using both regular, infrared, and thermal imaging.
8. What will the drone do if it is compromised (unplanned retrieval)?
    a. Blow itself up

6: Manufacturability

1. What considerations will be included for manufacturability
    a. Standardize components to minimize the amount included in assembly/possibility for improper installation
2. At what stage in the prototyping process do manufacturers [redacted] to be contacted?
3. Does this product [redacted] non-standard manufacturing methods?
    a. No
9. What materials will be used?
    a. Titanium, Aluminum, Steel, etc.
10. How much does this weigh?
    a. Expected weight of >1ton for module, and <1 ton for drone
11. What manufacturing processes will be utilized?
    a. CNC, Welding, Metal forming, Robotic Assembly, Injection molding
12. What rapid prototyping technology can be used to create a representative sample?
    a. 3d printing, waterjet, CNC and metalforming can be utilized
13. What types of interfaces will the solution [redacted] as a whole?
    a. A strong hatch, and interactions between hull and
14. Can the design rights be sold to an existing manufacturer?
    a. Yes, this is patentable and licensable.
15. How much raw material is [redacted] to produce the device?
    a. This is dependent on final design size. Likely, material will weigh >1 ton
16. Where will materials be sourced?
    a. The materials will be sourced from companies that are trusted to produce military grade materials.
17. Will supply chain cause issues with scaling up production?
    a. The supply chain will not cause issues with scaling because it will be scaled up by the military or large defense contractors that already have existing scaling models.

18. How much will raw material cost?
    a. Budget estimates can be found from metal manufacturers, and prototyping values can be seen on McMaster Carr
19. What level of security is [redacted] to manufacture this device?
    a. Secret Clearance
20. What level of security will be [redacted] to prototype this solution?
    a. Top Secret Clearance
21. What machinery is [redacted] to build a full device?
    a. CNC, Welding, Metal forming, Robotic Assembly, Injection molding
22. What level of precision is [redacted] within the parts?
    a. The parts will [redacted] to be manufactured with the tightest possible tolerances to work properly.
23. Do the manufacturers [redacted] to reach a tighter tolerance with this project in comparison to standard projects?
    a. Yes, the manufacturers [redacted] to work as efficiently as possible to produce the finest results.
24. How many different manufacturers will [redacted] to be contacted to produce one final product?
    a. With all the complicated system level specifications, there are many manufacturers [redacted].

8: [redacted]

1. Who [redacted] this solution?
    a. Military & navy, along with any intelligence/analytical organizations can use this product
2. Why is this solution [redacted]?
    a. Alternatives of aircraft carriers are too expensive/easily detectable prior to drone launch
3. What are companies willing to pay for this product?
    a. Companies will pay a lot to license this design, but most money will come from the military.
4. Does the price make up the cost of creating this solution?
    a. Yes, this will greatly improve submarine missions which the military will pay lots for
5. How much are potential purchasers willing to pay?
    a. Roughly 10 million per module is acceptable
6. How many modules will be sold per year?
    a. 3-4 modules per year
7. How long could this product extend naval operations?
    a. Theoretically infinite but due to crew moral +2 months
8. Could this solution be improved to transport humans?
    a. At this point there is no way to transport humans as the launching system is rough and untested.

9: Engineering

1. How will this device be deployed?
    a. Utilizing a method similar to Multiple All Up Round Canister
2. What depth can this device withstand underwater?
    a. 10,000m
3. How large will canister be
    a. Under 2.5m diameter
4. How many sensors will be included on the drone?
    a. At least 100, but this will vary based on specific end user [redacted]
5. How many miles will drone be able to travel?
    a. 1000 miles round-trip will be the minimum specification
6. How deep will submarines with this module be able to go?
    a. At least 10km
7. How much hydraulic force will it take to open the hatch?
    a. At least 10 Newtons
8. How large will the battery in the drone [redacted] to be?
    a. Minimum of 5000 amp hours
9. How long will the recovery system be?
    a. No longer than 50 meters, so it can fit on existing submarines
10. What is the maximum force a drone will experience in launch/recovery
    a. Roughly 100kN of force during landing, slightly higher for launch
11. How much pressure will the launch canister be able to withstand
    a. Minimum of 100 atmospheres of pressure
12. How long will it take drone to orient in adverse conditions
    a. No more than 1 second
13. What is the minimum component lifespan?
    a. 1000 launches to failure
14. What equation models the recovery system?
    a. Mod-Con values for settling time, overshoot, and frequency will model it
15. What equations will model the launching system?
    a. Bernoulli's extended equation can be used to model it
16. What is the maximum drone weight?
    a. Under 1000 lbs
17. What is the maximum drone payload?
    a. Under 200 lbs
18. How long will the overall launching process take?
    a. 10s<
19. How will the drone travel without cavitation?
    a. Manufacturing practices combined with top secret material properties.
20. What are the surface conditions that the Drone can launch without failure?
    a. Waves with max height of 2m with period of 3s
21. How will you be able to open the launcher hatch?
    a. Flood the cavity with water and use hydraulics to open hatch

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
www.uspto.gov

ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
63/611,870	**12/19/2023 12:33:51 PM Z ET**	**104916-100**

Title of Invention

ADVANCED DRONE DELIVERY AND RECOVERY METHOD

Application Information

APPLICATION TYPE	Utility - Provisional Application under 35 USC 111(b)	PATENT #	-
CONFIRMATION #	9683	FILED BY	Liza Blair
PATENT CENTER #	63668137	FILING DATE	-
CUSTOMER #	140282	FIRST NAMED INVENTOR	Ian Gannon
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	Stephen Kulhanek

Documents

TOTAL DOCUMENTS: 3

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
104916_100_ProvisionalSB.pdf	4	Provisional Cover Sheet (SB16)	2561 KB
104916_100_Transmittal_Letter.pdf	1	Transmittal of New Application	85 KB
104916_100_Detailed_Description.pdf	24	Specification	830 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)

104916_100_ProvisionalSB.pdf	8D95365FD557ACB9B07DC5F4D280C190F1A9043E3670E75A03BFAD8E1A7ECCF284E485C0C2102B885ECD3D938C9AEDA85CEF39170088DACE248E27B5D0F69C7B
104916_100_Transmittal_Letter.pdf	DE74A83419F0BCB45DF3E5585FEEFA15A2639A83D47221DF61715C59B16A607CA901B1CA08919F76CF2D4165EDC579FF6FACD6313FEB196B630BD486EC2E70A6
104916_100_Detailed_Description.pdf	51A63508A1D2F1FED63B0FA15E5823150F2D02DB5789E767488CAF82B4E8193E45E94F8DA7F041A4FD7F155AF7F4E8917AA741E3047C2808458A84415D4425C4

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
www.uspto.gov

ELECTRONIC PAYMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
63/611,870	12/19/2023 12:33:51 PM Z ET	104916-100

Title of Invention

ADVANCED DRONE DELIVERY AND RECOVERY METHOD

Application Information

APPLICATION TYPE	Utility - Provisional Application under 35 USC 111(b)	PATENT #	-
CONFIRMATION #	9683	FILED BY	Liza Blair
PATENT CENTER #	63668137	AUTHORIZED BY	Stephen Kulhanek
CUSTOMER #	140282	FILING DATE	-
CORRESPONDENCE ADDRESS	-	FIRST NAMED INVENTOR	Ian Gannon

Payment Information

PAYMENT METHOD	PAYMENT TRANSACTION ID	PAYMENT AUTHORIZED BY
CARD / 1044	E2023BIC35078025	Liza Blair

PRE-AUTHORIZED ACCOUNT

081388

PRE-AUTHORIZED CATEGORY

37 CFR 1.16 (National application filing, search, and examination fees); 37 CFR 1.17 (Patent application and reexamination processing fees); 37 CFR 1.19 (Document supply fees); 37 CFR 1.20 (Post Issuance fees); 37 CFR 1.21 (Miscellaneous fees and charges)

FEE CODE	DESCRIPTION	ITEM PRICE($)	QUANTITY	ITEM TOTAL($)
2005	PROVISIONAL APPLICATION FILING FEE	120.00	1	120.00
			TOTAL AMOUNT:	$120.00

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.