Development Of A Tag Release Mechanism For Soft-Bodied Invertebrates

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ABSTRACT

Despite their prevalence since the Cambrian period, jellyfish in the world's oceans are understudied. Previous studies used a variety of methods including: scuba, sampling, echo-sounders, etc. However, these forms of study are unable to provide information that informs researchers about the daily lives of jellyfish, vital to understanding a species. Contrarily, tagging devices can provide researchers with this information. However, one major challenge faced with jellyfish tags is a reliable release mechanism that allows for retrieval of the tag after a set period for data collection. Previous experiments utilized various methods ranging from a cable-tie technique to tethering the device to the jellyfish. These methods are limited to more controlled environments. Successful deployments of tags with release mechanisms have been limited to jellies with large crowns due to the size of tagging electronics. One such example is the iTAG, a device developed for deployment on jellyfish and also for squid. This paper will describe the development of a galvanic release mechanism that can implemented into the design of the iTAG. The implementation of a galvanic release mechanism will become a more viable option when tagging Medusozoa in comparison to past techniques. The research conducted on galvanic release mechanisms explained here will be vital for not only further development of the iTAG, but further development of any marine animal tagging device that requires the retrieval of the tag for data analysis.

INTRODUCTION

Gelatinous animals such as jellyfish are prevalent across all oceans. Fossilized records have shown that jellyfish have been present on Earth since about 500 million years ago, making them the oldest known multi-organ animal group (Cartwright *et al.* 2007). They have often been cited as providing a link between smaller prey such as plankton or fish eggs, and larger predators such as sea turtles or in some cases, other larger jellyfish(Pauly *et al.* 2008). Jellyfish can be considered detrimental to the health of a marine ecosystem (Doyle *et al.* 2014). However, they are also capable of causing large amounts of damage due to the fact that they eat fish eggs and in some cases, juvenile fish, they can cause damage to fisheries worldwide (Hays *et al.* 2012). Estimated costs of regional damage associated with jellyfish outbreaks can reach up to hundreds of millions of dollars (Kim *et al.* 2012). Although some studies have argued for increasing observations of jellyfish blooms around the world (Brotz *et al.* 2012), other studies conflict with this information, stating that jellyfish go through periodic rises and falls in population (Condon *et al.* 2013). Regardless, understanding more about jellyfish is vital to not only understanding marine health, but also understanding how they play a role on fisheries worldwide.

Most studies conducted on jellyfish in the past used traditional methods such as sampling, scuba, and submersibles (Hamner *et al*., 1975; Madin, 1988; Costello *et al*., 1998). Although these methods of gathering information are efficient and still used for various marine species studies today, it is limited in the information it can provide. Using echo sounders, more long term data could be collected for longer periods of time (Lynam *et al.* 2006). This did allow for more data collection of jellyfish, however it is limited in which jellyfish can actually be noticed. Since jellyfish are soft bodied invertebrates, it is difficult to notice smaller species of jellyfish using an echo sounder. Jellyfish tagging, although nothing new, is a more promising method of comprehension into the daily lives and movements of jellyfish.

Having a better understanding about the daily behaviors of jellyfish gives a glimpse into how they are able to interact with their environment, and how and when they switch between different swimming behaviors. In order to get a glimpse of the daily behaviors of marine animals, motion tracking tags are commonly used. Motion tracking tags not only track animal acceleration, magnetometer, and gyroscope (or 9 axes of motion), but also the temperature and pressure (or depth) changes that the animal might be experiencing. Although the development of a device that can log this information is available, developing a smaller logger that can be ideal for jellyfish is challenging.

Lack of deployments of data logging devices on jellyfish can be explained by the difficulty of trying to affix a device to such small and gelatinous creatures. However, a comprehensive guide has been developed to demonstrate the variety of methods when trying to attach a device to a jellyfish (Fossette *et al.* 2015). Jellyfish are easily affected by buoyancy, and it was found that a tag that is less than 0.1% of the jellies wet weight in air is ideal for minimal interference (Fossette *et al.* 2015). These findings illustrate the challenge in creating a small enough device that can eventually be retrieved from a jellyfish in order to analyze the data. To overcome some of the challenges associated with tag retrieval, researchers have used a method known as tethering(Bastion *et al.* 2011; Hays *et al.* 2012; Fossette *et al.* 2015). Tethering allows for tests where a monofilament line is attached to both a float and a tagging device affixed to an animal, allowing the jellyfish to swim freely and allowing for easy retrieval of the device. By attaching the monofilament line to a float, researchers can keep track of the location of the jellyfish at all times. Although this method, when implemented correctly, is able to give information about some swimming behaviors, jellies are often constrained to remain alongside floats and potentially altering their behavior. By developing a release mechanism for tag retrieval, in situ studies of jellyfish tagging can remove the impact that tethering may have on jellyfish behavior.

Galvanic release mechanisms have previously been implemented in an earlier version of the iTAG (Mooney *et al.* 2015). However, a cumbersome package, long release time (on the order of hours), and difficulty in keeping the device attached to the jellyfish limited the functionality of the device. The current version of the iTAG (v0.4), uses a galvanic release mechanism similar to the previous version. A galvanic release mechanism uses the process of galvanic corrosion in order to corrode a wire. Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially when in electrical contact with another, through the presence of an electrolyte. Galvanic corrosion happens naturally, however by connecting the two dissimilar metals with an external voltage source, the speed of the process can be drastically increased. Here the paper will provide a description of the process to integrate a galvanic release mechanism on a newer, smaller version of the iTAG (v0.4) for future deployment on jellyfish.

METHODS

A new iTAG electronics package was recently developed by Loggerhead Instruments that is more compact and lightweight in comparison to the previous design. The previous iTAG v0.1 measured: 108.4 mm × 64.0 mm × 28.7 mm, while the iTAG v0.4 measures: 63mm x 36mm x 11mm (Fig A). With this more compact design, it gives the freedom to create a release mechanism. Specifically for the iTAG, a galvanic release mechanism is incorporated into the electronics package using a FET (field effect transistor). Using a built in clock, a pre-configured time can be set before deployment to activate the FET. With this built in release mechanism, more information about what factors can either increase or decrease release time upon activation were important for the project. Upon activation of the iTAG release mechanism, a switch activates two pins on the circuit board, labeled BAT+ and BURN (Fig. 1). These pins can be used to initiate a galvanic corrosion mechanism allowing for the release of the tag from the animal. One or more wires can be connected to the anode and configured such that corrosion of these wires release the electronics package from a base plate affixed to the animal. Another wire connects the cathode (BURN) to a piece of metal with a higher cathodic quality. Since the wire connected to BAT+ will corrode away due to the presence of the cathodic metal, it is important to understand more about which factors can cause either an increase or decrease in corrosion times.

To test these variables in a controlled environment, several corrosion tests were performed in a beaker filled with seawater (Fig. 2). Single strand 30 gauge nickel wire was used. The first variable tested was exposed wire length in order to determine how this affected corrosion time. A copper plated material was suspended in the water to serve as the cathodic surface, completing a circuit from the anode exposed wire, through the sea water, to the cathodic surface. Using a DC power supply, a constant voltage of 2.5 V was applied across the electrodes, and the current through the wire was monitored. This test setup allowed different variables to be tested while also ensuring that accurate measurements of the current and time were measured before release. Factors that were tested include: stripped wire length, wire tension (weight attached to the end), water temperature, surface area of the cathode exposed to the water, and corrosion times when testing using two wires. Throughout the experiment, the following factors were maintained constant: the copper cathode used, 30 gauge (24-25 micron diameter) Nickel wire, and 2.5V as the voltage supplied through the circuit.

HDPE (high-density polyethylene), a positively buoyant material, was used and machined to sizes that mimic the already podded iTAG. The final design used two pieces with each piece having the dimensions: 64mm x 12mm x 30mm. In order to combat the difference in release times when using two corroding wires as a connection between the electronics package and baseplate, compression springs were implemented(Fig. 3). The springs provide enough force to separate and essentially break apart the already corroding wires. Once assembled correctly, the package with springs sits compact (Fig. 4A). Screws were implemented, allowing the wire to be tucked underneath the screw and washer, remaining taut throughout their corrosion (Fig. 4B). Connecting directly to the iTAG (Fig. 6) allowed not only testing the prototype using the actual release mechanism built into it, but also to see that this is a viable method. Successful deployments have been done using this prototype design, showing that it can be implemented.

RESULTS

The final product of this project is a better understanding of galvanic corrosion and demonstrating how this release mechanism works. This began by first understanding each varying factor that had to be tested in order to determine which were more detrimental to the release time. Beginning with the exposed wire length was important as it gave a better understanding as to what sized strip length would be optimal before testing other factors. It was found that a larger strip of exposed wire lead to an increase of current flowing through the circuit (Fig 7B). Wires of exposed length (≤5mm) had an average max current of 4.2 ± 2.5 mA, whereas wires of exposed length greater than 5mm had an average max current of 25.7 mA. Through the tests, it was found that having a small strip length (≤5mm) is the viable option, since it will corrode efficiently and have less current draw, regardless of which other variables were tested (Fig. 7A). With this information understood, then began the process of understanding how important of a role the area of cathodic metal used affects corrosion time. Using a relatively small piece of copper (area 185.42 mm^2) with an exposed strip of wire (length 3mm), quick corrosion time was still possible regardless of other variables tested (Fig. 7C), with an average corrosion time of 567.6 ± 87.8 seconds. Looking at the overall corrosion time of all the tests conducted, regardless of the variables changed, an average of 527.4 ± 92.6 seconds was calculated.

Further tests were conducted using the release mechanism, however it was connected to an external power source and not directly to the iTAG as showcased (Fig. 6), Due to time constraints of the summer project, only one test was conducted using the iTAG as a power source for the release mechanism. Although, it did demonstrate a successful release, the time for separation was 19 minutes and 12 seconds (Fig. 8). At minute 1 is where we can see the activation of the switch, allowing for the voltage to power the release mechanism. Interestingly, at minute 4, we see a sharp decrease to around 1.8V.

DISCUSSION

Looking at the results for tests of corrosion wires, it was apparent that many of these factors have some small influence over corrosion time, but none of them stood out enough that they were detrimental to having a relatively quick release time. Interestingly enough was the fact that regardless of which factors were changed, generally the range of separation time was within 430~620 seconds.

(Fig. 7) Showcases how even when testing different wire lengths, using a larger wire length did not correlate with a more rapid corrosion time. This is likely due to the fact that although the wire did corrode faster and produce more current through the circuit, separation was always achieved at one point of the wire. Even though current through the circuit is directly influenced by the length of the anode, (Fig 7B) it was inefficient to be using a large strip of exposed wire. Unexpectedly discovered from the results, using a smaller area of copper (185.42 mm^2) in comparison to a larger area (4652 mm^2), separation was well within the same range of time. Likely after a certain size (<185.42 mm^2), the size of the cathode will no longer have additional effect on the corrosion time of a 3mm strip of wire. Further tests could be done using smaller sizes of copper (<100mm^2) in order to determine what is the minimal size that can still have successful release within the range of 527.4 ± 92.6 seconds. This shows that using these materials is a good starting point. Should release time need to reduced, then the material of the anode itself could be changed to something that is more cathodic in the galvanic index. Alongside that, the gauge of the wire could be reduced in order to allow for a more swift separation, although this likely would also require springs that have a different rate.

Overall, a key factor that likely played a more important role in the release time of the wire was the tautness of the wire. Although some tests were conducted using two or three times the normal weight, further tests could be conducted using more weight on the wire, ensuring that the wire is as taut as possible while in the seawater. When using the prototype, the screws allowed for the wires to remain taut, likely this explains why the preliminary tests of the release mechanism had such rapid release times. However, as stated previously, further tests would need to be conducted in order to see if this had a large influence.

Another factor that would need to be further tested would be the battery life of the iTAG upon activation of the switch. Looking at the voltage supplied by the iTAG during one of the tests (Fig. 8), we see a sharp decrease in the voltage around 4 minutes. It can be see that when using the iTAG not connected to the release mechanism (Fig. 9), that the switch activates and remained at near constant voltage of around 4 volts for 19 minutes. Upon speculation, the likely reason for the sharp decrease in the voltage supplied by the iTAG is due to it not being fully charged. Further tests would need to be done in order to determine if this was due to the battery not being fully charged,the wire corrosion, or some other factor.

CONCLUSIONS

Although this demonstrates that a release mechanism can be implemented, much more work must be done to the overall design in order to ensure an optimal package(Fig 5). The design our ideal model allows for the package to sit compact similar to the prototype. In order to ensure that our wires remain taut,precise wire measurements would be needed and podding of the wire would be essential. The ideal model would also include springs similar to the prototype. Foam allows for the electronics package to float up, while the base plate & springs would remain affixed to the animal upon separation. The most important change in the idealized model would be the material used that withholds the iTAG. Since the springs were selected based on their size for the release mechanism, smaller springs would likely need to be implemented if they are unable to be incorporated into the ideal model. The two main improvements that would need to be made to the materials is based upon the electronics package housing and the base plate that would remain affixed to the animal.The electronics package housing would need to be a material that is more lightweight and compact in comparison to the prototype while also being neutrally buoyant / slightly buoyant in order to ensure it floats to the surface upon release. In order to ensure near neutral buoyancy when attached to the jellyfish, a negatively buoyant material would need to be used for the base plate. In order to retrieve the data from the iTAG, a VHF antenna would need to be implemented (either internally using the iTAG battery, or externally) in the design. However, a change in the mechanical design would be necessary when implementing a VHF. The need to have the device sitting parallel to the bell of the jellyfish when attached is important for taking accurate data and having minimal interference (Fossette *et al.* 2015).

However, upon release, the electronics package would need to float perpendicular to the bell, allowing for the VHF antenna to be out of water. This allows for it to send a signal that could be located using either a ship, or upon further development, a wave glider (Masmitja 2018).

Although there is much more development work before this device can be tested in a controlled environment on a jellyfish, this shows a step forward in the development of a reliable release mechanism for the iTAG. Implementing these tags on jellyfish will not only give more information about their horizontal and vertical movements, but also more about their daily lives. Further developments will allow for longer periods of data logging, increasing the possibility of understanding the behavioral cues that may lead to blooms and understanding even more about about the daily lives of jellyfish. This information is vital to understanding any species. Having this information about jellyfish will not only lead to a better understanding about jellyfish, but a better understanding of their impacts on marine ecosystems and the role that they play in our oceans across the world.

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Tables and Figures

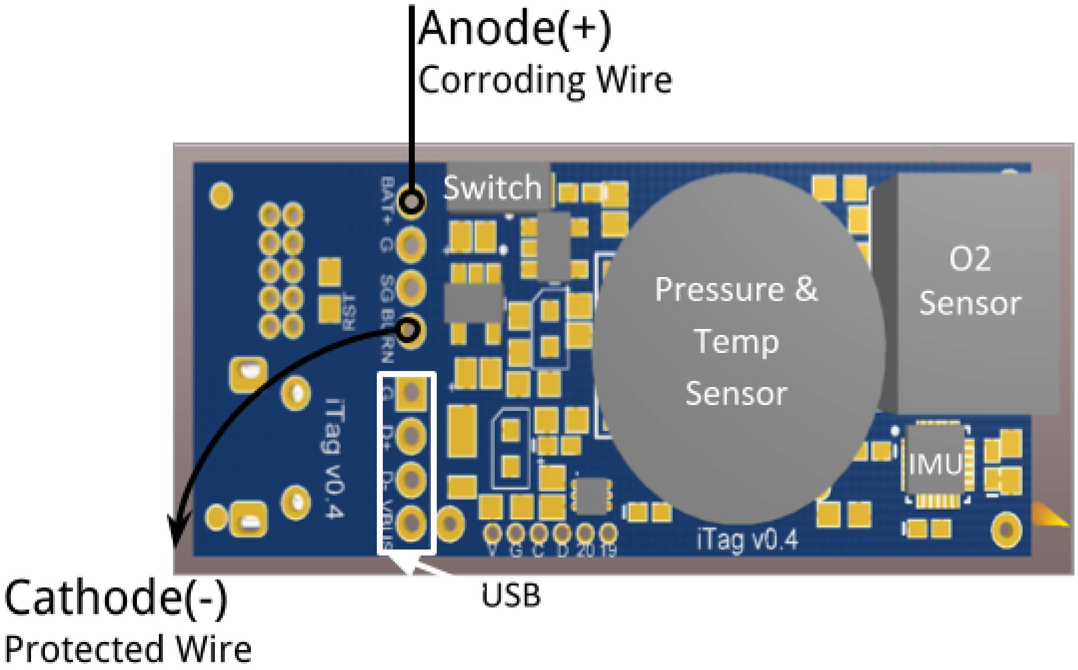

Fig. 1: Layout design of the iTAG (courtesy of Loggerhead Instruments). The labeled BAT+ and BURN. The positive corroding wire is connected to [BAT+], while the negative corroding wire/post will be connected to [BURN].

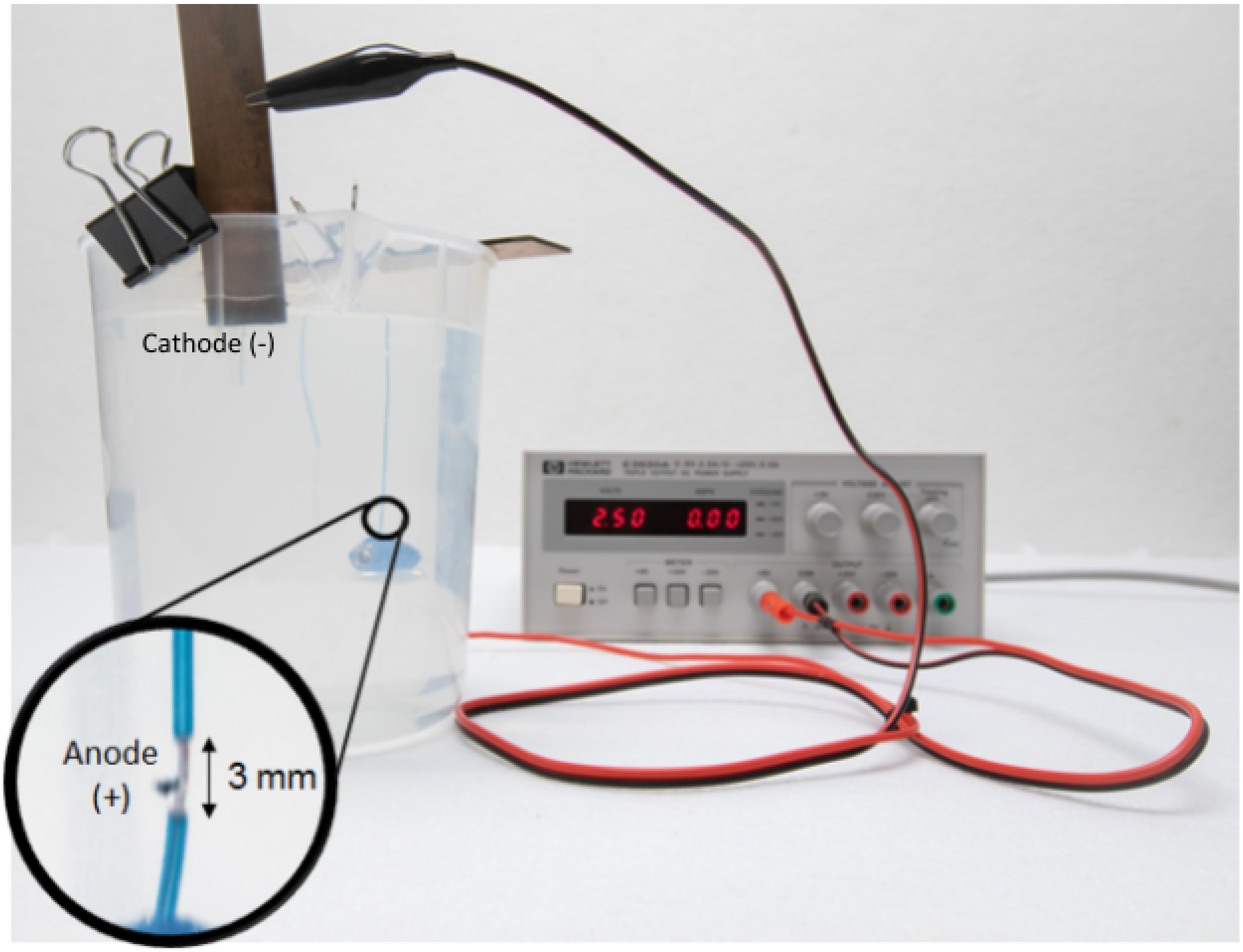

Fig. 2: Example of the galvanic corrosion test setup.. The cathode is a piece of copper hooked up to the negative terminal while the 30 gauge Nickel wire serves as the anode. The small 3 mm of exposed wire serves as the corrosion surface.

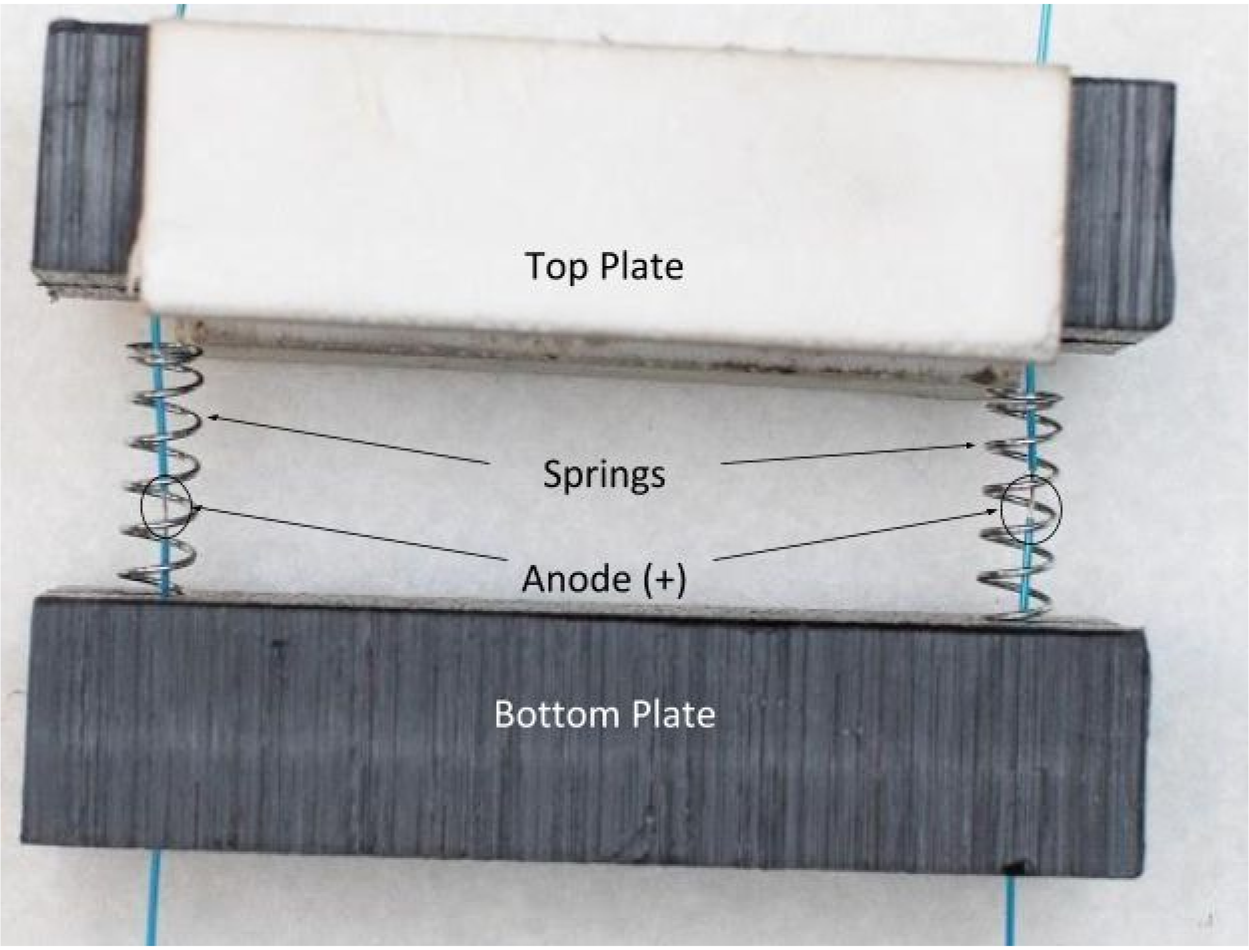

Fig. 3: Side view of the prototype assembly (opened). Top plate serves to mimic the electronics package with syntactic foam allowing it to float to the surface. Bottom plate when tested has a weight attached to it to simulate being negatively buoyant.

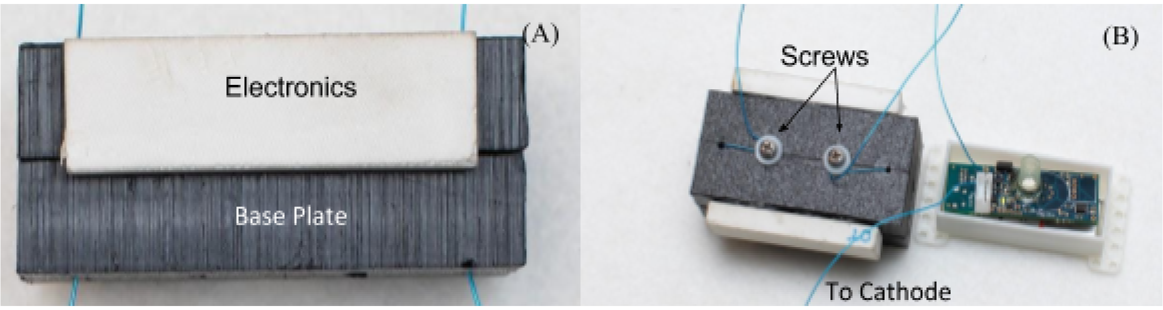

Fig. 4: (A) Side view of the release mechanism when closed and compacted. Inside is the springs and the anode stripped wires. (B) Top view of the release mechanism connected to the iTAG board. The screws serve to keep tautness of the wires.

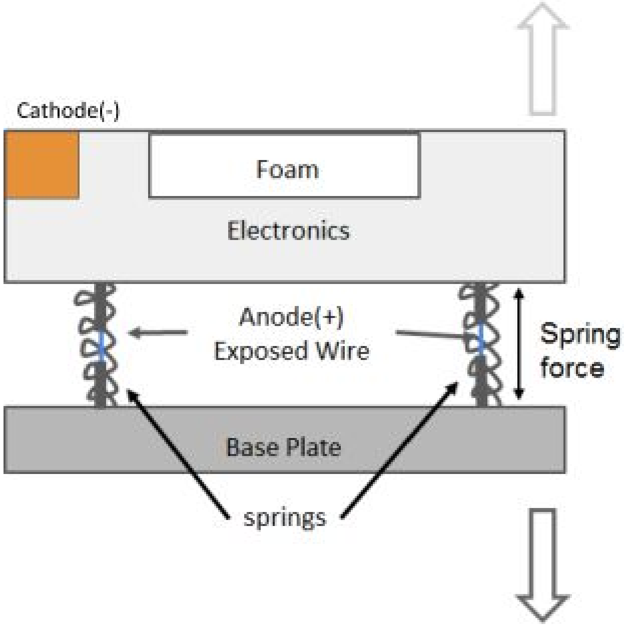

Fig. 5: Side view of the idealized model (open). The cathode would be exposed in salt water, allowing for the circuit to be completed.

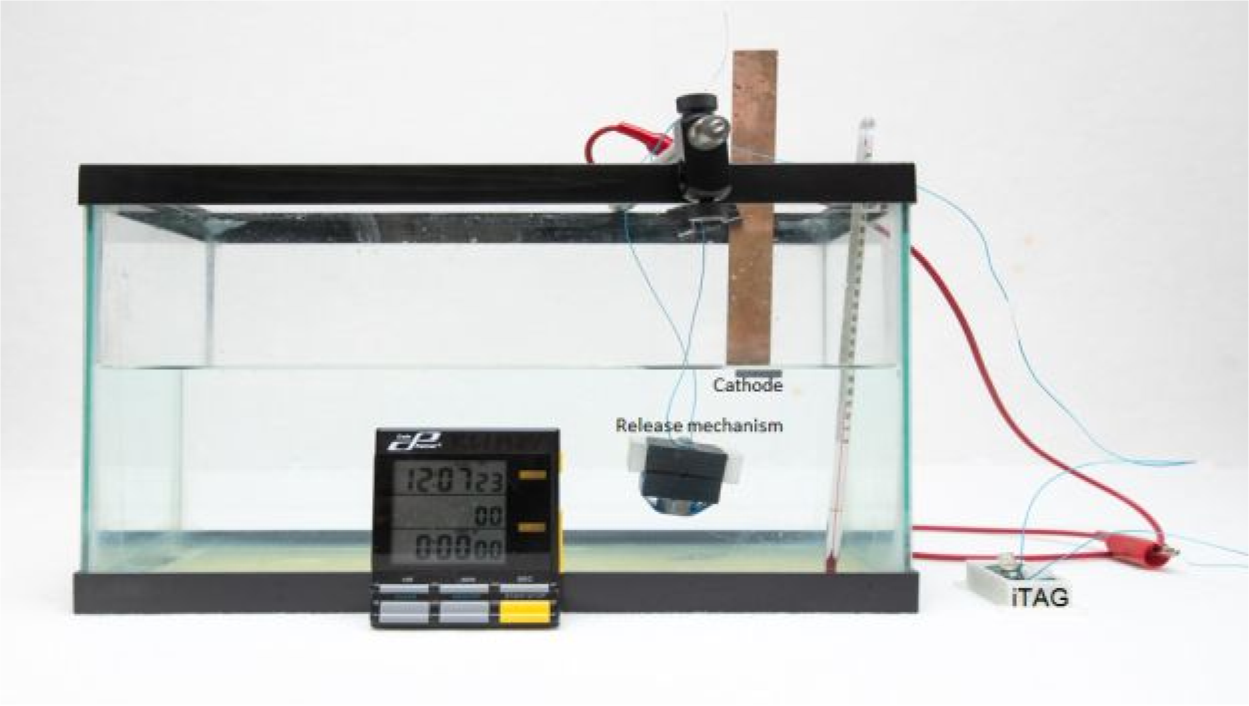

Fig 6: Shows the release mechanism setup. Connected directly to the iTAG, it can be pre programmed to a specific time for the release mechanism to activate. A multimeter(not pictured) shows the change in voltage once the switch is activated.

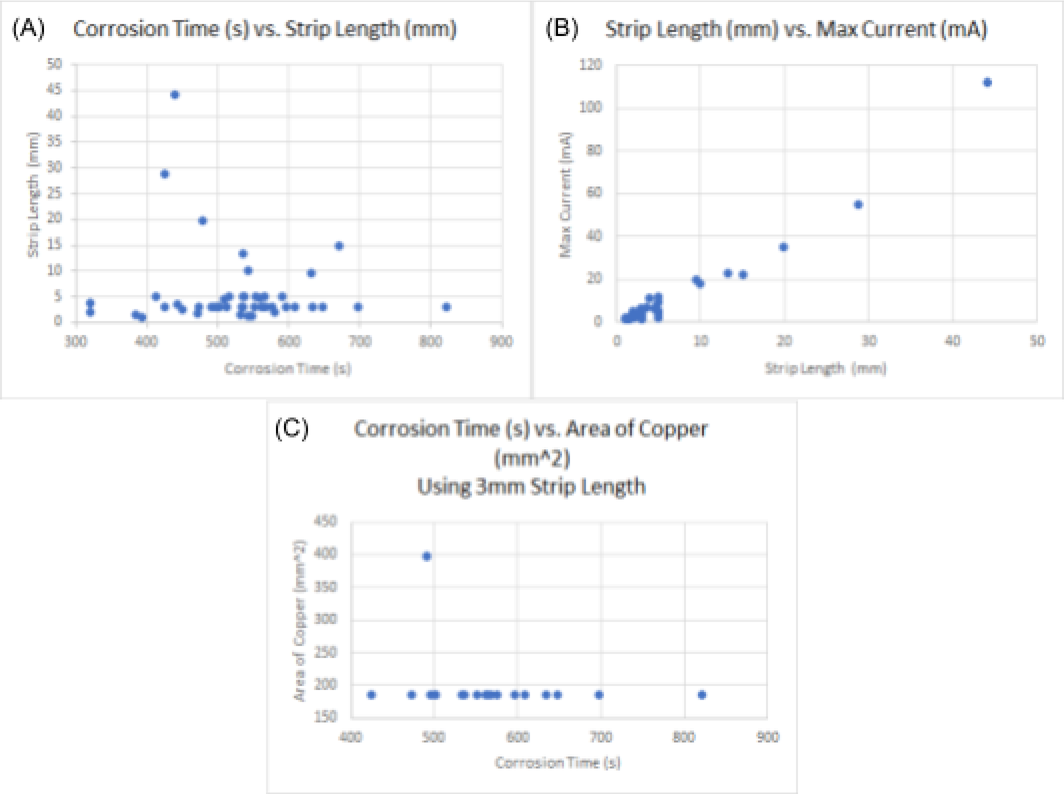

Fig. 7: (A) Corrosion Time in comparison to exposed wire length. (B) Corrosion time in comparison to the max current. Current was recorded at each minute interval until separation. (C) Corrosion time in comparison to area of copper exposed in the sea water.

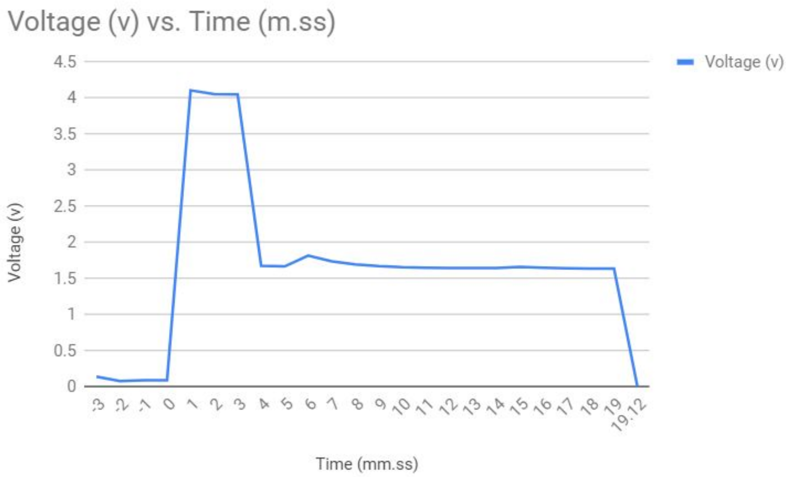

Fig. 8: Shows the change in voltage over each minute intervals. Minute 1 is where the voltage saw a significant increase, this was the activation of the release mechanism that was pre-programmed using the iTAG software. Minute 4 we saw a significant decrease due to the battery.

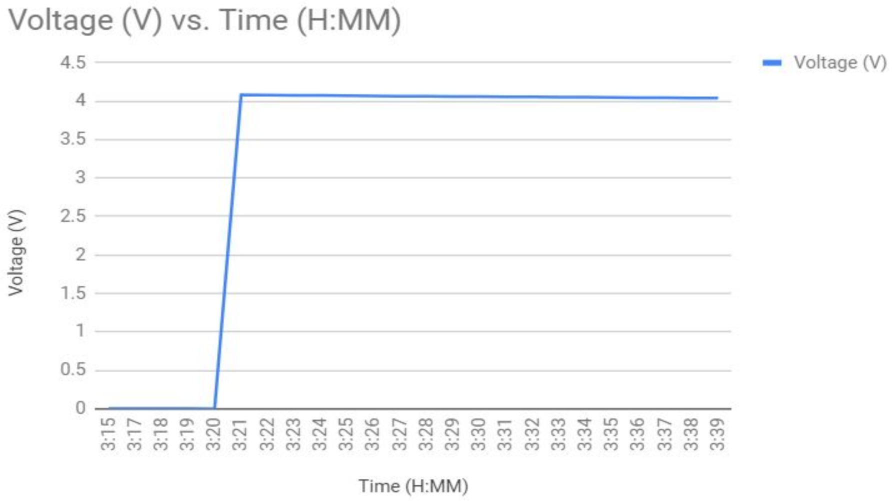

Fig. 9: Testing the iTAG battery using a multimeter. 3:20 was the activation time of the release mechanism.

Supplemental Info:

Fig. A: Shows the size comparison between the potted iTAG v0.4(left) & the iTAG v0.1(right). Although both versions are intended to be placed on the bell of a jellyfish, The v0.4 uses glue to remain affixed whereas the v0.1 uses suction cups.