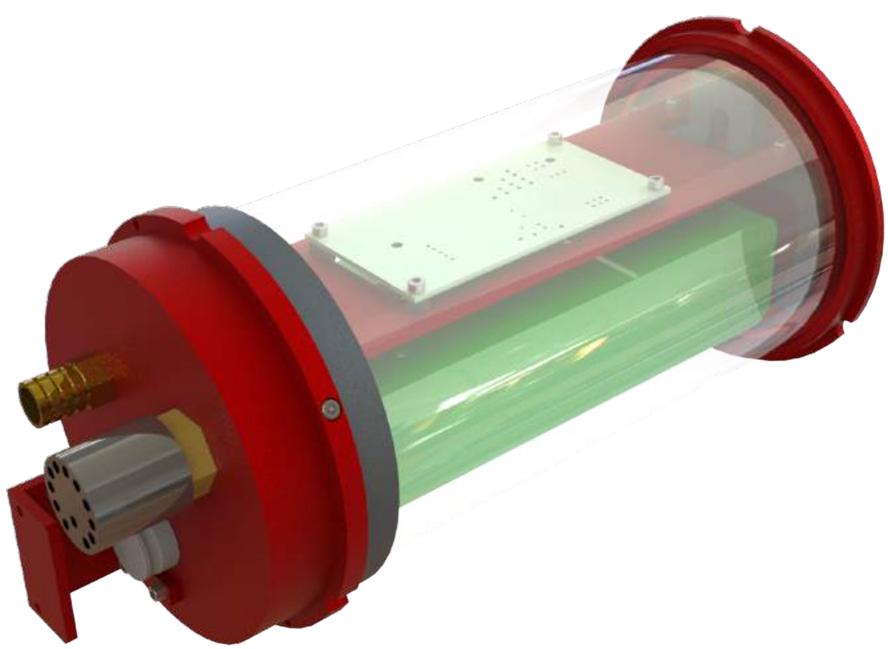
Cornell University Autonomous Underwater Vehicle Team

Spring 2017

Battery Pods



Technical Report

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Contents

1 Abstract

The two battery pods on each vehicle house the 14.8 volt batteries which power the submarine's operations, and connect to the upper hull pressure vessel (UHPV) via a MCBH-16 connector which carries power and data from each pod's battery managment board (BMB). In this iteration of the battery pod design, we are returning to our older, cylindrical design from a rectangular design used on the sub the past two years in order to eliminate the need for CNC manufacturing of the pods, as well as to return the design to a hot swappable form since the batteries will remain fully sealed even during swaps. Additionally, as this iteration of pods will be the first used on both a main and mini sub, they will be interchangable between the two so that a smaller total number of pods can keep both subs in constant operation during testing.

2 Design Requirements

2.1 Constraints

The design of the battery pods will adhere to these constraints:

- The pods must seal the batteries at/beyond competition depth (30-50ft).
- They must be swappable without fully powering down/drying off the sub.
- Both Artemis and Apollo's pods need to be interchangable.
- Each pod must enclose both a battery and that battery's charging board.

2.2 Objectives

In addition to the above constraints, I will ensure that the pods' design also includes the following:

- A battery charge indicator should be integrated into the design.
- Batteries and their charging boards should be removeable/swapable between pods.
- The design should aim to minimize weight, size, and cost.
- The pods should require no CNC operations.

3 Previous Designs

3.1 Killick/Ragnarök

Killicks/Ragnarök's battery pod design functions like the earlier Tachyon battery pod design. The three-rail support mechanism is carried over from Tachyon; each end cap has

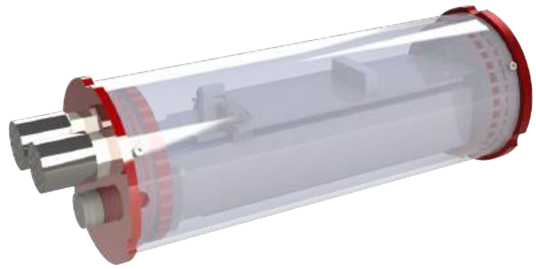


Figure 1: Killick/Ragnarök's battery pod design.

three indents so the battery pod can sit on the rails. Also the end caps are still attached by radial set screws and bore seals as they were in Tachyon, although some extra steps were taken aluminum hull design to reduce wear on the O-rings and to interface with half-moon hull removal tools. The main difference is the layout inside the battery pods, which allow the battery pods to be shorter than those of Tachyon by almost 10 percent, now measuring 9.4 from end cap to end cap.

3.2 Gemini

Figure 2: Gemini's battery pod design.

Due to the new AE8000-6S4P battery packs used in the 2013-14 year, Gemini's battery pods had a much wider diameter and a shorter overall length than Ragnarök's. As a result, the battery pods were mounted underneath the UHPV instead of on the side of the vehicle, allowing for easier pod-swapping. Overall, Gemini's pods still used the radial set screws and bore seals to keep the enclosure together. However, the bulkhead inside the pod proved insufficient to hold the battery packs in place without the use of sticky tape - great consideration must be taken for mounting battery packs in future enclosures.

3.3 Argo/Thor

Figure 3: Argo/Thor's battery enclosure design.

Due to the battery charging board being moved inside of the UHPV in Argo's design, its battery enclosures were no longer held by the constraint of enclosing both batteries and the charging board. In order to take advantage of this, the battery enclosures on Argo were made as retangular prisms to eliminate the amount of wasted space inside the enclosures. This design was successful in minimizing space on the sub, but required both CNC manufacturing to produce the enclosures, and also unsealing the batteries every time a battery swap must be made, putting the batteries at greater risk of getting wet.

3.4 Loki

Loki's design did not include actual battery pods/enclosures, with its single battery being located within its main hull. This resulted in the battery's size being limited by the fact that it competed for space with all electrical components within the hull, and also required unsealing and resealing the main hull during any battery swap.

4 High Level Description

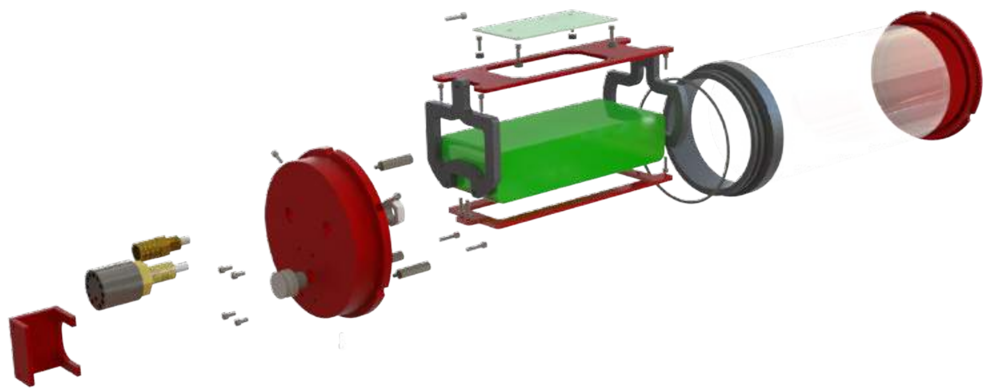


Figure 4: An exploded view of the battery pod components.

Each battery pod for Artemis and Apollo is comprised of three major components: an acrylic hull with an aluminum endcap and collar epoxied onto it, a removable endcap with a pressure release valve, HUMK5, and MCBH-16 connectors in it, and finally a frame which the battery and charging board attach to. The pods seal with a bore seal which seals the interface betwen the ported endcap and collar. The endcap is held in place by three radial set screws. There are three half-circle cutouts around the edge of the two endcaps on the pods which align with rods on each sub's frame to align the battery pods in use.

4.1 Hull

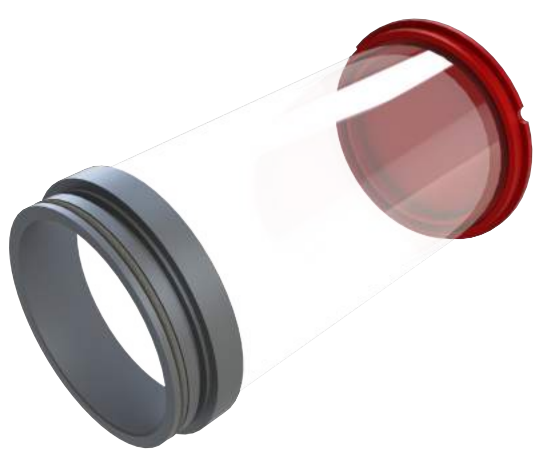


Figure 5: The hull enclosing the battery and BMB.

The hull enclosing the battery and BMB is made up of three components: an aluminum endcap which seals one end, an aluminum collar which provides a sealing interface for the bore seal with the ported endcap, and an acrylic tube which is epoxied to the two aluminum components. The hull is larger in length and diameter than absolutely necessary for coponents to fit, but after issues involving batteries puffing up during the 2015-16 season extra space was worked into the pod design to leave a margin of error for battery expansion. The endcap on the hull includes three cutouts along its edge for mounting on the subs, as well as the AUV logo cut into it for aesthetic purposes. The collar on the other end includes a O-ring groove for a #154 male bore seal, and also another groove for radial set screws for locking the endcap in place.

Figure 6: Detail of the AUV logo cutout.

4.2 Ported Endcap

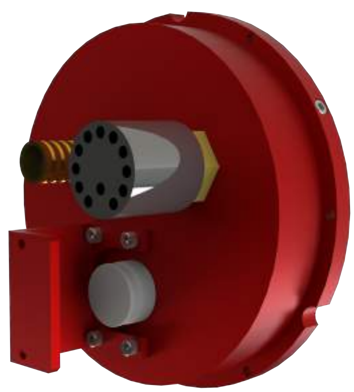


Figure 7: The outside of the endcap with SEACON connectors and handle.

The ported endcap provides the battery pods with connectors to interface between the components within each pod and the rest of the vehicle. HUMK5 and MCBH-16 connectors connect the pod to the UHPV and provide a point to attach a charger for in-pod battery charging. The Deep Sea release valve allows for the pod to vent pressure as the sub dives (or in event of a battery explosion), and the handle around it provides a non-SEACON part to grab hold of when removing a pod from the sub. Finally, the larger ring around the rear edge of the endcap serves four purposes: it includes the half-circle cutouts for alignment of pods on the subs' frames, it has three tapped radial holes for set screws to lock the endcap to the collar, six holes in it allow for attaching it to a fixture plate for milling operations, and also gives a better edge to grip for unsealing the pods (an issue with previous designs).

Figure 8: The inside of the endcap the battery frame attaches to.

The inside of the endcap has cutouts to reduce its weight and allow for proper thread engagement for the HUMK5 into its nut. Additionally three standoffs are attached to each endcap for the battery frame to mount to. The standoffs keep the battery frame out of the connectors' wires' bend radii.

4.3 Battery Frame

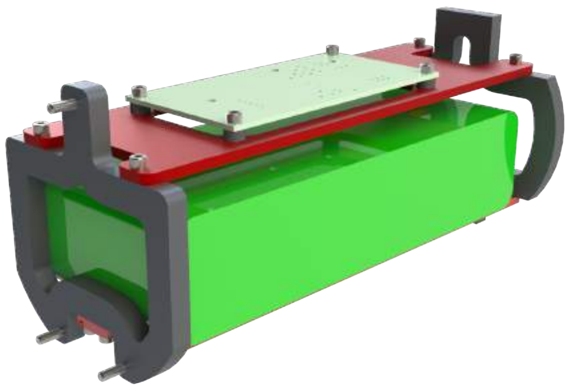
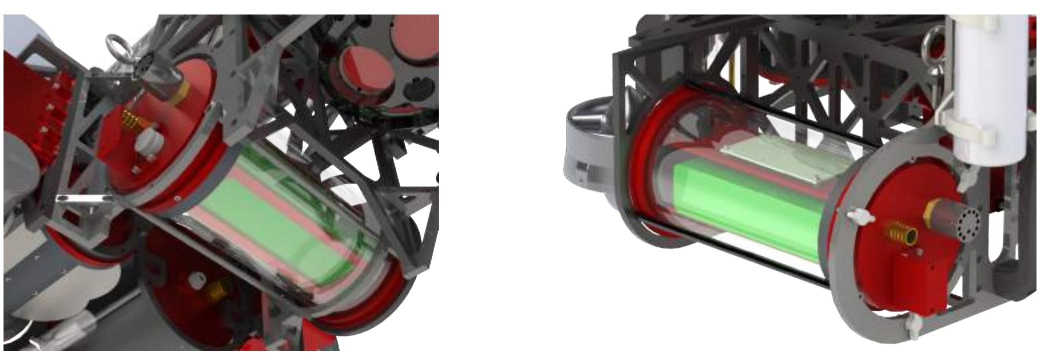


Figure 9: The removable frame which the battery and BMB mount to.

The battery frame consists of four pieces of aluminum which mounts to standoffs on the ported endcap and centers itself in the battery pod. The battery itself mounts to the battery frame via velcro straps, while the BMB board attaches via four tapped 4-40 screw holes. The cutout in the top plate of the battery frame gives clearance underneath the BMB for components, while still minimizing its height to fit through the collar. The pods are designed so that every battery and BMB stay attached to their battery frame, and if there are more batteries than pods, it's a relatively simple process to swap a fresh battery frame into a pod with a drained battery.

4.4 Mounting



(a) Artemis (b) Apollo

Figure 10: Battery Pod mounting on Artemis and Apollo.

The battery pods attach to both of the submarines by sliding into enclosures with rods which support the three half-circle cutouts in the pods' endcaps, and then are held in place by a loop of bungee cord.

5 Manufacturing

Manufacturing the battery pods took a huge amount of time, and this time commitment should be kept in mind during any other year which new pods are being manufactured. Even though 40 of the 80 individual parts had most of their work CNC'd over winter break, battery pods were still one of the last projects to finish. The long manufacturing time is mostly due to the large number of pods, the long boring operations required on the ported and boring endcaps, and the numerous parts which were boned (due ineffective groove tools, misread dimensions, or the drop saw being problematic). The fact that Jira indicates that manufacturing took a week less than anticipated should be ignored because since so many people ended up putting in time working on different parts of the pods, a large amount of time was never properly logged. In the future, having the proper tools (ie. the THINBIT groove cutter) is cirtical for getting the collars machined in a timely fasion, and without a CNC router to quickly machine them, the BatteryFrames will add a significant amount of time to manually machine.

6 Modifications

Since the intitial "final" design at the end of last semester, a number of small adjustments have been made to the battery pods. None of these adjustments impact the overall operation of the pods, and most serve to smooth out their functionality and/or fix mistakes made during the design and manufacturing process. These modifications are:

- Adding curved edges to the frames since they were manufactured on a CNC router.
- Changed the hole size for the pressure relief valve and MCBH-16 since the origionals were not the proper size.
- Added a large chamfer on the inside of the PortedEndcap so the set screw holes do not tear o-rings.
- Removed the jam nut from the HUMK-5 connector since there were not enough threads for it.
- Reduced the outer diameter of the BatteryCollars slightly to make unsealing the pods easier.
- Slight changes to the PortedEndcap weight reduction to make it easier to machine.

7 Current Status

The barrety pods are currently fully completed and assembled, though 3 are not yet leak tested. Once they are, battery pods will be mechanically complete for this year, though electrical elements such as the BMBs and in-pod charging capibilities have not yet been added.

8 Future Improvements

If the BMB is successful in preventing batteries from expanding over the course of the season, then the most immediate improvement which can be made to the battery pods is decreasing the acrylic tube size by 0.25" in diameter, which makes the entire profile of the pods smaller and reduces their bouyancy. Additionally, though this year's design initially planned to have a charge indicator integrated into the design, the final version will not include this. Future designs should look into seeing if it's feasible to incorporate some sort of indicator, especially because the arcylic hull makes viewing components like it relatively easy. Set screw grooves should also be given more tolerance than other areas because currently the pods' radial screws interfere with the aluminum of the collar (but can still be screwed in). Finally, having an equal number of pods and batteries is preferred in order to minimize the sealing/unsealing required, though the interchangable frames mitigates a protion of this issue.

Appendices

A Purchased Components

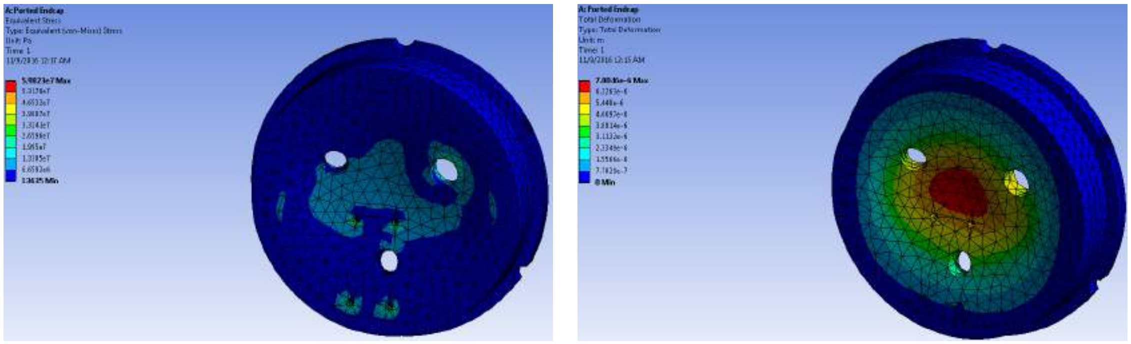
Component	Link
DeepSea Pressure Relief Valve	Pressure Relief Valve User Manual
15" Velcro Straps	Velcro Specifications
1" 4-40 Male/Female Standoffs	Standoffs Specifications

B Finite Element Analysis

In order to ensure the battery pods' ability to remain sealed even at 30ft or 50ft depth underwater during competition, we used ANSYS to calculate the stress and deformation that the pressure will cause on the different elements. All of the components' maximum stresses are well below the ultimate stress of aluminum, and no sealing surfaces deform in any way which would impact sealing. Additionally, this analysis indicates that the handle will have no touble serving as a way to pull the pods out of the submarines.

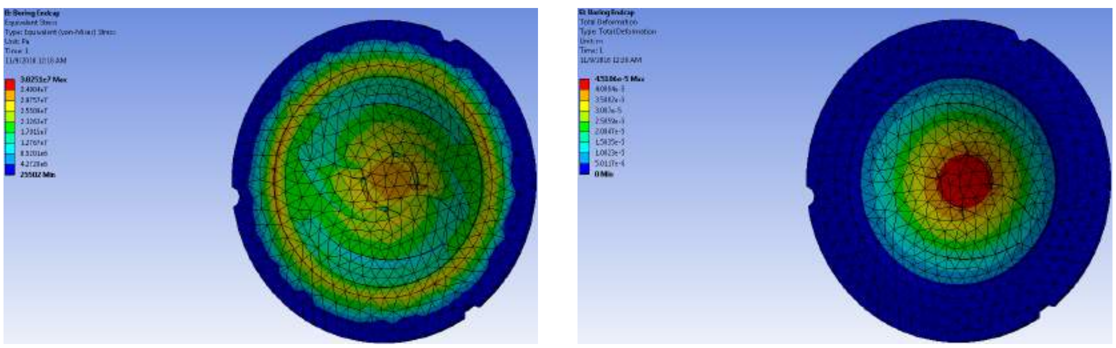
Part	Max Stress (ksi)	Max Deformation (0.001")	Factor of Safety
PortedEndcap	8.67	0.275	5.19
BoringEndcap	5.55	1.77	8.11
BatteryCollar	0.049	2.23e-4	918
BatteryFrame	53.4	7.87	0.84
Handle	2.64	1.41	17.0

The <1 factor of safety on the BatteryFrame is under a standard loading test case which we apply to all parts during analysis. This loading (30 pounds at an arbitrary point) is unlikely to every occur during the BatteryFrames' use on Artemis or Apollo since the frames are always inside of the Battery Pods.



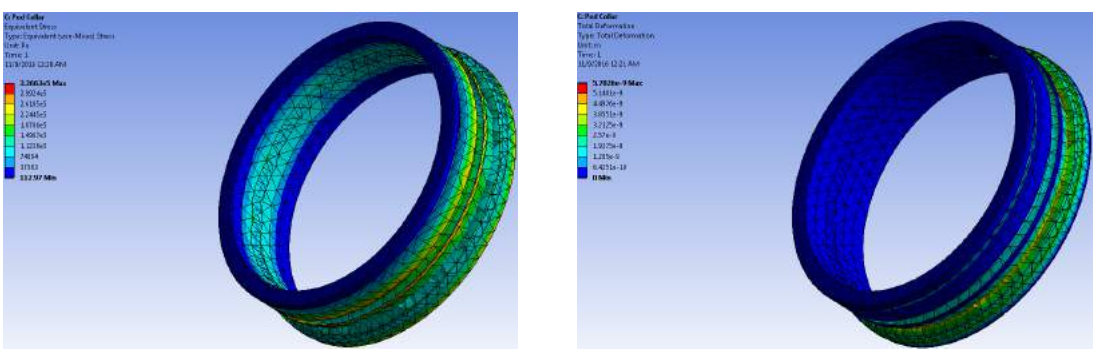
(a) Max Stress (b) Max Deformation

Figure B.1: Stress and deformation at a depth of 50ft on the ported endcap.



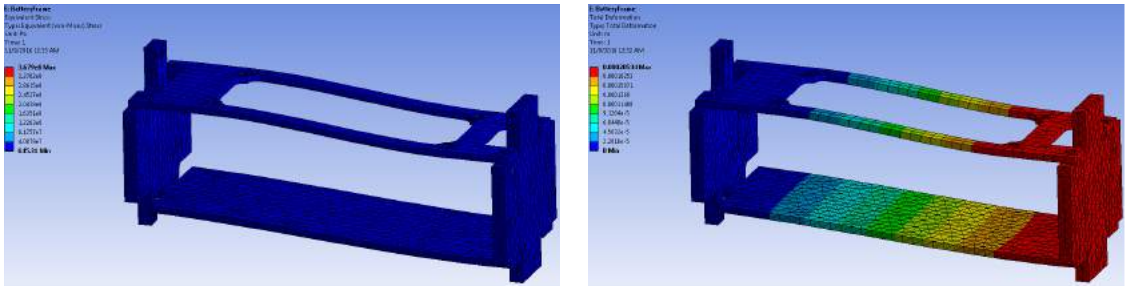
(a) Max Stress (b) Max Deformation

Figure B.2: Stress and deformation at a depth of 50ft on the non-ported endcap.



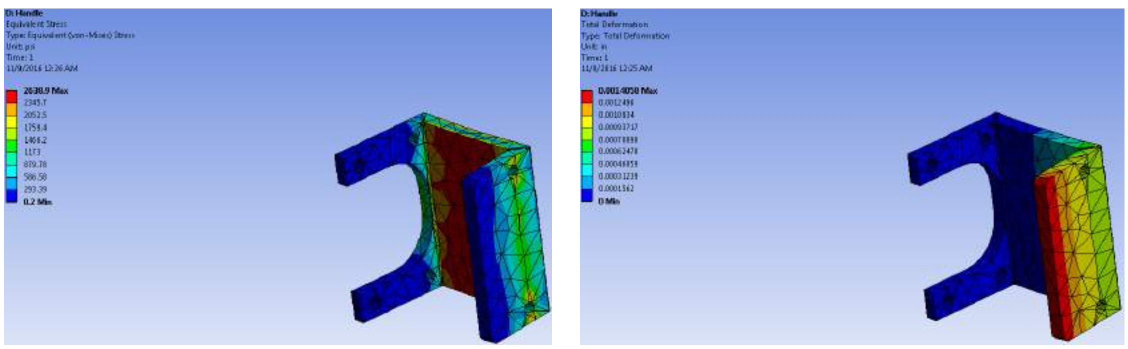
(a) Max Stress (b) Max Deformation

Figure B.3: Stress and deformation at a depth of 50ft on the battery pod collar



(a) Max Stress (b) Max Deformation

Figure B.4: Stress and deformation of the battery frame.



(a) Max Stress (b) Max Deformation

Figure B.5: Stress and deformation of the handle