Underwater Tablet Enclosure Final Report
by Miguel de Villa

Abstract:

The underwater tablet enclosure is a device used to maximize the protection and survivability of a tablet underwater without losing any of its functionality at depths of 100ft to 200ft underwater. The tablet can then be used to access a web app that allows the diver to manipulate parameters on the underwater stereo rig camera to result in better data acquisition during the dive. Additionally, the design must allow the tablet to be removable after each dive to permit charging and any necessary maintenance. Static analysis using engineering simulation software is used prior to fabrication in order to validate performance at target depths.

Introduction:

The underwater tablet enclosure is a project designed to complement the existing underwater stereo rig by allowing the diver means by which to manipulate the stereo rig while underwater. Previously, this level of coordination had to be accomplished by a crew of two people--one diver with the platform underwater and one laptop operator in charge of the stereo rig settings. As the laptop had to remain on dry land in order to function, communication between the diver and laptop operator was often inconvenient and time-consuming, causing unnecessary difficulty when using the stereo rig. The solution became for the diver to bring a platform with the same level of functionality and accessibility as a laptop but also allow them to do the job themselves on the fly, according to their environment. This would result in higher quality data gathered more efficiently in a much greater user-friendly matter. However, due to the physically demanding nature of an underwater deployment and lack of availability in the marketplace of an underwater tablet enclosure that fit all of the stereo rig team's needs, we decided that we had to design one from from the ground up.

The most simple and effective solution would be to completely enclose the tablet prior to every dive, thus guaranteeing that it would be, at the very least, waterproof. However, doing so creates new complications that must also be addressed and can fail to address other concerns if not done properly.

Most modern tablets available in the market today utilize a capacitive touch screen that is based around the concept of a conductive material--a human finger or stylus tip--coming into contact with an area of the screen which is created using an electrically conductive material. In Once contact is achieved between the conductive material and the touch screen, a charge is transferred and the circuit is completed, a change that is sensed by the device and registered as a touch. In short, direct physical contact is necessary to use most tablets, which would be impossible in a full enclosure scenario. Unfortunately as well, water is also a very good conductor and can cause false touches to be registered on the device, making it impractical to expose the screen of a tablet device to water in any capacity. As a result, we have selected the Samsung Galaxy Note 10.1" Tablet as our device of choice as it overcomes these issues.

The Galaxy Note Tablet's main attractive feature is that a secondary method of control is through a Wacom pen that not only is able to function as a regular stylus but is also able to react to a close range electromagnetic field emitted by a circuit underneath the tablet screen. This reaction is able to be sensed by the tablet in order to determine the location of the stylus tip once it is within a certain minimum range. This eliminates the need for direct contact in order to use the tablet underwater and adds the advantage of a full enclosure to provide both resistance from water and pressure.

Once the major hurdle of being able to select a tablet device capable of being fully enclosed and utilized underwater was resolved, the remaining portion of the project was dedicated to devising a sturdy water-proof case capable of withstanding high-pressure loads without significant deformation that might damage the tablet.

The key deliverables of this project are the following:

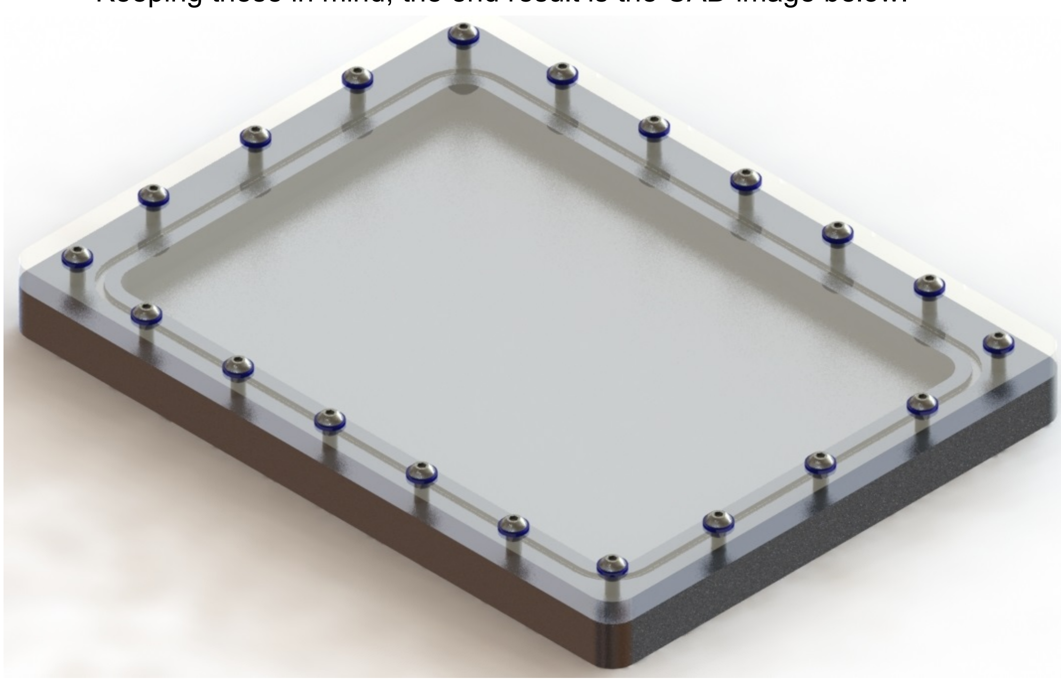
1. Create a waterproof region for the tablet.
2. Guarantee that the tablet will remain usable in spite of being enclosed.
3. Utilize engineering software to verify that under pressure loads the enclosure will not harm the tablet itself

Design:

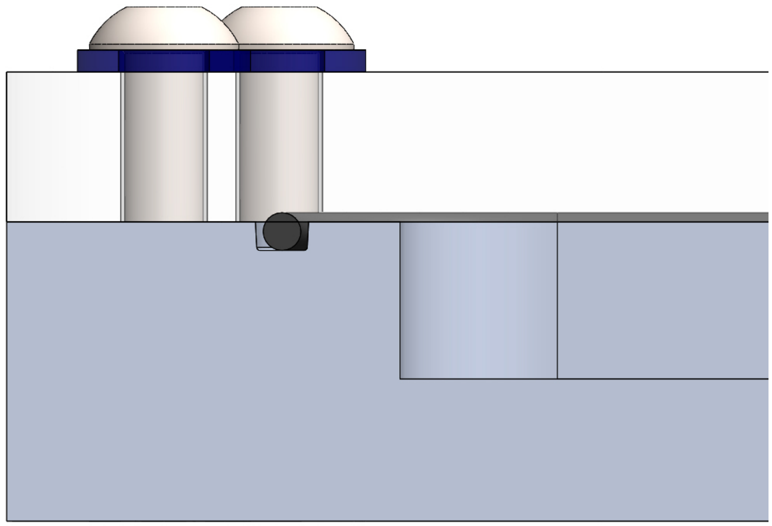
In supplement to the key deliverables, the design had to adhere more specifically to the following physical design restrictions:

1. Transparent screen
2. Removable tablet/Accessibility
3. O-Ring Seal
4. Minimal components

Keeping these in mind, the end result is the CAD image below.



*Final Render of CAD



*Cross Sectional View of Enclosure assembly

This prototype incorporates a machined transparent plastic screen, an o-ring seal, an aluminum base, and a series of M5 bolts. This minimized the number of location where a possible leak may develop by keeping a majority of component contact points external to the waterproofing seal while maximizing component strength and performance. This simultaneously cut down on necessary machining jobs and part orders to improve production times.

Additionally, the CAD software that was used to generate these engineering model--Solidworks 2015--provided files that were importable into the simulation software that was later used. This cut down on time spent having to recreate this model for each software and having to reconcile both in the end for any inconsistencies.

O-Ring Seal:

For the purposes of this project, we opted to use an axial face seal using a 2.4mm thick rubber o-ring to create our waterproof seal for the following reasons:

1. Minimal machining and design requirements
2. High performance for cost of components
3. Easy installation

The only major component required in order to incorporate an o-ring seal into any design is to select and manufacture the correct size and type of groove into the material one would be placing the seal in. The groove is a precisely machined channel in which the o-ring sits and the dimensions of which for any o-ring application type and size can be found on any manufacturer’s website. As the o-ring’s primary feature is that as a result of compressing between two component faces, the rubber material attempts to resist this elastic deformation and pushes back against the component faces, creating a waterproof seal whose strength is determined by the amount of compression present in the cross section of the o-ring. The result is that even for a relatively small cross sectional diameter, the seal is able to resist a very high pressure differential as seen in the durometer hardness charts.

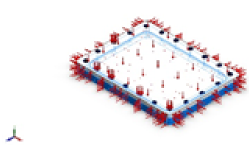
However, the primary disadvantage of using an o-ring is that the groove must be machined precisely otherwise problems could occur immediately or as a result of extended use. For example, two common issues are the groove fitting too loosely or too tightly. If the o-ring sits too deeply in the groove, it won't come into contact sufficiently with the the two contacting component faces and result in poor compression and seal. Should the inverse be true and the groove too small or tight, then the o-ring might extrude into the gaps between contacting faces and eventually rupture. In order to avoid these complications, we employed the professional services of the Prototyping Lab at Calit2 to achieve the exact groove dimensions that we required to optimum performance and minimal maintenance/replacement.

<u>Static Analysis/Simulation:</u>

Early on in the design process I discovered that regardless of what material was used for the screen, I was going to expect some amount of deformation due to the shape of the tablet enclosure. Basic solid mechanics teaches that for a pinned beam like the tablet enclosure screen, beam bending is focused at the midpoint of the beam when a uniform distributed load like pressure is applied. Additionally, the amount of beam bending is a function of the cross sectional area of the beam such that the greater the cross sectional area of the component in the axis perpendicular to the applied load, the more likely it will be to bend. Thus, as the maximum amount of force necessary to break the tablet screen was unknown, the enclosure's screen would have to be stiff enough to resist deformation and applying and serious load onto the screen upon contact. Doing so protects the screen and preserves the tablet from any damage due to pressure loads. That was the main goal of my analysis and was accomplished through Solidworks Simulation.

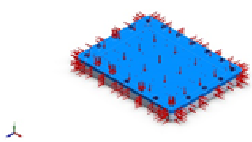
Assumption and Simulation settings at 100ft.

Material Properties

<table>
<tr><th>Model Reference</th><th>Properties</th><th>Component
s</th></tr>
<tr><td></td><td><table>
<tr><td>Name:</td><td>6061 Alloy</td></tr>
<tr><td>Model type:</td><td>Linear Elastic Isotropic</td></tr>
<tr><td>Default failure criterion:</td><td>Unknown</td></tr>
<tr><td>Yield strength:</td><td>5.51485e+007 N/m^2</td></tr>
<tr><td>Tensile strength:</td><td>1.24084e+008 N/m^2</td></tr>
<tr><td>Elastic modulus:</td><td>6.9e+010 N/m^2</td></tr>
</table></td><td>SolidBody 1(Split Line1)(UTE Base Mk 3-2015-1)</td></tr>
</table>

Poisson's ratio:	0.33
Mass density:	2700 kg/m^3
Shear modulus:	2.6e+010 N/m^2
Thermal expansion coefficient:	2.4e-005 /Kelvin

Curve Data:N/A



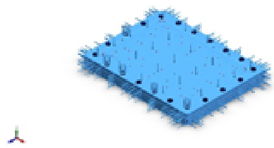
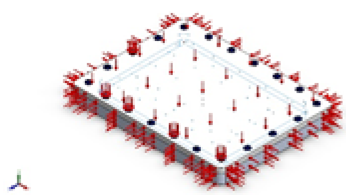
Name:	Polycarbonate
Model type:	Linear Elastic Isotropic
Default failure criterion:	Unknown
Yield strength:	7e+007 N/m^2
Tensile strength:	7.7e+007 N/m^2
Compressive strength:	7.93e+007 N/m^2
Elastic modulus:	2.7e+009 N/m^2
Poisson's ratio:	0.42
Mass density:	1200 kg/m^3
Shear modulus:	9.7e+008 N/m^2
Thermal expansion coefficient:	70 /Kelvin

SolidBody 1(Split Line2)(UTE Screen Mk 3-2015-1)

Curve Data:N/A

Pressure Loads

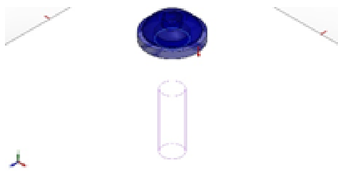
Load name	Load Image	Load Details

Pressure-1		**Entities:** 18 face(s) **Type:** Normal to selected face **Value:** 0.3 **Units:** N/mm^2 (MPa) **Phase Angle:** 0 **Units:** deg
Pressure-2		**Entities:** 10 face(s) **Type:** Normal to selected face **Value:** 0.101 **Units:** N/mm^2 (MPa) **Phase Angle:** 0 **Units:** deg

Connector Definitions

Pin/Bolt/Bearing Connector

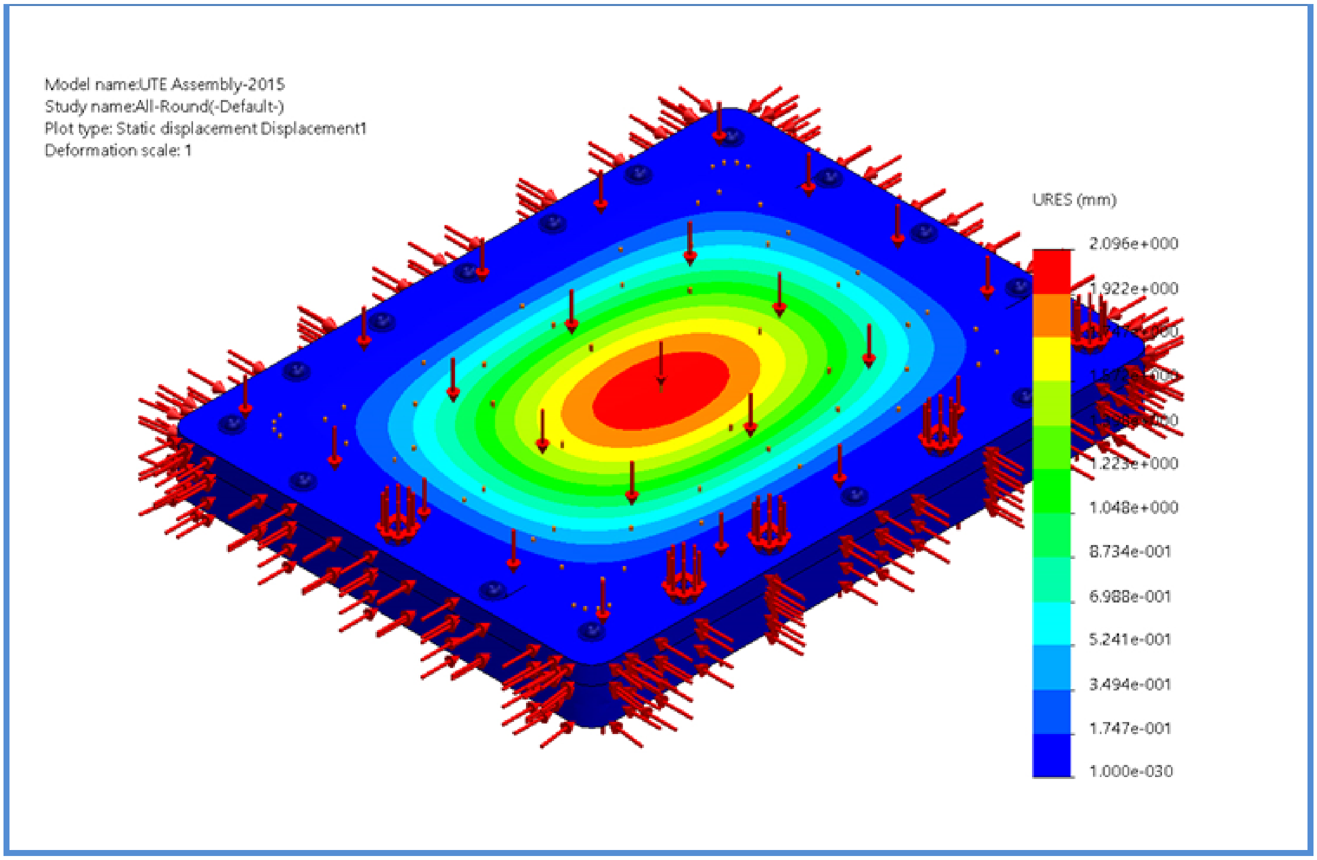
Model Reference	Connector Details	Strength Details
B18.3.4M - 5 x 0.8 x 20 SBHCS --N - 1	Entities: **1 edge(s), 1 face(s)**	Bolt Check: OK



Type:	**Bolt(Head/Nut diameter)(Counterbore screw)**
Head diameter:	**11 mm**
Nominal shank diameter:	**5**
Preload (Axial):	**1319.87**
Young's modulus:	**2.1e+011**
Poisson's ratio:	**0.28**
Preload units:	**N**

Calculated FOS:	5.41333
Desired FOS:	2

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 541	2.14071 mm Node: 86487
UTE Assembly-2015-All-Round-Displacement-Displacement1			



In conclusion, from the results of the simulation, we will be facing approximately 2mm of deformation at the center, which is within the acceptable limits given the 2mm of clearance between the screen and tablet during a deployment situation.

Milestones:

Initial milestones: (All completed on time by May 7):

- Determine screen thickness
    - The maximum screen thickness was determined through a simple test of inserting several thicknesses of transparent acrylic between the stylus and the tablet screen until we achieved a distance at which the stylus was no longer registered by the screen.
- Seal type and specifications
    - Previous research that I had done on o-ring seals determined that, assuming proper assembly and machining practices, a custom-sized o-ring could be cut, assembled, and installed to be highly effective against pressure.
- Simulation and analysis methods
    - Research on finite element analysis(FEA) software commonly used to analyze and simulate physical systems determined that Solidworks Simulation and ANSYS were attractive options due to their robustness and compatibility with the CAD files used for the project.

- Conceptual design
  - Due to the simplicity of the design as outlined in the previous section, the concept was to have the main three components with the material properties to be determined later on after additional research.

Initial milestones were easily met due to the fact that it was based mostly on prior project experience and the gathering of physical measurements. It was during this stage that I was able to finalize many of the physical parameters of the enclosure without going heavily into the solid mechanics aspects of their analysis.

Secondary Milestones:

- Design consultation with prototyping lab (Projected Deadline: May 1st Completed May 8)
  - Delays for this milestone were due to scheduling issues with regards to finding a time that fit Isaiah's available periods during the lab's normal business hours.
- Determine material properties of components (Projected Deadline: May 10. Date of Completion May 24th)
- Simulate performance of components in Solidworks (Projected Deadline: May 10. Date of Completion May 24th)
  - These two milestones were heavily intertwined. Given my relatively small range of viable plastic and ceramic options, I could not rule out any material choice until I was confident my simulations accurately portrayed their performances. Vice Versa, my simulations could have been faulty due to an improper selection of material properties that I had difficulty in locating a "true" value for due to the great variety of materials in the market.
- Ordering parts for the tablet enclosure and having them machined Projected Completion May 15. Date of Completion, May 29th)
  - Delays were incurred because without a reliable analytical model, I could not commit to the design and have it manufactured.
- Pressure Testing at NOAA Fisheries laboratories(Projected Completion May 22. Date of Completion June 10)
  - Delays were incurred due to the availability of a testing time at the acoustics lab and the lack of a completed enclosure.

After the initial milestones, the secondary milestones were set back a week to the then projected deadlines due to anticipated difficulties with generating a reliable model. I greatly underestimated these difficulties due to my inexperience with the software and the degree of complexity that I felt satisfied the requirements of this project. In the end, I decided to go with my results with Solidworks as I could only effectively learn one new software before I had to act on my results.

<u>Conclusion:</u>

In summary, the project was able to deliver by the end of the quarter an enclosure that was able to protect a tablet from water and water pressure at 100ft while still giving it full functionality. Recent testing at the NOAA Fisheries Acoustics lab has show that even during an event of severe screen deformation, the waterproofing seal will hold and the screen is capable of rebounding elastically from a deformed state, which speaks greatly for the durability of the platform. However, our initial factor of safety designated our target to be similar levels of enclosure deformation at 200ft in order to safely guarantee that the tablet would survive at that depth and this was not met. In addition, the current prototype is very heavy and large, making it not ideal for extended use by the diver. Corrosion as a result of exposure not only to seawater, but the contact between different metals of the screws and the base is also a possible long term application that needs to be addressed.

The largest contribution of this will have been the wealth of knowledge and experience I have gained as a result of my attempts to design an enclosure with such a large factor of safety. Future revisions to this design will come more easily and result in a more polished product due to the shortcomings of the approach to this designs that incorporate a large flat window in an underwater enclosure.