

UNDERSEA AID MODULE

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Problem Statement

Across the globe, island nations are impacted disproportionately by natural disasters, limiting their access to emergency aid. While access to aid is still possible, it is limited by the damage to infrastructure, such as shipyards and airports. The critical response window for natural disasters lasts only 48 hours; after that, the World Health Organization (WHO) reports that the search-and-rescue success rate drops to 40%, while the risk of disease and long-term PTSD increases. There are no current solutions to deliver immediate aid to those in need, and, as such, the team has worked to develop a unique solution using insights and statistics provided by Paul Knudsen and the sponsors.

Customer Background

As part of the United Nations' World Food Programme, the Humanitarian Response Depot (UNHRD) is a humanitarian platform that enables emergency and preparedness response efforts. The UNHRD plans to provide emergency supplies to those in need in six key areas: Indonesia, Papua New Guinea, Taiwan, Philippines, Sri Lanka, and Haiti.



Figure 1. Aftermath of Typhoon Haiyan in the Philippines, 2013. UN Photo/Evan Schneider

Requirements

Offshore Underwater Aid Modules (UAMs) are proposed solutions to alleviate the effects of natural disasters on island nations. The team will develop a capsule to protect all housed aid materials from the underwater environment, including salt water, pressure, temperature, and biological growth.

Container	
Duration	3 Years
Mass Limitations	None
Volume Limitations	2.1 cubic meter capacity
Environmental	304.58 psi 200-meter depth 15-30 degree Celsius Watertight Resistance to saltwater degradation Anti-fouling Neutral Buoyancy or Low Buoyancy
Hatch and Door	
Duration	3 Years
Mass Limitations	None
Dimensions	Must accommodate a 50cm x 50cm cross section
Environmental	300 psi 200m depth 15-30 degree Celsius Watertight Resistance to saltwater degradation

Table 1. Underwater Aid Module (UAM) Requirements

Prototyping & Experimentation

Multiple concepts were developed and explored to improve the capsule's structural integrity. Internal rib structures were considered to enhance strength and resistance to deformation under high external pressure. Two primary concepts were developed: an I-beam ring design to provide stiffness while minimizing material use, and a tube-truss structure to enable efficient load distribution throughout the capsule.



Figure 2. Fiberglass Endcap Mold

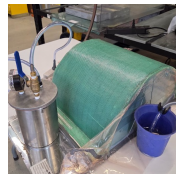


Figure 3. Fiberglass Infusion Process

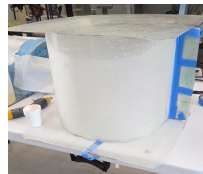


Figure 4. Fiberglass Final Prototype



Figure 5. Fiberglass Reference Model

A physical prototype was developed using fiberglass to produce a Fiber-Reinforced Plastic (FRP) laminate. Prototype was at 1:3 Scale to document fiberglass manufacturing processes and procedures.

- Construction: 2 plies of fiberglass twill [45 -45]
- FEA Prediction: Simulated failure rate of 19.40 Psi.

Final Design

The UAM's final design includes a pill-shaped fiberglass container produced in four parts and assembled with 316 stainless steel hardware. This shape was selected for its simple geometry, accessible manufacturing, and hydrodynamic efficiency.

The main components include: two half-cylinders, two end caps, a hatch for access, and one anchoring point on each end cap for safe, simple deployment.

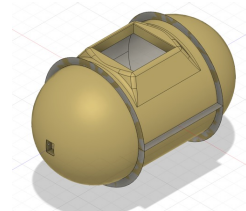


Figure 6. Manufacturable Capsule Design

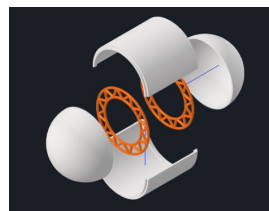


Figure 7. Capsule Design Assembly View

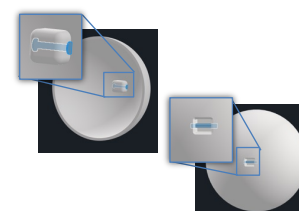


Figure 8. Anchoring Points

For material selection, the focus was on durability in harsh underwater environments, leading to the use of fiberglass and 316 stainless steel for corrosion resistance and strength.

A 1:3 scale prototype was manufactured to test structural performance, pressure resistance, and manufacturability.

Testing & Validation

- **Target Spec:** Fiberglass-wound RV water softener rated for a maximum of 150.00 Psi.
- **FEA Prediction:** ANSYS Eigenvalue Buckling test predicted failure at 104.00 Psi.

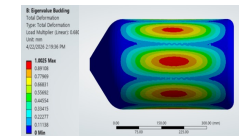


Figure 9. Reference Model FEA (Eigenvalue Buckling)

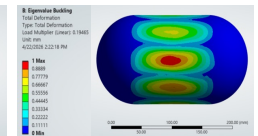


Figure 10. Fiberglass Prototype FEA (Eigenvalue Buckling)

- **Physical Testing:** Autoclave ramped from 0-100 Psi over 40 minutes.
- **Result:** Observed imminent failure at 100 Psi (autoclave's maximum limit), validating the software's accuracy.



Figure 11. Reference Model Autoclave Testing



Figure 12. Reference Model Water Tank for Testing

Results & Recommendations

Results

- Chemical reactions caused part-to-mold bonding
- Mold shapes made demolding difficult
- Improperly sealed vacuum bag prevents resin distribution

Prototype Construction

- Filament winding machine
- Unidirectional Fabric for Predictability & Simplicity
- Symmetry and Balance Rule with Fiber Composites
- Look into using LSAM to print 1:1 molds & machine to spec
- Verify chemical compatibility to prevent unintended bonding
- Steps to mold prep: Cleaner, primer, sealer, release

Recommendations

- Operating Pressure: 2.10 MPa or 304.58 Psi.
- 36 Unidirectional Plies of Fiberglass with Polyester Resin
- Maximum Pressure Capacity: 448.20 Psi (3.09 MPa).
- Safety Factor: 1.50 or greater