TITLE:	DOR-E: Conceptual Design Report (CDR)				
COURSE	ENGR-459-01	**SPONSOR**	Dr. Crow White	**REV**	A

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1. Introduction

Dr. Crow White, an Associate Professor from Cal Poly's Biological Sciences Department, conducts research on marine species population dynamics, trophic processes, and human impacts. Through his research, Crow aims to guide conservation efforts for marine ecosystems and drive sustainable management of renewable natural marine resources. Over the past few years, Dr. White has worked with interdisciplinary senior design teams to design, test, and deploy a deep-sea ocean lander to survey marine life at varying locations in the Chumash Heritage National Marine Sanctuary. The team from the previous year redesigned the original rover, which was lost during testing, to achieve theoretical depths of 1200 meters; however, they were only able to successfully test the full assembly at a depth of 300 meters. Dr. Crow White needs continued iteration and further testing of the deep-sea ocean lander to reach a minimum target depth of 1000 meters due to incomplete validation for the most recent design changes in the lander's intended use environment.

1.1 Background

The Deep Ocean Research-Explorer (DOR-E) project continues Cal Poly's effort to design and build an autonomous deep-sea lander for affordable marine research. This project is sponsored and advised by Dr. Crow White from the Cal Poly Biology Department and supports long-term studies of the ocean floor along California's central coast. The DOR-E lander is intended to serve as a small, reusable platform capable of collecting underwater video and environmental data at ~ 1000 meters. This data will help scientists better understand and survey marine life on the ocean floor.

1.1.1 Purpose and Motivation

The DOR-E project currently focuses on the Chumash Heritage National Marine Sanctuary which exists as a proposed federal area located on the Central Coast shown in **Figure 1**. The sanctuary extends across 5,000 square miles of ocean space that runs from Cambria to Gaviota Creek. The sanctuary protects various marine ecosystems which include sandy sea floors together with rocky underwater terrain. The diverse marine environments support numerous organisms which scientists have not yet fully identified.

The DOR-E system provides researchers at Chumash Heritage and their regional associates with an affordable method to monitor deep ocean life. Scientists can study animal behavior, structure, and habitat conditions in inaccessible areas through the system's underwater video and environmental data collection.

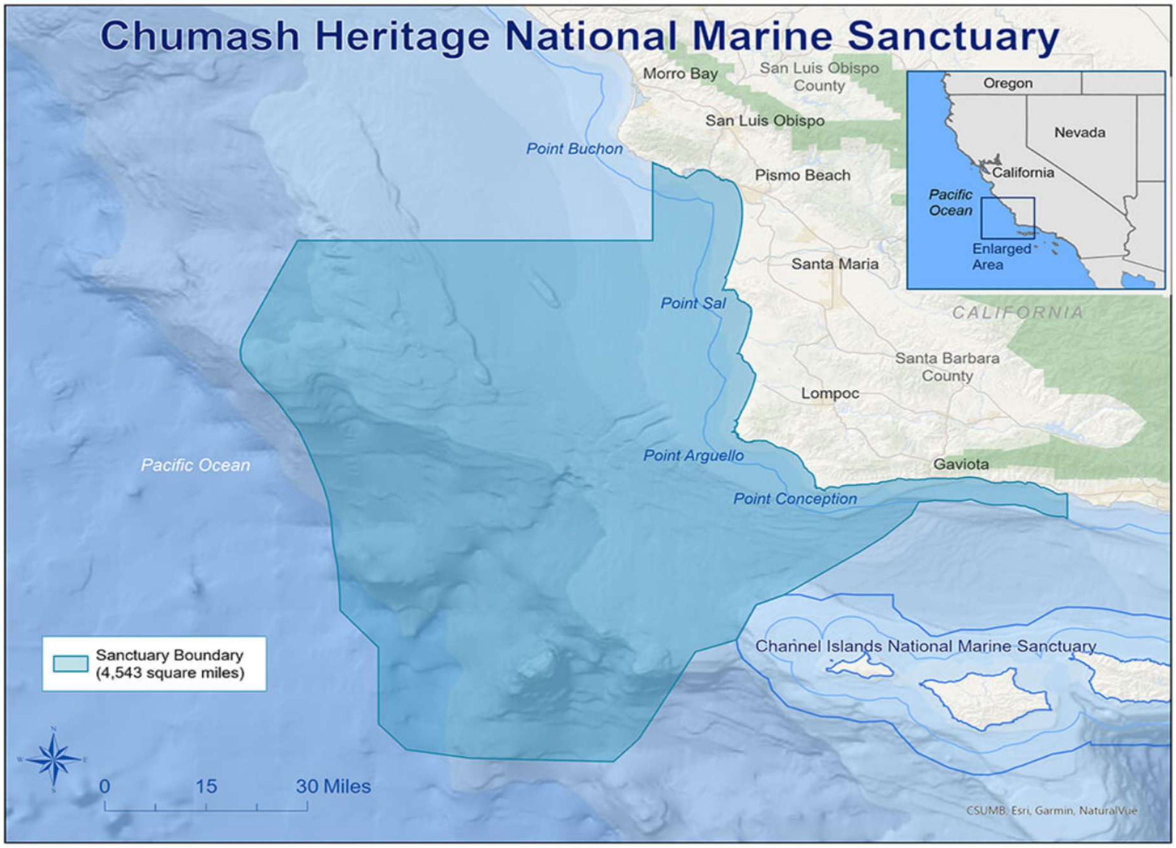


Figure 1: Proposed boundary of the Chumash Heritage National Marine Sanctuary (National Oceanic and Atmospheric Administration [NOAA], 2024)

1.1.2 Previous Work at Cal Poly

The DOR-E project continues a series of senior design efforts that have advanced capabilities in deep-sea observation. The first team, known as the Barrel Eye Explorers (2021-22) seen in **Figure 2**, built the original baited underwater video system using a frame donated by Global Ocean Design. It was designed to attract and film marine life using a bait arm and a GoPro camera. Their lander successfully operated in shallow water but was lost during a deep-sea descent due to flotation failure.

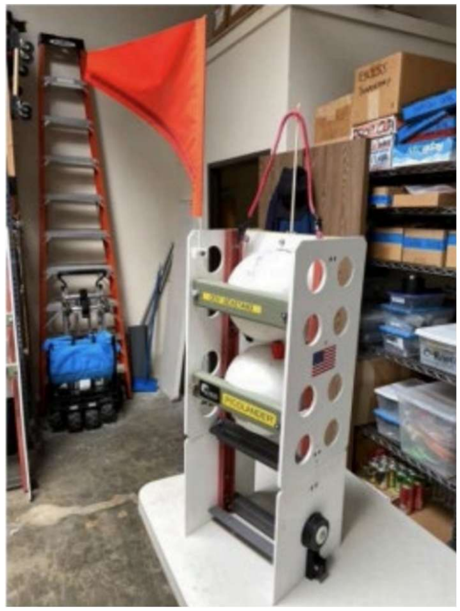


Figure 2: Early BRUV lander built by the Barrel Eye Explorers (Arm, Gariepy, Roberts, & Walsh, 2022)

The following year, the Pier Pressure team seen in **Figure 3** and **Figure 4** (2023-24) redesigned the frame using acetal copolymer panels and introduced a pressure-rated Barlus camera with a servo-controlled release mechanism. Although their prototype was never tested to full depth, it did provide valuable design improvement for future iterations.

Figure 3: Pier Pressure prototype and frame design in SolidWorks (Gaskell et al., 2024)

Figure 4: Pier Pressure Final Build (Gaskell et al., 2024)

The most recent group, the BRUVERS (2024-25), produced a fully integrated version of the lander with major system upgrades seen in **Figure 5** and **Figure 6**. They added an electromagnetic release, a reed-switch control system, and improved LED lighting. They conducted successful short-depth pier tests, demonstrating the reliability of individual components. However, their testing was limited to around twenty-five feet, meaning the full system was never validated under deep-ocean conditions. On top of this, the lander was also never tested as a fully integrated unit with all subsystems operating together.

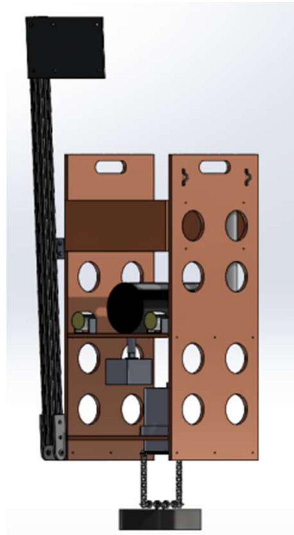


Figure 5: BRUVERS Final SolidWorks Lander (Closser et al., 2025)

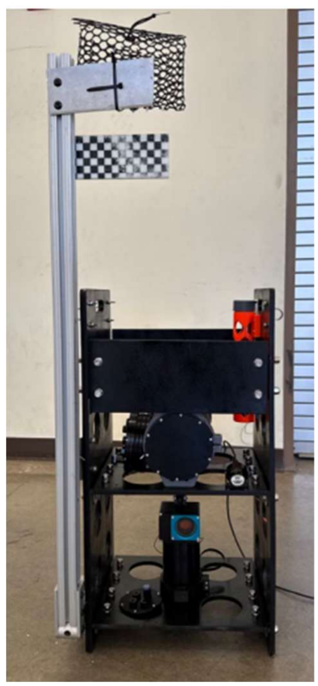


Figure 6: BRUVERS Final Ocean Lander (Closser et al., 2025)

These past projects produced valuable knowledge and data about pressure housing, buoyancy, and material selection, but none performed a complete system validation at operational depth. DOR-E's primary goal is to fill that gap by conducting comprehensive system testing, ensuring that every subsystem functions together under the high-pressure, low-light conditions found on the deep ocean floor.

1.1.3 Study Area and Research Focus

The Chumash Heritage National Marine Sanctuary contains a variety of benthic habitats that support deep-sea corals, brittle stars, and bottom-dwelling fish as shown below in **Figure 7**. These ecosystems are key to understanding the Central Coast's marine environment. Specifically, why it remains largely undocumented. DOR-E will be used to explore these regions, collect imagery of local species, and gather data that can serve as a long-term ecological baseline for future studies. Our numerical goal, as seen in Appendix A, is to observe 8 distinct species per bait used. This primary objective will ensure the health of the ecosystem for CHNMS. Also, discovering a new species would be an additional achievement as there is limited data currently for the CHNMS seafloor.

Figure 7: Example of deep benthic habitat within the proposed Chumash Heritage National Marine Sanctuary (NOAA Ocean Exploration, 2023)

Unlike earlier lander projects, which were limited to short tests and shallow environments, DOR-E will undergo field trials within the sanctuary itself (**Figure 7**). These tests will include fully assembled system deployments, verifying both mechanical integrity and electronic performance. We are also in contact with the department of marine diving technology at Santa Barbara Community College to use their hyperbaric chamber facilities, to pressure test the lander in a controlled environment.

1.1.4 Related Research and Technology

Scientists now have better capabilities to study and track the deep ocean through advancements in marine robotics technology during the past twenty years. The Monterey Bay Aquarium Research Institute (MBARI) and the National Oceanic and Atmospheric

Administration (NOAA) operate as major institutions that have built multiple submersible systems. The platforms obtain imagery and environmental data and biological samples from depths exceeding 1000 meters. MBARI operates two prominent underwater systems which include the MiniROV and Benthic Rover II.

The MiniROV, shown below in **Figure 8**, is a compact, remotely operated vehicle capable of reaching depths near 1,000m while transmitting live video and sensor readings. It allows researchers to study deep-sea habitats with precision, but requires surface support ships, winches, and a full operations team.

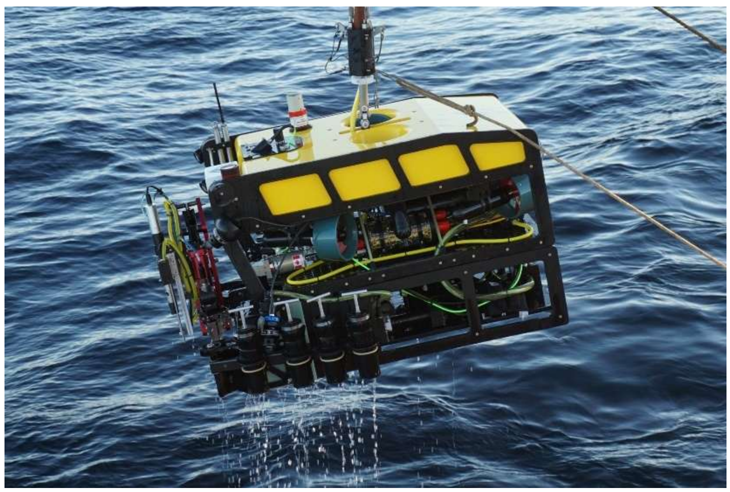


Figure 8: MBARI MiniROV used for benthic imaging and deep-sea surveys (Monterey Bay Aquarium Research Institute, 2023).

The Benthic Rover II operated by MBARI functions autonomously for extended periods reaching months and can be seen in **Figure 9**. The vehicle moves at a slow pace across the ocean floor to capture images and monitor environmental factors. The Benthic Rover II showcases extended observation capabilities, yet its operational expenses reveal the actual financial burden of underwater exploration. The construction and upkeep of the Benthic Rover II requires substantial funding because its price reaches hundreds of thousands of dollars which limits its availability to well-funded research institutions with extensive infrastructure.

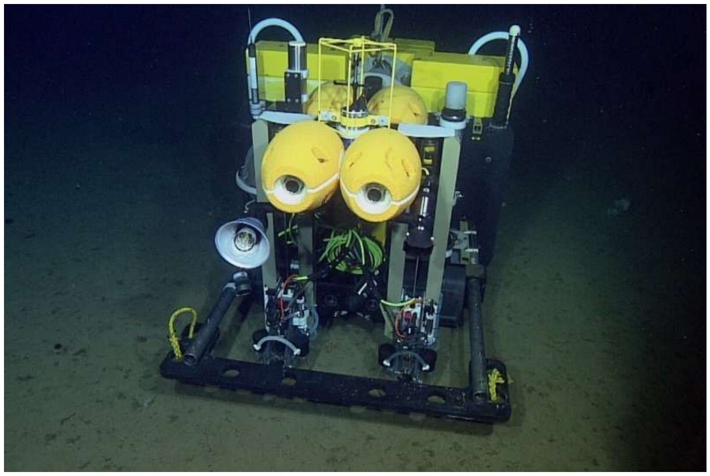


Figure 9: Benthic Rover II conducting long-term seafloor monitoring missions (Monterey Bay Aquarium Research Institute, 2023).

Compared with these high-end systems, the DOR-E lander operates as a low-cost research instrument which functions as a small-scale system compared to high-end systems. The system operates with stable seafloor imaging, controlled lighting, and a timed release for retrieval functions which operate at a reduced scale for deployment from small boats without heavy infrastructure. The simplified design of DOR-E along with its modular structure allows Cal Poly and local partners to conduct deep-sea biological surveys in the Chumash Heritage National Marine Sanctuary at costs significantly lower than traditional deep-sea missions.

1.1.5 Environmental and Engineering Challenges

The DOR-E benthic lander will go far deeper than previous iterations of this project and with that comes additional challenges. Our research location, as previously discussed, is the Chumash Heritage National Marine Sanctuary and the organization has requested strict environmental regulation to be upheld. Ideally a "Leave No Trace" set of environmental ethics is expected for our expeditions. This largely entails the ballast weight that we will drop on the seafloor to resurface must not affect the local ecosystem through heavy metal leaching. A variation of marine grade steel is the most conventional solution for other benthic landers (Williams, 2008). If a soluble dense material can be found or possibly not using ballast weights at all, that would be an even better alternative. However, the feasibility of this is yet to be proven.

Another challenge is the recovery of the lander at a depth of 1000m. Given our tight budget, it will be impossible to communicate with DOR-E once it has been released, therefore everything must be autonomous. In past groups, this has been the hardest challenge to overcome and has even resulted in the loss of the lander. Having multiple fail-safes is crucial to a successful mission. A timed electromagnetic weight release system has already been installed and is theoretically reliable in high pressure, cold temperature environments although it hasn't been tested yet by previous groups. Experiments are to be done in the hyperbaric chamber at Santa Barbara Community College to have confidence in the lander achieving a complete 1000m mission. An additional consideration is finding DOR-E once it has surfaced. Due to strong ocean currents, landers often stray from the initial drop point. Previous groups have installed a GPS that could communicate with the boat; however, it is no longer functional because the subscription that is required to use the application has expired. Renewing or replacing the GPS will be essential and increasing the visibility of the surfaced lander using bright colors, flags, or reflectors will help as well.

1.1.6 D.O.R.E. Goals and Validation Plan

The Deep Ocean Research-Explorer (DOR-E) project focuses on advancing the functionality and reliability of Cal Poly's deep-sea lander through targeted design improvements, comprehensive testing, and full-system validation. The primary goal is to create a reliable research platform capable of reaching and operating at depths up to 1,000 meters within the Chumash Heritage National Marine Sanctuary.

This year's work emphasizes three main objectives. The first is to conduct complete system integration, ensuring that all subsystems operate together as one cohesive unit. This includes electromagnetic release, buoyancy control, lighting, and imaging systems. The second goal is to perform progressive depth testing, beginning with shallow deployments off the coast of Avila Beach shown below in **Figure 10** then progressing to deep-ocean trials. The third objective is to evaluate and enhance the durability and repeatability of the system so it can be deployed multiple times with minimal maintenance between missions.

Figure 10: Planned Shallow Deployment Location, Harford Pier (Leverage Global Partners, 2018).

The performance validation of DOR-E will depend on laboratory tests and outdoor field assessments. The bench test will evaluate mechanical and electrical reliability through simulated conditions which include pressurizing housing tests and battery endurance assessments and electromagnetic release verification. The system will prove its functionality in real marine conditions through field deployments which will record video data and measure light performance and validate the automatic weight release and recovery mechanism.

By completing these tests, the DOR-E team aims to achieve the first fully validated deep-ocean lander designed and built at Cal Poly. The verified system will provide a reusable, low-cost platform for studying benthic ecosystems and will also serve as a foundation for future interdisciplinary research within the sanctuary.

1.2 Objectives and Engineering Specifications

The customer requirements are derived not only from the sponsor himself, but also from the successes and failures of the previous teams. Though critical elements are the most prioritized, additional preferences were also included, ranked by importance. In order to measure how effectively we meet the desired requirements, engineering specifications and target values were created. Identification of these design requirements was obtained through discussions with product stakeholders outlined in **Table 1** below.

Table 1: Evaluation of Stakeholders

Stakeholder	Category	Role/Description	Needs/Expectations	Project Influence	Impact of Project Outcome
Dr. Crow White	Primary	Project sponsor and end user of the product	Project successfully meets specified requirements and pre-determined deadlines.	High	High
Chumash Heritage National Marine Sanctuary	Primary	Organization and end user	Reliable lander with low environmental impact and an ability to survey marine life at varying depths.	High	High
Project Team: DOR-E	Primary	Student team designing and building the lander	Clear goals, resources, and manageable project scope.	High	Medium
Baker-Koob Foundation	Primary	Providing grant funding for the project	Product successfully meets pre-scoped goals and remains cost effective.	Medium	Low
Cal Poly College of Engineering	Secondary	Department facilitating the project	Concrete delivery of concept that fulfills the original problem statement and positively reflects the college.	Low	Low
Dr. Jenna Kloosterman	Secondary	Providing guidance adherence to academic standards	Learning outcomes and professional development of the team.	Medium	Medium
Student Research Divers	Secondary	Assisting in data acquisition and design validation of the product.	Clear direction on intended data collection procedures during testing.	Low	Medium
Cal Poly Pier Workers	Secondary	Facilitators of product testing environment	Following safety standards and guidelines while respecting the public space	Low	Low

1.2.1 Customer Requirements

To survey the necessary sections of the ocean floor in the Chumash Sanctuary, we need to have a depth rating of at least 1000m. This is the main requirement which drives the majority of the design focus. The lander should ideally be easy to redeploy, with minimal environmental impacts. It needs to be light enough to move with one or two researchers and use fish-friendly lighting. The goal is to deliver high quality video and depth data to the Chumash Heritage National Sanctuary in a cost-effective manner.

1.2.2 Engineering Specifications

To develop our specifications, we started with the depth rating requirement. While its own engineering specification with a goal of 1000m, it is tied to other specifications as well. The weight and buoyancy force will determine the lander's ability to descend and ascend from deeper depths; included is a rate of ascension metric to test for the effectiveness of the weights vs ballasts. The material strength will define how well our lander will withstand the increasing pressure as we reach our desired depths. Next was analyzing redeploy ability and endurance. The reusability/lifecycle parameter offers an overall goal of 30 deployments that our other specifications will help us achieve. The fail-safe weight release parameter was added to ensure the lander will be retrievable in extreme cases and the battery life to ensure it will be operational for two consecutive uses. The corrosion resistance would serve as the final limiting factor assuming all other parts to work at their highest efficiency. The visibility, remote control, and weight factor into the ease of use, making it easy to see and handle from the boat on deployment/retrieval. The requirements from the Chumash Sanctuary derive the leaching resistance to measure the environmental impact of the lander. Video resolution, luminosity and bait effectiveness will gauge the quality of data that is collected for the sanctuary's research. All of these specifications were analyzed in detail in Appendix A, our house of quality. This is where we connected what our requirements are to how we were going to meet them. Moreover, in the following **Table 2**, we analyzed the risks and compliance methods for each specification.

Table 2: Engineering Specifications

Spec #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1	Depth Rating	1000m	Min	H	A, T, S
2	Weight	60 lbs	Max	L	T, I
3	Cost	$4,000	Max	L	A
4	Luminosity	50 lumens	Max	L	T, I
5	Video resolution	1080p	min	L	I
6	Battery life	4 hours	min	M	A, T
7	Material strength	1470 psi	min	L	A
8	Bait Effectiveness	8 species/bait	Min	M	T I
9	Buoyancy force	90 lbs	Min	L	A, T

Spec #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
10	Corrosion resistance	0.03 mm/year	Max	L	A
11	Reusability\ lifecycle	30 deployments	Min	M	A, T
12	Remote control	Operating distance 2 ft	Min	L	T, I
13	Visibility	100m	Min	M	I
14	Rate of ascension	2m/s	min	L	A, I
15	Fail-safe weight release	4 hours	max	M	A, T
16	Leaching resistance	9.5 µg/(cm^2 * day)	Max	L	A

1.3 Methods of Approach

To meet the goal of creating a verified deep-sea lander that can operate at depths of around one thousand meters, our team plans to take a step-by-step engineering approach built around testing and refinement. The team follows the Cal Poly senior design framework but will be adjusted for the specific challenges. We will focus on practical testing, careful documentation, and reliability at every stage.

The first step will be to confirm the design requirements and performance objectives established with project sponsor, Dr. Crow White. Reviewing the data and lessons learned from the BRUVERS team will allow the current team to identify weaknesses in the previous design, such as limited depth testing, uncertain release performance, and incomplete system integration. These findings will also guide future adjustments of subsystems, including the electromagnetic release, buoyancy configuration, power management, and lighting arrangement.

Once requirements are validated, the team will model conceptual improvements using SolidWorks and other design tools. Analytical calculations and simulations will predict how the lander will behave under hydrostatic pressure and buoyant forces, as well as verify the structural strength of key components. Each subsystem will then be prototyped individually so that the electromagnetic release, pressure housing, lighting system, and camera assembly can be tested under controlled conditions. These bench tests will evaluate pressure resistance, power consumption, illumination range, and release consistency to ensure compliance with all the engineering specifications outlined previously in the report.

After individual testing of every component, all components will be integrated into one single working prototype. The complete DOR-E assembly will first be tested in shallow water near Harford Pier on Avila Beach. This location is chosen as step one because recovery is straightforward, and conditions can easily be monitored. These tests will confirm that the lander's subsystems interact correctly. It will also confirm the reliability of the ballast release triggers, and buoyancy system. Findings from the first few tests will help the team make small adjustments to mechanical joints, improve seal performance, and clean up the wiring layout.

After the shallow-water trials, the team will begin deeper testing within the Chumash Heritage National Marine Sanctuary and Santa Barbara Community College. We have contacted SBCC to request use of their hyperbaric chamber so that we may perform pressure tests to verify function of all components before testing in the field. These tests will show how the lander performs in a truly deep-ocean environment. The system will face high pressure, low light, and cold temperatures while recording data during descent and ascent. The team will check stability, battery life, and the overall reliability of the system. Recovery performance will also be evaluated to confirm that the release and flotation mechanisms work as intended at depth. Once the lander is recovered, the team will review all data and footage to see if DOR-E meets the performance targets.

During the design and testing phase, the team will record all results in detail to track how the lander performs over time. Notes from both lab and field tests will help guide small design changes as the project develops. The team will look at factors such as materials, part placement, and electrical layout to improve the system after each test. All test results, SolidWorks models, and technical documents will be organized into one final report. This process will help ensure that DOR-E becomes a reliable and fully integrated lander that supports Cal Poly's future research in the Chumash Heritage National Marine Sanctuary.

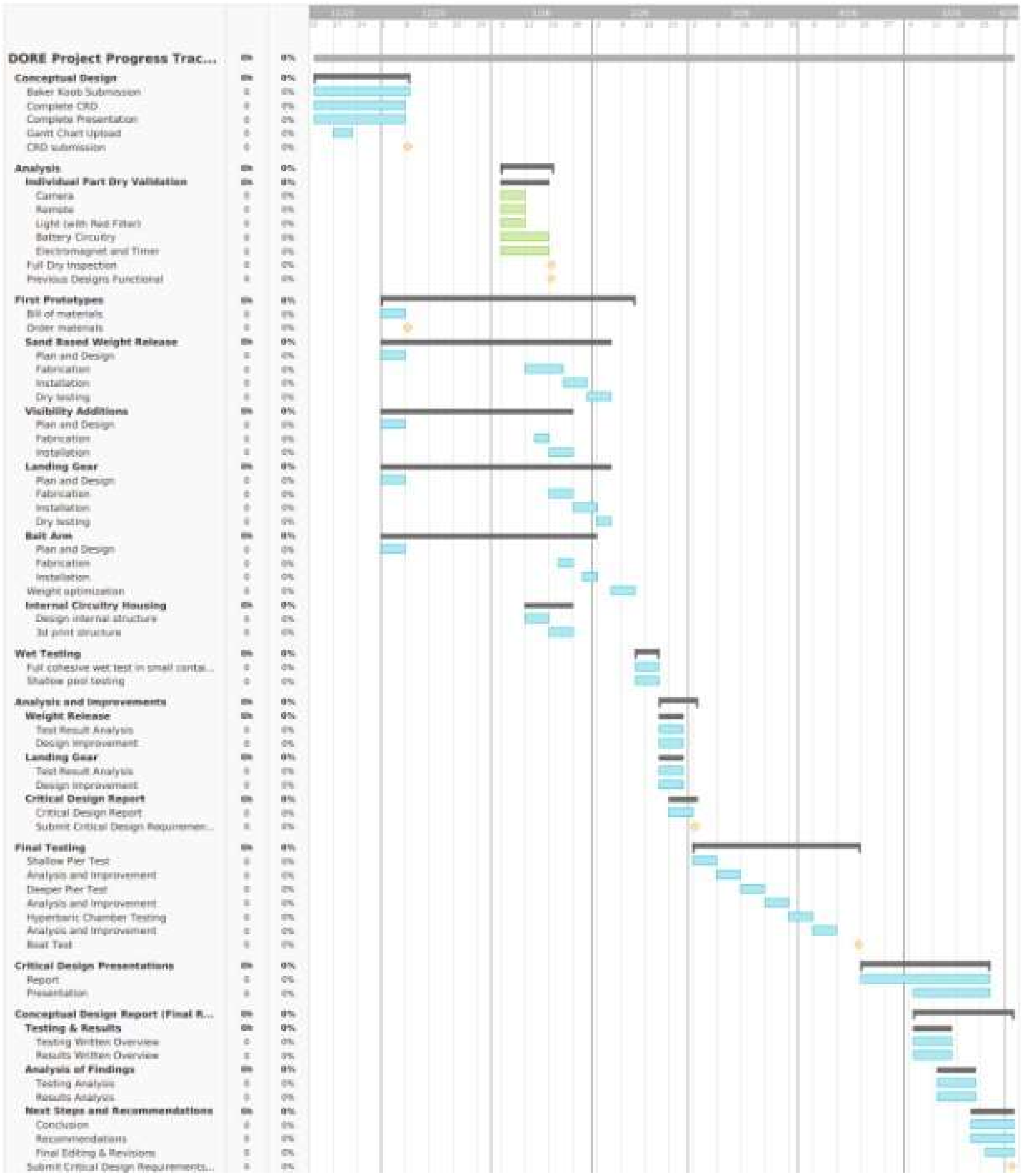
1.4 Management Plan

Our project team, consisting of five members, operates with a collaborative and fluid structure where all members contribute equally to the project's overall success. While individual roles aren't rigidly defined, we strategically leverage the diverse technical backgrounds within the group. Patrick provides an essential biomedical engineering perspective and serves as the primary sponsor contact, managing external communication and coordination. August's computer engineering experience will cover all electrical components, circuitry, and programming required for the project. The mechanical design and fabrication will rely on the combined mechanical engineering expertise of Spencer, Arav, Patrick, and Bruce, utilizing their background in hands-on design as well as their skills in various CAD and FEA software. This structure allows us to maintain flexibility and ensure that the most appropriate skills are brought to bear on each design challenge. We each plan to invest between 2 – 4 hours of work on this project every week outside of the 6 hours we are already scheduled, for a total of 240-300 hours as a group after 30 weeks. Multiplied by our five team members, this project would total 1200–1500-man hours.

Communication is a key part of any team's success in achieving their goals. Our primary method of communication between Dr. Crow, various sponsors, or other official team messaging will be through email with Patrick McGee as our primary contact. Intra-team communication will be conducted in person during the lab hours, and through text or discord discussions outside of class. As per our team contract, our outside-of-class communication will be as follows:

1. Respond or react to all group directed messages.
2. Respond to texts within 24 hours.
3. Update availability as soon as it changes.

1.4.1 Timeline



November 4th - Finalize Idea selection & design scheme

December 2nd – CDR Presentation

February 7th – Testing weight release and other individual components

February 27th – Testing at the pier

April 13th - Testing hyperbolic chamber in Santa Barbara

May 21st - Testing out at sea with Chumash Reservation, weather permitting

2. Design Development

The design development phase of the project focuses on converting initial requirements, stakeholder needs, and engineering specifications into measurable subsystem improvements for the lander. The design development approach emphasizes concept generation, evaluation, and justification using structured decision-making tools such as Pugh Matrices and the House of Quality. Each subsystem, including the weight-release system, landing gear, visibility enhancements, bait arm design, and lighting improvements, were analyzed independently to identify shortcomings in past iterations and opportunities to improve performance, reliability, and environmental impact.

This section presents the conceptual solutions generated for each subsystem, the reasoning and justification behind the selection of each design, and the engineering specifications that they address. For every component, broad brainstorming was performed, concepts were narrowed down using objective evaluation criteria, and refined designs were developed that aligned with the project's primary goal: achieving a fully validated 1000-meter research lander that is recoverable, environmentally responsible, and capable of high-quality data collection. The following subsections document this process by summarizing alternative ideas, providing sketches or models of the top candidates, and explaining how each selected design contributes to the overall functionality and reliability of the DORE Ocean Lander.

2.1 Environmentally Friendly Weight Release System

The primary objective of changing the weight-release system would be to minimize long-term environmental impact on the seafloor while maintaining or improving the reliability of the release schedule. The current ocean lander uses iron chains as an expendable ballast. These chains are released at the end of a deployment and remain on the ocean floor, contributing to metallic debris and potential heavy-metal leaching over time, across repeated deployments. Using the Pugh Matrix developed for the weight-release system in **Appendix C.1**, multiple ballast concepts were evaluated, and a sand-based system was determined to provide the best balance between environmental performance, practicality, and compatibility with the existing lander architecture. Sand is locally available, inexpensive, and bioinert in the ocean once released.

After selecting a sand-based weight release concept at the material level, the team generated several mechanisms for storing and releasing the sand. In total, four distinct concepts, including the chain system as the datum, were considered for the weight-release system:

1. **Hook system with canvas sandbag**: A canvas sandbag filled with sand, attached to a set of hooks held in place by electromagnets. At the end of the mission, the electromagnets de-energize, the hooks release, and both the sandbag and hooks remain on the seafloor.
2. **Hook system with tarp attachment**: A variation of the hook concept where a tarp or sling is attached to the hooks instead of a discrete bag. When released, the tarp and hooks are left behind with the sand.
3. **Motorized container with "eyeglass-style" twisting lids:** A rigid container subdivided into chambers, each with a rotatable lid. A small motor would twist the lids open at the end of the mission to dump sand from the chambers.
4. **Electromagnet-supported sand container platform:** A rigid platform carrying multiple sand containers, held in place against the underside of the lander by an electromagnet. Smaller magnets or seals on each container maintain closure against the platform. When the electromagnet de-energizes, the platform slides down along vertical rails, opening the lower faces of the containers and allowing sand to fall out, while all hardware remains attached to the lander.

Concept sketches of the electromagnet-supported sand container and hook-based sand systems are shown below in **Figure 11, Figure 12** and **Figure 13.**

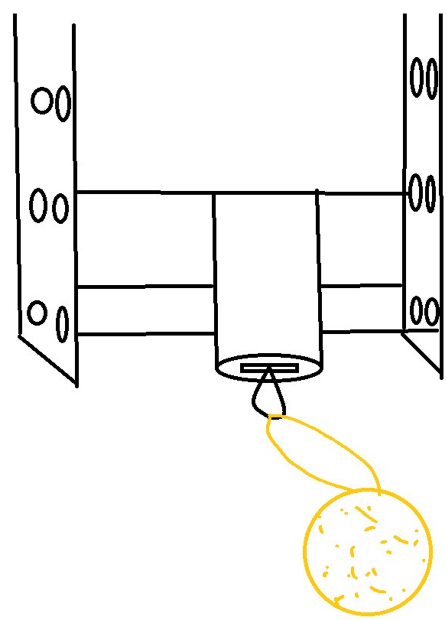


Figure 11: Hook and Sandbag Weight Release Sketch

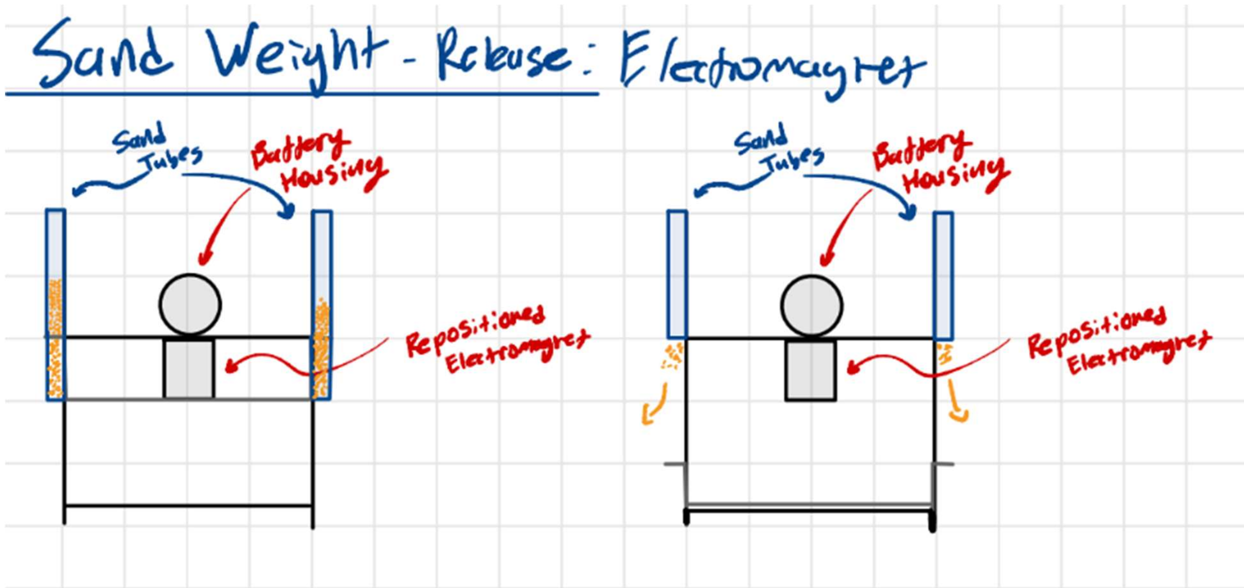


Figure 12: Electromagnet-support sand container weight release system

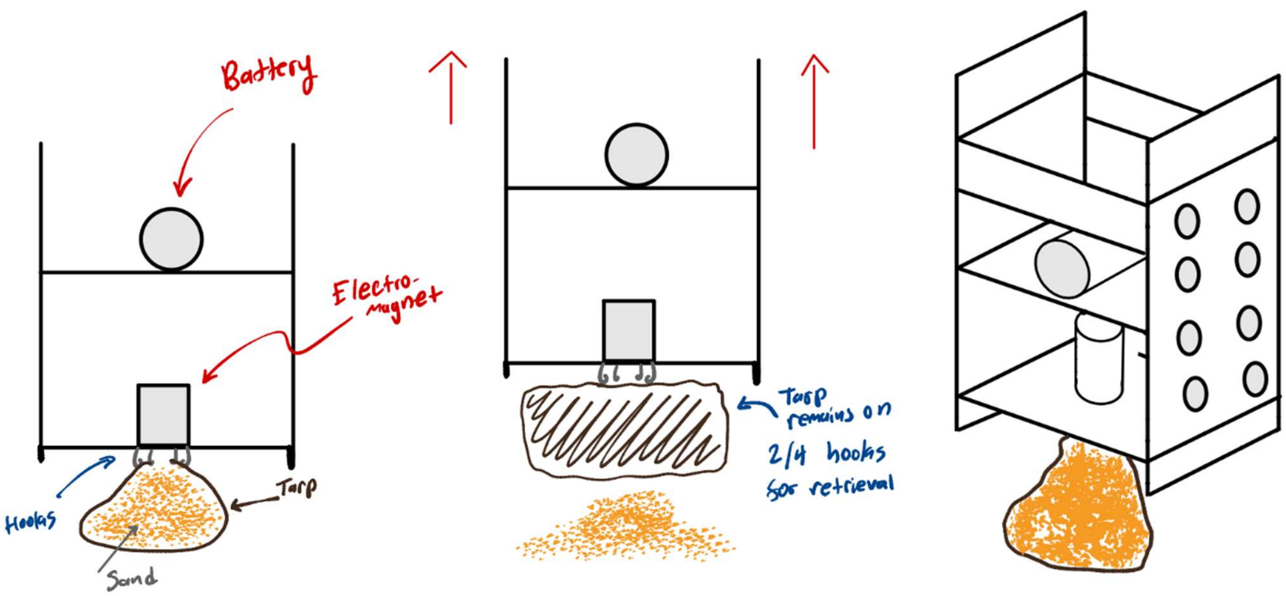


Figure 13: Hook and Sand-filled Tarp Weight Release System

These concepts were developed to explore a range of trade-offs between mechanical complexity, environmental impact, integration effort, and reliability under deep-sea operating conditions. Concept selection for the weight-release system was carried out in two stages using Pugh matrices.

In the first stage (**Appendix C.1**), ballast material and general approach alternatives (iron chains, sand in expendable bags, sand in reusable containers, etc.) were compared using the existing iron-chain design as the datum. Criteria included environmental impact, cost, ease of reset between deployments, compatibility with current electronics, and perceived reliability. This evaluation showed that a sand-based system, where only sand is left on the seafloor at the end of a mission, significantly outperformed the existing chain-based approach.

In the second stage, a new Pugh matrix was created to compare specific mechanical implementations of the sand-based system (hook-and-sandbag, hook-and-tarp, motorized twist-lid containers, and the electromagnet-supported platform concept). The same datum was maintained for consistency. Key evaluation criteria included:

- Environmental footprint (amount and type of hardware left on the seafloor)
- Dependence on new underwater electrical components
- Ease of resetting and refilling between missions
- Mechanical robustness at depth (1000 m)
- Integration complexity with the existing lander frame and electronics

The motorized twist-lid container system was penalized heavily due to its reliance on additional motors and moving parts operating at high pressure, which increases failure risk and power consumption. The hook-based systems reduced the number of long-term debris compared to iron chains, but still required leaving hooks, bags, or tarps on the seafloor and added more external hardware that could snag or trap sediment.

The electromagnet-supported sand-container platform scored highest overall in the second Pugh matrix. It leverages the existing electromagnetic release hardware, requires no additional electrical complexity, and ensures that all structural components (platform, rails, and containers) remain attached to the lander. Only sand is released to the seafloor, satisfying the "leave no trace" goal as closely as practical. The platform can be designed with a simple vertical sliding motion guided by rails, which reduces mechanical complexity and makes the system straightforward to reset and refill on deck.

The chosen configuration is shown schematically in **Figure 12** and is referenced in the Pugh matrices in **Appendix C.1** and **C.2**.

The environmentally friendly weight-release system was developed to address several key engineering specifications outlined in **Table 2:**

- **Fail-safe weight release (Spec 15):** The platform design maintains compatibility with the existing timed electromagnetic release and allows the inclusion of redundant release strategies (e.g., backup float, manual safety link) without major geometric changes. By guiding the platform on rails, the risk of binding or jamming is reduced, helping to ensure that the sand weight is reliably released within the 4-hour maximum window specified.

- **Depth rating (Spec 1):** All components of the new system (platform, rails, and containers) can be fabricated from materials already proven or commonly used for 1000-meter-class systems (e.g., acetal copolymer, anodized aluminum, or 316 stainless steel). The design avoids thin, complex housings or delicate mechanisms that would be especially sensitive to deformation at high pressure.

- **Weight (Spec 2) and Buoyancy force (Spec 9):** The total sand mass carried on the platform will be selected to provide sufficient net downward force to ensure stable descent while still enabling the specified rate of ascension once released. Because sand density is well known and easily adjusted by changing fill volume, the new system provides a tunable way to match mission-specific ballast requirements without major structural changes.

- **Cost (Spec 3):** Sand is an inexpensive, readily available ballast material. The main added costs are the platform, rails, and containers, which can be manufactured using standard machining or polymer fabrication methods. The reuse of existing electromagnets and control electronics helps keep overall system cost within the project budget.

- **Reusability/lifecycle (Spec 11):** The platform and rails are designed as permanent hardware, while sand itself is a consumable. Between missions, the platform can be slid back into its loaded position, containers refilled with sand, and the system reset without replacing any specialized components. This supports the target of at least 30 deployments over the system's lifecycle.

- **Leaching and Corrosion Resistance (Specs 10 and 16 for new parts):** All new manufactured components in the weight-release system will be made from corrosion-resistant materials such as acetal, HDPE, or marine-grade stainless steel. Because only inert sand is released, there is effectively no contribution to heavy-metal leaching, directly supporting the Chumash Heritage National Marine Sanctuary's environmental expectations and the leaching resistance target.

Overall, the environmentally friendly weight-release system evolves the DOR-E lander away from iron-chain ballast and toward a sand-based platform that leaves bioinert material on the seafloor. A structured concept generation and selection process, supported by Pugh matrices **(Appendix C.1 and C.2)**, led to the selection of an electromagnet-supported sand-container platform guided by rails. This design minimizes environmental impact, maintains or improves reliability of the release event, and integrates well with the existing lander while satisfying key engineering specifications related to depth rating, fail-safe operation, buoyancy, cost, and reusability.

2.2 Landing Gear

From the instance where the lander failed to return to the ocean surface, we can only theorize what went wrong. One of the theories is that the lander may have gotten wedged in the sand at the bottom of the ocean upon landing. We suspect this would occur if the lander were descending too quickly, as a hard impact with the ocean floor may imbed the lander in the sand at the bottom. Over the course of its recording, the lander may also slowly sink into the sand. The goal with this subsystem would be to prevent these possibilities while maintaining the following engineering specifications outlined in **Table 2.**

- **Weight (Spec 2) & Buoyancy Force (Spec 9):** Balanced weight of ocean lander with the buoyancy force needed to lift the lander off the ocean floor once weight is released.
- **Material Strength (Spec 7):** Adequate strength of any material used, especially for landing gear as it would be taking the brunt of the impact with the ocean floor.
- **Leaching (Spec 16) & Corrosion Resistance (Spec 10):** Any new materials used must pass leaching and corrosion requirements
- **Cost (Spec 3):** Cost of new materials and implementation of chosen solution should be minimized

To begin with, we deliberated how to slow the ocean lander’s descent. For this, we thought to add a parachute that would release as the lander reached its target depth before impacting the ocean floor. This would ensure a soft landing and allow the lander to sit loosely on top of the sand. This idea would require the ability to gauge ocean depth and initiate the parachute release at a specified depth for each deployment. We would also need to develop a way to prevent the parachute from interfering with other subsystems on the descent and ascent. We considered the possibility of having multiple, smaller parachutes that are permanently deployed to minimize this risk but to slow the lander’s descent too much would make it increasingly susceptible to ocean currents knocking it off course. Given the various complications and variables that arise with the parachute method, we deduced that a different approach could result in a more reliable option.

As an alternative, we took the route of implementing landing gear at the bottom of the ocean lander. The right design would lessen the effects of the impact on landing and provide a platform for which the lander can sit and easily ascend from. The following ideas were generated and compared, along with the parachute method, against the default frame of the ocean lander in **Appendix C.5**.

1. Legs (**Figure 14**): Taking inspiration from lunar landers made by NASA, these legs would protrude from each of the four corners with sizeable pads on the bottom with enough surface area to remain on the sand's surface.

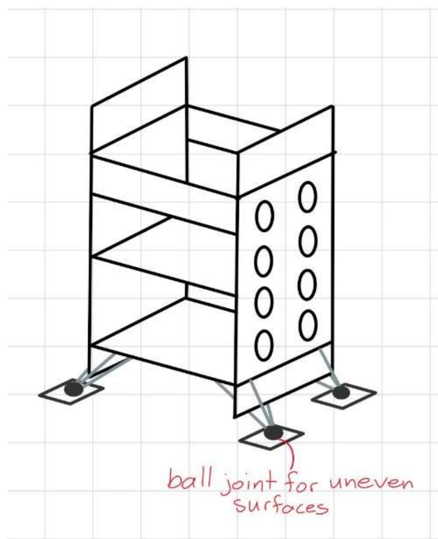


Figure 14: Landing Gear – Legs Sketch

2. Flat Platform (**Figure 15**): A large flat sheet that would be attached to the bottom of the lander. This idea represents the extreme on one end as an increasing the surface area of the landing gear would distribute the force of the impact and prevent any protrusions from imbedding themselves in the sand and acting as an anchor.

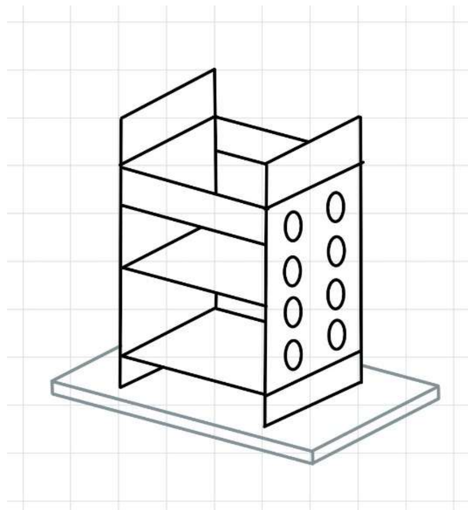


Figure 15: Landing Gear – Platform Sketch

3. Spikes (**Figure 16**): Where the other ideas attempt to prevent any parts of the lander from imbedding in the sand, the spikes would purposefully stick in the sand in a controlled manner and act as a safeguard from any components that would act as an unwanted anchor. With the right size, array, and material of the spikes, the lander would be able to lift from the ocean floor with minimal interference.

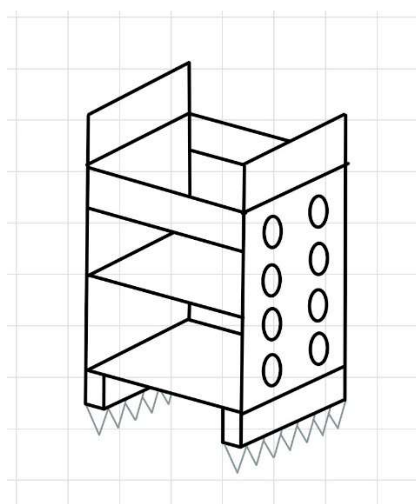


Figure 16: Landing Gear – Spikes Sketch

4. Rails (**Figure 17**): Reflecting the design of helicopter skids, rails would extend slightly from the ocean lander's frame and act as landing gear in a manner similar to the leg design, while offering a sturdier frame. Placing the rails parallel to the side panels would be the natural application and may offer extra support for the new

weight system. Placing them perpendicular to the side panels would provide additional cross support and could be preferred if we find that beneficial.

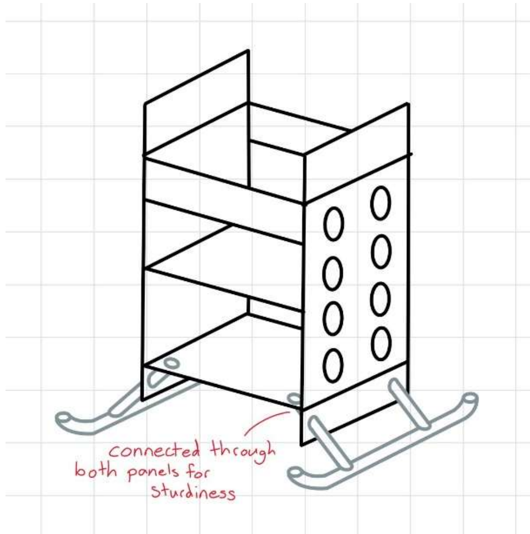


Figure 17: Landing Gear – Rails Sketch

Through the Pugh Matrix for these landing gear options (**Appendix C.5**), we concluded that the leading design is the spikes. This design would allow for a smooth lift off from the ocean floor while increasing structural integrity and decreasing the force exerted on the frame upon landing compared to the other designs. However, this analysis is only theoretical. The spike design relies on the ocean floor comprising of sand or small rocks that the spikes can land in. A floor made of solid rock would likely damage the spikes and provide an unstable landing site. Testing of each design's practical efficiency as well as research and surveying of deep ocean terrain would be necessary and will be explained further in **Section 2.10**.

2.3 Visibility Markers

In order to increase the likelihood of recovering the vehicle, we would like to maximize the visibility of our design. We considered five methods, including repainting it marine orange to increase contrast against darker water, adding mirrored reflectors, building a tall flag and securing it to the frame, attaching an automated flare gun, or creating an expandable tarp system. The previous team painted the lander from orange to black, claiming that black would be an easier color to spot on the horizon as it contrasts the shiny reflective waters. However, we believe there are better ways to increase visibility on the horizon, such as adding a tall flag to stick out from the water. Having a bright color would increase the visibility as we near the craft, making it much more visible on its ascent near our boat, see for paint reference.

Figure 18: Painted lander from the Pier Pressure team (Gaskell et al., 2024)

Reflectors attached to the frame should also increase visibility, as they reflect daylight from the lander, making it appear shiny underwater or while bobbing on the surface. Having a tall flag could also be implemented along with the orange paint and the reflectors, combining their benefits into one design with the most visibility range with a reasonable amount of modification and low cost. Both ideas are shown below in **Figure 19**.

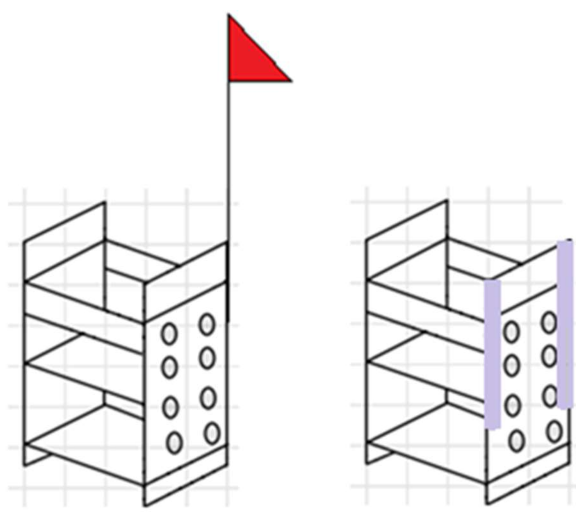


Figure 19: High Contrast Flag and Reflector Based Visibility Sketches

The last two designs, shown in **Figure 20**, involve more complex moving parts that would require further waterproofing and storage but have a large visibility range. A release mechanism would trigger either the flare or a large unfolding tarp when it hits the surface and would certainly increase the distance at which the lander would be detected. They would also be more expensive and incur recurring costs per deployment.

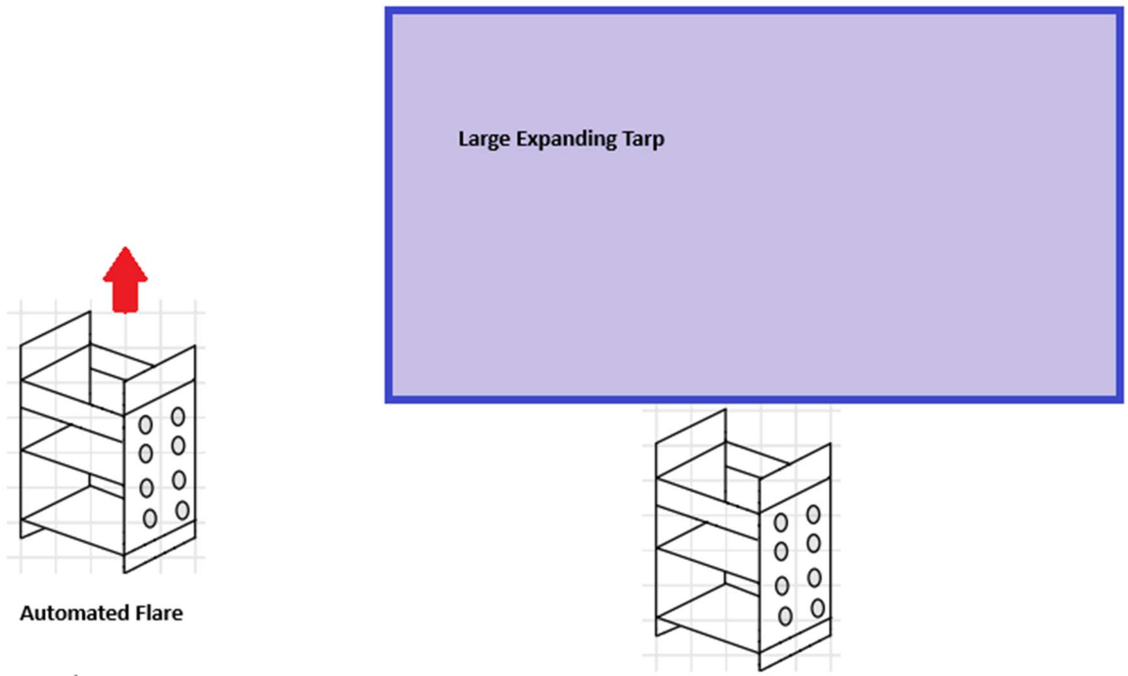


Figure 20: Concept Sketches for Flare and Tarp Deployment from Ocean Lander

When making the final decision on which solution would be best to maximize visibility, there were five key criteria:

- **Visibility Range (Spec 13)**: The general distance from which the design is visible, should be maximized
- **Low Recurring Cost (Spec 3)**: We would rather have a design that has no recurring costs, minimized if necessary.
- **Low Initial Cost (Spec 3)**: The cost of implementing the specific solution should be minimized
- **Compact Size – Weight (Spec 2) & Reusability (Spec 11)**: Must be compact to optimize the rapid deployment of multiple landers. The bigger and bulkier each lander is, the more complicated it is to move and deploy.
- **Feasibility – Lifecycle (Spec 11):** the more complex an addition to the lander, the more likely a source of possible failure.

Each design was analyzed for these five criteria, and though the flare would have been the most visible, its recurring costs and high complexity meant that it would not have been as reliable as the flag, reflectors, and paint. Overall, the single best design was adding reflectors, as seen by the Pugh Matrix in A**ppendix C.4**, but we are most likely going to implement three designs, adding the flag and possibly painting it orange as well.

2.4 Bait Arm Improvements

The BRUVERS team used a simple bait holder, seen in **Figure 21**, made from loose nylon netting zip-tied to a flat bait plate. While this worked for early shallow-water tests, it created several problems that would limit repeatable biological surveys. The netting was difficult to reload, it sometimes sagged out of the camera's field of view, and repeated cutting of zip-ties made the system slow to reset. It also introduced small pieces of plastic that could detach during deployment, which conflicts with the "Leave No Trace" expectations of the Chumash Heritage National Marine Sanctuary. The figure below shows the previous system as documented by the BRUVERS report.

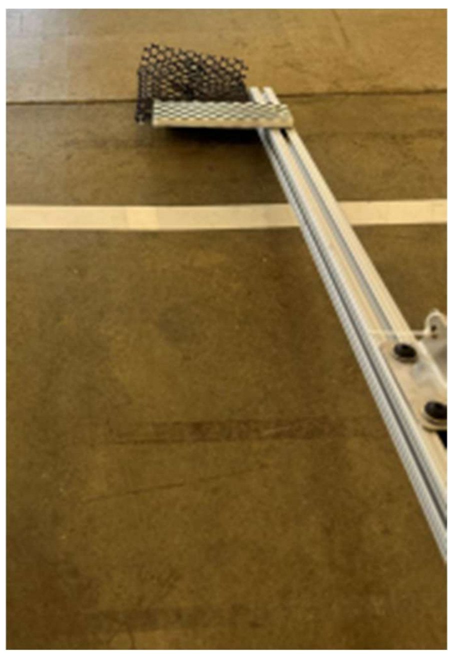


Figure 21: Previous nylon net bait holder (Closser et al., 2025)

To improve consistency, reduce environmental impact, and simplify reloading, our team generated five alternative bait-holder concepts:

1. Stainless wire-mesh bag **(Figure 22)**: This idea uses a flexible stainless-steel mesh bag that behaves similarly to a small metal net. It offers strong durability and excellent resistance to corrosion. However, the open mesh can snag easily on the frame, and its shape may deform under motion, which can shift the bait out of view.

Figure 22: Stainless wire-mesh bait bag ("Stainless Knitted Pouches," n.d.)

2. Crab snare cage **(Figure 23)**: This option adapts a crab snare-style wire cage with spring-loaded loops. It is very secure for bait retention and resists tearing, but it is heavier than other designs and increases drag. It also holds a small volume of bait compared to other alternatives. Furthermore, its wire loops can also present snagging hazards during ascent or handling.

Figure 23: Crab-snare style bait cage (Calissa Offshore Tackle, n.d.)

3. Rigid chum basket/bait cage **(Figure 24)**: This design uses a rigid perforated plastic or polymer cage that allows consistent scent release while keeping the bait centered in the frame. It is easy to reload, resists snagging, and can be cleaned quickly between dives. Its predictable geometry also improves the repeatability aspect for surveys.

Figure 24: Rigid chum basket / perforated bait cage (Promar, n.d.)

4. Screw-top jar with drilled holes **(Figure 25)**: A repurposed HDPE or poly jar with small, drilled holes. This concept is inexpensive, easy to clean, and ideal for rapid reloads. Its downside is reduced scent diffusion unless the opening pattern is optimized, increase drag, reduced visibility, and that the jar may trap air pockets during descent.

Figure 25: Screw-top perforated bait jar (Seattle Marine and Fishing Supply Co., n.d.)

5. Biodegradable drawstring bait bag **(Figure 26)** This variation uses a cotton or jute fiber pouch that naturally breaks down if lost. It has excellent scent diffusion and the lowest environmental impact. However, its durability is limited, and it may release fibers or tear under strong currents or repeated deployments.

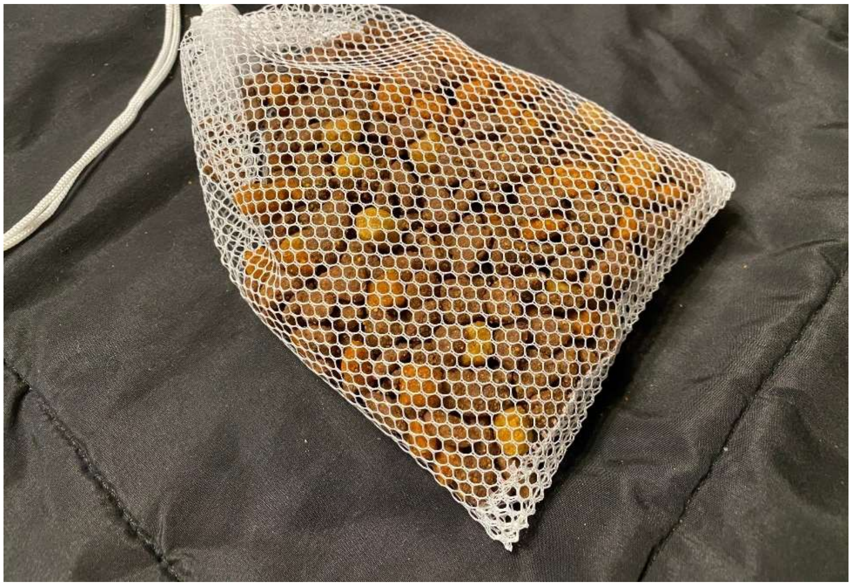


Figure 26: Biodegradable drawstring bait bag (Reel Texas Outdoors, n.d.)

These concepts were compared using a Pugh matrix (Appendix C.6), based on criteria such as scent diffusion, bait retention, snag risk, ease of cleaning, durability, and environmental impact. The chum basket/bait cage produced the highest weighted score and was selected as the primary design.

The selected bait cage is a rigid perforated container similar to those used in recreational and scientific chumming as seen in **Figure 27**. Its structure allows continuous scent diffusion while preventing large pieces of bait from falling out during descent. Unlike the netting, the rigid walls keep the bait centered in front of the camera at all times and reduce the chance of snagging on the frame. A hinged lid with a simple latch allows divers or researchers to reload the bait within seconds on the deck. A general example of this style of chum basket is shown in the figure below, which mirrors the design principles we adopted for DOR-E.

Figure 27: Example chum basket design (Beau-Mac, n.d.)

The rigid bait cage improves reliability while also aligning with our environmental goals. The cage will be mounted using two stainless steel hose-clamp brackets, so the bait remains fixed in the camera's field of view during descent and bottom contact. It eliminates single-use plastic and significantly reduces the chance of losing material into the marine sanctuary. It also improves survey repeatability since the bait's location and orientation remains the same between deployments.

2.5 Lighting System Improvements

The current lighting system, as seen in **Figure 28**, consists of a small concentrated white LED light that provides a listed 1720 lumen light source in a concentrated area. However, neither the luminosity rating nor functionality of the light has been tested by the previous group. In their report it stated that the prior 2 lights of the same model were faulty, so it is of utmost importance to conduct a luminosity test to determine whether we can move forward with the current system. This can be done with a smartphone light sensor at various distances at no additional cost. Additionally, the white LED light is visible to fish and other benthic organisms, so it would very likely scare away these animals that are used to very low light conditions at 1000m depths. A red-light filter, as suggested by our advisor Dr. Crow, would be the simplest solution as most fish cannot see red light and it is commonly used in night fishing applications. This would slightly increase the overall cost but would significantly increase the bait efficiency and video quality when the camera records on the seafloor.

Figure 28: Current Light System

2.6 Design Validation Testing: Depth Pressure

In the past iterations of this project, safely testing the ocean lander at great depths has been the greatest challenge. In 2023, the ocean lander was lost to sea because it was unable to return during depth testing of 100m on the Cal Poly boat. Various options to improve this testing method were considered in the Depth Testing Pugh Matrix, listed in **Appendix C.3**, with the top 3 choices being testing off the pier, off the boat, and in a hyperbaric chamber. The main considerations were the ability to test the full assembly, the retrievability of the lander if it were to fail, and the maximum depth it could be tested at. The overall best choice was the hyperbaric chamber because it is very easy to retrieve in the case of component failure while meeting other criteria sufficiently. The main drawbacks are the availability of these chambers because they're part of the Marine Diving school at Santa Barbara Community College, and they can only test to a maximum of 100m. However, it is still very valuable because many of the other engineering specifications like battery life, material strength, and corrosion resistance can be safely tested in a controlled environment. To prepare for this principal test, the preliminary tests (discussed in the following sections) will be conducted at the Hartford pier **(Figure 29)** with the lander attached to a rope at very shallow depths to ensure that our full assembly is functioning properly together. The final testing phase following the pier and chamber tests will be to drop it from a boat for real world depth testing. There are 2 test locations available to us, the Santa Barbara basin that reaches a 500m depth collaborating with SBCC, and the CHNMS with a depth of 1000m accessible through Dr. Crow. Due to availability and the weather conditions, we will likely only have one scheduled opportunity at each location to test the lander. The lander will be equipped with an additional surface buoy connected by a fishing line to track the lander's drift experienced by the ocean current to improve retrievability. These trials will conclude whether the lander is ready for full scale research.

Figure 29: Hartford Pier Test Location

2.7 Design Validation Testing: Improved Weight-Release System

The previous BRUVERS lander used a simple electromagnetic release attached directly to a hanging chain of ballast seen below in **Figure 30**. The magnet grabbed a small steel tab, and when the timer shut the magnet off, the chain was supposed to fall away. This worked in shallow trials, but it had several problems. The chain segments stayed on the seafloor after every deployment, which is not ideal for a protected marine sanctuary. The free-hanging chain could also swing, catch on the frame, or load the magnet at an angle. On top of that, the system was never tested at pressure or as part of a fully loaded lander, so its reliability at depth was unknown.

Our updated system, conceptualized in **Figure 31**, keeps the electromagnetic release concept, but it changes how the weight is handled. Instead of a loose chain, we use a sand-based ballast load mounted on a guided platform. A flat steel plate on the platform sits directly against the face of the magnet. This gives a consistent contact surface and removes the twisting that came from a swinging chain. When the magnet turns off, the entire platform drops straight down and leaves no metal behind. The sand itself is environmentally neutral, as it’s homogenous to surrounding sediment rather than scrap hardware.

Figure 30: Previous BRUVERS electromagnet and chain ballast system (Closser, 2025)

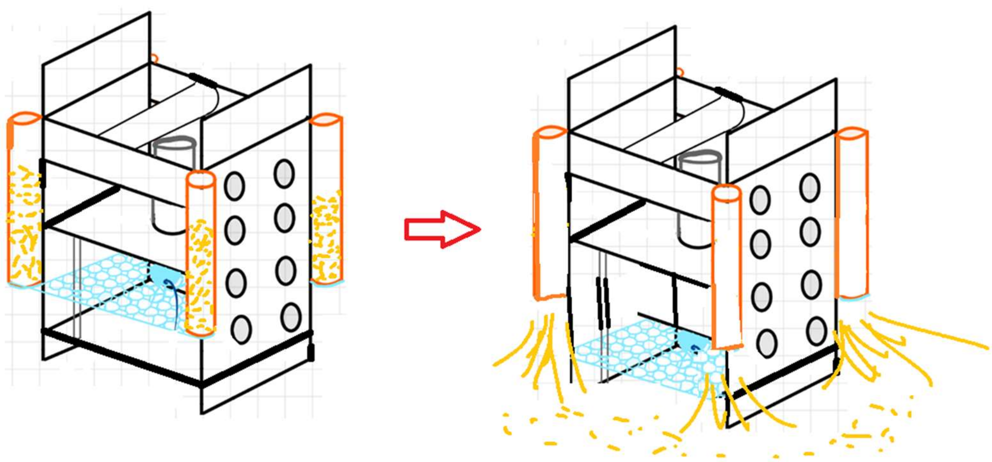


Figure 31: New sand-platform weight-release concept

Before any pier or water trials, we will start with land-based tests to measure the basic reliability of the new platform. These tests involve mounting the release assembly on a fixed frame and repeatedly cycling the magnet while the platform carries a full sand load. We will record how consistently the platform falls, how quickly it disengages after power is cut, and whether the rails keep the drop path straight. Land-based testing also helps us check things like mechanical interference and latch sticking without risking the full lander.

To validate these improvements, we will compare how the new system behaves against the expectations set by the old design. Test will measure release consistency of the lander. Pier deployments with the complete lander will also confirm that the ballast stays attached during descent, releases on command, and does not leave any hardware behind on the bottom. If the lander surfaces reliably in these trials and the seafloor is left clear of debris, we will consider the new weight-release system successfully validated and a clear improvement over the previous chain-based design.

2.8 Design Validation Testing: Visibility

In order to validate the new visibility design implementation, we will need to conduct a test that evaluates the additional visibility from the flag, orange paint, and reflectors. The only accessible way we can effectively simulate the ocean horizon would be going to a beach, placing the lander near the water's edge, and backing up until we can no longer effectively distinguish it. During this test, the five of us will all walk backwards in a line and stop when it is no longer visible. This will give us a rough idea of how close we need to be to the ascension point of our lander and the radius it is able to drift via underwater currents while still being recoverable. First, we will take the average distance, in meters, our team is able to spot the lander without visibility changes and use this as a benchmark. Then, we can repeat this test after adding the flag, new paint and reflectors, and see by how much we have increased the distance from which we can see the lander. We will also repeat this test on particularly foggy days, to simulate the worst-case environmental conditions for visibility.

2.9 Design Validation Testing: Bait Arm

To validate the new design, the team will conduct three stages of testing. First, a timed reload simulation for each system, recording time and comparing the efficiency of repeatability. Second, a water-tank test which will evaluate bait retention, scent diffusion, and latch security during shaking and simulated impacts. Third, pier-drop tests will confirm that the bait cage remains mounted, stays visible in the camera frame, and does not snag as the lander lands on or lifts off the seafloor. Successful completion of these tests will confirm that the chosen bait cage satisfies the engineering specifications for bait effectiveness, durability, leaching resistance, and reusability.

The purpose of these tests is to verify that the new bait-holder design performs better than the loose nylon netting used by the BRUVERS team, which often shifted during deployment and made bait placement inconsistent. The rigid chum-basket design selected by DOR-E fixes the bait in a centered, predictable location and prevents the netting from sagging or shedding material into the water column.

The first round of testing focuses on human-factor repeatability, since each pier drop will require quick resetting on deck. By measuring how long each reload takes, the team can confirm that the bait cage meets the requirement for ease of use and supports the specification for reusability.

The second round, performed in a water environment, checks behavior under motion. By shaking the bait arm assembly and applying small impacts against the tank wall, the team will confirm that the latch remains secure and that bait does not escape during deployment.

The final stage consists of real-environment pier tests. The lander will be lowered from Harford Pier and retrieved by hand while the onboard camera records the bait cage throughout descent and ascent. This footage will confirm whether the cage remains in view, whether sediment or currents disrupt its position, and whether the cage maintains its attachment during bottom impact. Any failure during these tests will lead to future iterations in hardware.

2.10 Design Validation Testing: Landing Gear

To validate the chosen landing gear design, we need to conduct tests that would evaluate the stability of each proposed design and the effective prevention of each design getting stuck in the sand. To do so we can perform the tests in the same environment and perhaps on the same day as the visibility validation testing to maximize testing efficiency. First, we would need to create prototypes of each design to bring to the beach. These can be 3D printed or made from PVC as we are primarily testing the designs and how they interact with a sand floor rather than the durability itself. For the spike design, multiple prototypes can be made from different materials to test which has the least friction with the sand when pulled out.

To assess the stability of each design upon landing, we can take each prototype and thrust them into the sand and gauge the impact of each, its effectiveness to distribute the force and likeliness to dig into the sand. This test would be relatively subjective, forming opinions and observations on how each design interacts with sand and how it would operate with the full lander. Each team member can take turns with each design and create a discussion on these terms.

To assess the ease with which each design can lift from the ocean floor we can use a hanging scale attached to the prototypes to measure and compare the force needed to lift each design. To simulate the worst-case scenario, we can forcefully embed each design deeper in the sand and measure the force needed to get them out.

The design that does the best overall at redistributing the force of the landing and guaranteeing an easy ascent will be the final design. The validity of the validation testing also depends on the composition of the ocean floor as it may not be solely fine sand. We would need to confer with Dr. Crow and the Chumash Sanctuary to get a survey of the ocean floor to know if the ocean lander is likely to interact with things like gravel and solid rock which would impact our final design.

2.11 Final Concept Selection

The final concept selection for the upgraded ocean lander integrates the highest performing subsystem designs that were identified from the concept generation and evaluation process thoroughly documented throughout this chapter. The designs for each subsystem were evaluated using Pugh matrices shown in **Appendix C,** the engineering specifications in **Table 2**, and environmental operational constraints defined by Dr. White, and the Chumash Heritage National Marine Sanctuary. Together, the selected concepts form cohesive, reliable, and environmentally responsible additions to the existing ocean lander.

The final concept shown below in **Figure 32** and **Figure 33** consists of four major subsystem improvements: the sand-based weight release system, the spike-style landing gear, the visibility reflectors, and the rigid bait cage.

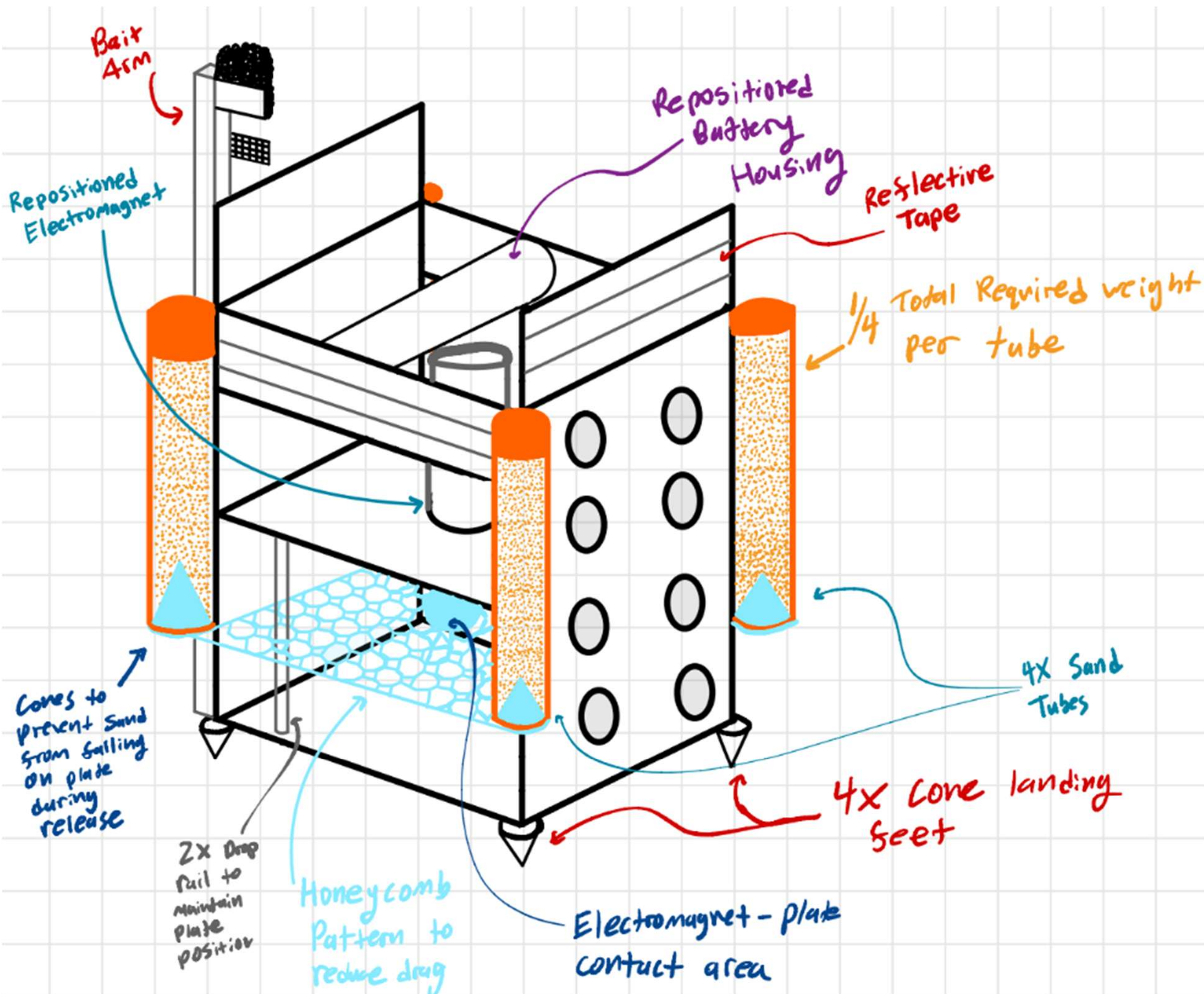


Figure 32: Final Concept Sketch

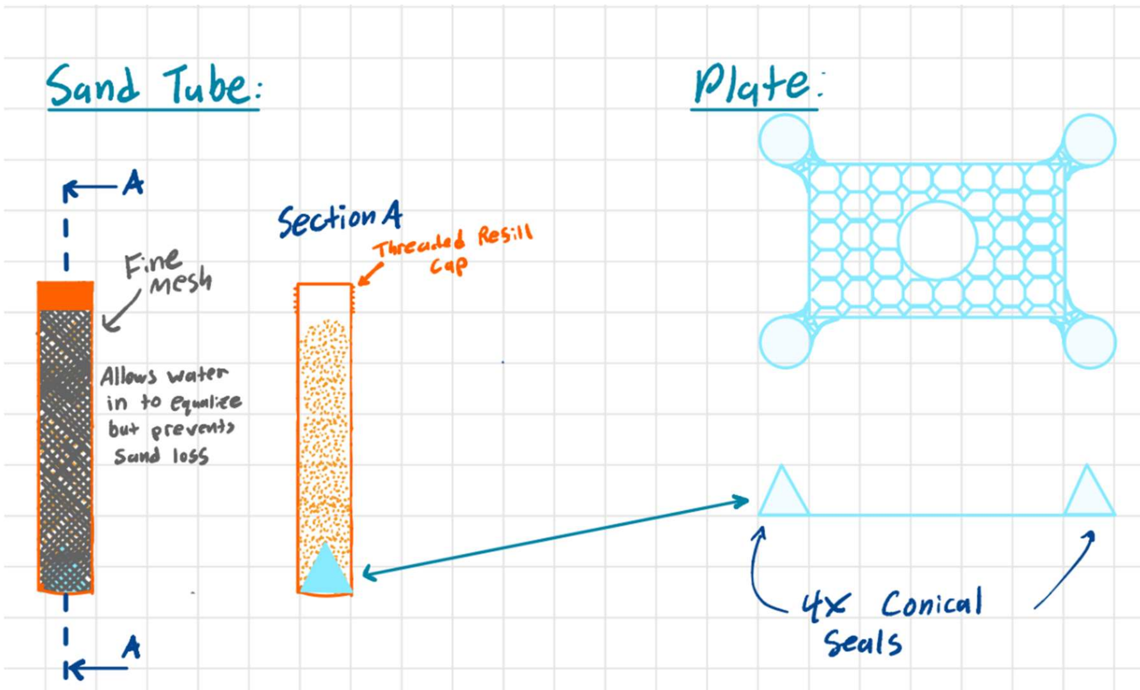


Figure 33: Descriptive Sketches of Sand Tubes and Drop Plate

2.11.1 Environmentally Friendly Sand-Based Weight Release System

The electromagnet based sand release system scored highest in the weight-release Pugh matrices. It eliminates metal debris, preserves compatibility with the existing electromagnetic hardware, and provides a guided drop mechanism that reduces jamming risk at otherwise unserviceable depths. Only sand, a bio-inert material is released, aligning with the Sanctuary's "Leave No Trace" expectation. This design best satisfies the previously outlined depth-rating (Spec 1), fail-safe operation (Spec 15), buoyancy requirements (Spec 9), and environmental criteria (Specs 10 & 16) in Section **1.2 Objectives and Engineering Specifications**.

2.11.2 Conical Spike-Style Landing Gear

Among the four landing-gear concepts, conical spikes were selected for offering the best balance between stability, low mass, impact force distribution, and ease of ascent from soft sediment. While legs and platforms improved stability, they introduced higher drag and risk of embedding. The spike design minimizes overall footprint, reduces settling depth, and is the easiest to extract from sand during ascent. Future terrain survey input from Dr. Crow will further refine spike geometry, but conceptually, the spiked gear best matches Spec 2 (weight), Spec 7 (material strength), and Spec 10 (corrosion resistance).

2.11.3 Reflector-Based Visibility Improvements

The reflective tape was chosen for its low cost and complexity. This waterproof reflective tape will increase visibility against the dark ocean water while requiring little to no maintenance. While the flare was an intriguing concept that had the greatest visibility radius, it adds a recurring cost and is another complex system that needs power and pressurized housing. Painting the lander orange was considered to reduce the range of visibility, as marine researchers claim that it is difficult to see bright colors in the context of the very bright sun reflecting off of waves on the horizon. We may paint stripes of orange in our final implementation, just to increase contrast as the lander ascends, but a full coat would not be as advantageous. We may also end up implementing a tall flag, simply due to the fact it would be easy to implement and may provide a clear pointer to our lander bobbing in the waves.

2.11.4 Rigid Bait Cage Improvement

The rigid polymer chum-style bait cage was chosen for its consistency, durability, ease of cleaning, and predictable scent diffusion. Compared to the flexible net used in previous iterations, the cage centers the bait in the camera's field of view, eliminates plastic shedding, and provides reliable retention during turbulence or landing impacts. This subsystem best supports Spec 8 (bait effectiveness), Spec 11 (reusability), Spec 16 (leaching).

When assembled together, the chosen subsystems aid in forming a cohesive final concept illustrated in **Figure 32** and **Figure 33** shown above. The sand-tube ballast mounts on the corners of the lander and interfaces directly with the plate that will be released by the electromagnet currently in use. The spike landing gear attaches to the bottom of the frame and provides a stable base for contact with the ocean floor. The rigid bait cage mounts to the bait arm bracket where the existing cage resides, maintaining visibility in the camera's field of vision. The added reflectors improve retrieval visibility once the lander reaches the surface. All components meet the corrosion and leaching standards required for repeated deployment within the marine sanctuary.

The final concept represents the most balanced solution to existing complications on the lander when evaluated across engineering performance, environmental impact, manufacturability, and cost. It provides a clear foundation for further development and sets the lander up for successful dry and wet testing, hyperbaric-based pressure validation, and deep sea trials at 500-1000 meters.

Appendices

Appendix A – References

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Appendix *B* - QFD House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

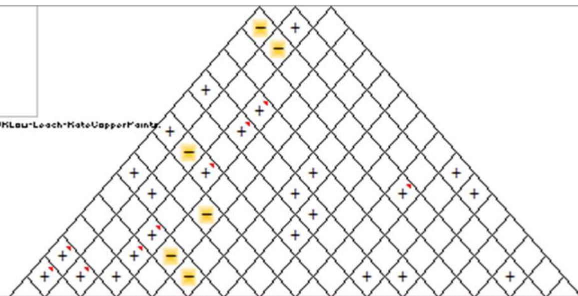
irection of Improveme	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: Deep Ocean Research Explorers (D.O.R.E.)

Revision Date: 10/9/2025

https://file.lacounty.gov/SDSInter/dbh/docs/1129661_MDRLow-Leach-RateCopperPaints



Row #	Weight Chart	Relative Weight	Dr. Crow White	Chumash Heritage National	Baker-Koob	Cal Poly Engineering Depart	Maximum Relationship	WHAT: Customer Requirements (Needs/Wan
1	IIIII	12%	7	7	5	9	9	Deep Deployment
2	IIIII	12%	7	7	5	9	9	High Video Quality
3	IIIIIII	15%	9	9	9	9	9	Reliable Recoverey
4	III	8%	7	4	5	3	9	Portable
5	IIIII	10%	7	7	5	5	9	Fish friendly light
6	IIIII	10%	7	7	5	5	9	Low Environmental Impacts
7	III	7%	7	4	5	1	9	Redeployability
8	IIIIIII	15%	9	9	9	9	9	Oceanproof
9	IIIII	11%	7	7	7	5	9	Cost Effective

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Direction of Improvement	▲	▼	◇													
HOW: Engineering Specifications / WHAT: Customer Requirements	Depth Rating	Weight	Cost	Luminosity	Video Resolution	Battery life	Material Strength	Bait Effectiveness	Buoyancy Force	Corrosion resistance	Reusability / Lifecycle	Remote On/Off switch	Visibility	Rate of Ascencion	Fail-safe weight release	Leaching Resistance
Deep Deployment	●	●	●			●	●		●	●	○					
High Video Quality	○		○	●	●	●		●								
Reliable Recoverey	○		○			▽							●	○	●	
Portable		●					○		▽			●				
Fish friendly light			○	●												
Low Environmental Impacts			○				●	●								●
Redeployability						●					●	●	○			
Oceanproof			○				●			●	●					●
Cost Effective	○	●	●		●	●										▽
HOW MUCH: Target Values	Minimum 1000m	Maximum 50 lbs	Maximum $4000	Maximum 50 lumens	Minimum 1080p	Minimum 4 hours	Minimum 1470 psi	Minimum 8 species/bait	Minimum 90 lb	Maximum 0.03 mm/year	Minimum n = 30 drops	Minimum Operating distance of 2 feet	Minimum 100m	Target 2m/s	Target 4 hours	Maximum 9.5 µg/(cm^2 * day)
Max Relationship	9	9	9	9	9	9	9	9	9	9	9	9	9	3	9	9
Technical Importance Rating	221	276	392	197	205	390	358	197	114	244	235	134	158	46	137	238
Relative Weight	6%	8%	11%	6%	6%	11%	10%	6%	3%	7%	7%	4%	4%	1%	4%	7%
Our Current Product	9	1	1	1	9	9	9	N/A	9	N/A	9	8	6	9	9	N/A
Curr. Products: Our Current Product	3	3	3	3	9	9	9		9		9			8	9	
Curr. Products: E/V Nautilus	9	1	1	1	9	9	9	N/A	9	N/A	9	3	9	5	9	N/A
Curr. Products: Schmidt Ocean Institute	9	1	1	5	9	9	9	N/A	9	N/A	9	3	9	4	9	N/A
Curr. Products: DOV Audacia	9	1	1	4	9	9	9	N/A	9	N/A	9	3	9	7	9	N/A
Curr. Products: DAP Ocean Lander	9	1	1	1	9	9	9	1	9	N/A	9	3	9	2	9	N/A

NOW: Curr. Products	Our Current Product	E/V Nautilus	Schmidt Ocean Institute	DOV Audacia	DAP Ocean Lander	Row #
Deep Deployment	1	5	5	5	5	1
High Video Quality	5	5	5	4	3	2
Reliable Recoverey	1	5	5	5	5	3
Portable	3	1	1	2	1	4
Fish friendly light	1	2	2	2	1	5
Low Environmental Impacts	3	2	3	3	3	6
Redeployability	1	4	4	4	4	7
Oceanproof	2	5	4	4	5	8
Cost Effective	3	1	1	1	1	9

Appendix C – Pugh Matrices

C.1 – Weight Release Pugh Matrix

Pugh Matrix

Concept Selection Legend	
Better	+
Same	S
Worse	-

Key Criteria	*Importance Rating*	Dropping Chains	Sand-Based Weights	Iron-Based Weights	Concrete-Based Weights	Lead-Based Weights	Pressure-Based Weight Relief
			Alternative Concepts				
Environmental Impact	10	Datum	+	S	+	-	+
Reconstructability	8		+	S	-	S	-
Cost	6		+	S	+	-	-
Existing Design Compliance	4		S	+	-	-	-
Volumetric Impact (weight vs. volume)	5		-	S	-	+	-
Reliability	6		S	S	S	S	-
Portability	6		+	S	-	-	+
		Sum of Positives	4	1	2	1	2
		Sum of Negatives	1	0	4	4	5
		Sum of Sames	2	6	1	2	0
		Weighted Sum of Positives	30	4	16	5	16
		Weighted Sum of Negatives	5	0	23	26	29
		TOTALS	**25**	**4**	**-7**	**-21**	**-13**

C.2 – Weight Release System Design

Pugh Matrix

Concept Selection Legend

Better	+
Same	S
Worse	-

Key Criteria	*Importance Rating*	Dropping Chains	Hook System with sandbag	Hook with tarp	Motorized container with twisting lid	Electromagnet-supported container
			Alternative Concepts			
Environmental Impact	10	Datum	+	+	+	+
Mechanical Robustness	8		-	-	-	S
Leverage of existing design	4		S	S	S	+
Ease of resetting	7		-	-	-	-
Integration complexity	9		-	-	-	+
Reliability	9		-	-	-	S
Cost	5		-	-	-	-
Sum of Positives			1	1	1	3
Sum of Negatives			5	5	5	2
Sum of Sames			1	1	1	2
Weighted Sum of Positives			10	10	10	23
Weighted Sum of Negatives			38	38	38	12
TOTALS			**-28**	**-28**	**-28**	**11**

C.3 – Depth Testing Pugh Matrix

Pugh Matrix							
Concept Selection Legend: Better +, Same S, Worse -			Alternative Concepts				
Key Criteria	Importance Rating	Off the Pier	Hyperbaric Chamber	Off the Boat	Cal Poly Pool	Bucket	Bathtub
Max Depth	8	Datum	+	+	-	-	-
Retrievable	9		+	-	+	+	+
Availability	7		-	-	-	+	+
Full Assembly Test	20		S	S	S	-	-
Duration	1		-	-	+	+	+
Iteration Capacity	2		S	-	S	-	-
Cost	3		-	-	S	S	S
Ease of Transport	5		S	S	S	S	S
Seawater	4		S	S	-	-	-
Real World Use Similarity	6		S	+	-	-	-
		Sum of Positives	2	2	2	3	3
		Sum of Negatives	3	5	4	5	5
		Sum of Sames	5	3	4	2	2
		Weighted Sum of Positives	17	14	10	17	17
		Weighted Sum of Negatives	11	22	25	40	40
		TOTALS	6	-8	-15	-23	-23

C.4 – Visibility Pugh Matrix

Pugh Matrix

Concept Selection Legend

Better	+
Same	S
Worse	-

Key Criteria	Importance Rating	Black painted body	Orange Paint	Tall flag	Mirrors \ reflectors	Automated flare	Large Tarp that expands on surfacing
			Alternative Concepts				
Feasibility	2	Datum	S	+	+	-	-
Low Recurring Cost	5		S	S	S	-	S
Low Initial cost	1		-	-	-	-	-
Visibility range	4		-	+	+	+	+
Compact size	3		S	-	S	S	-
Sum of Positives			0	2	2	1	1
Sum of Negatives			2	2	1	3	3
Sum of Sames			3	1	2	1	1
Weighted Sum of Positives			0	6	6	4	4
Weighted Sum of Negatives			5	4	1	8	6
TOTALS			**-5**	**2**	**5**	**-4**	**-2**

C.5 – Landing Gear Pugh Matrix

Pugh Matrix							
Concept Selection Legend Better + Same S Worse - **Key Criteria**	***Importance Rating***	Bare Ocean Lander Frame	**Alternative Concepts** Parachute	Legs	Flat Platform	Spikes	Rails
Landing Intensity	**6**	Datum	+	S	S	+	S
Reliability (deployment)	**8**		-	S	S	S	S
Reliability (ascension from floor)	**12**		+	+	+	+	+
Structural Integrity	**4**		-	-	S	+	+
Drag on Descent (increase drag = +)	**6**		+	+	+	-	S
Drag on Ascent (increase drag = -)	**4**		-	S	-	+	-
Ease of Implimentation	**3**		-	+	S	+	+
	0						
	0						
	0						
Sum of Positives			3	3	2	5	3
Sum of Negatives			4	1	1	1	1
Sum of Sames			0	3	4	1	3
Weighted Sum of Positives			24	21	18	29	19
Weighted Sum of Negatives			19	4	4	6	4
TOTALS			**5**	**17**	**14**	**23**	**15**

C.6 – Bait Arm Pugh Matrix

Pugh Matrix

Concept Selection Legend: Better = +; Same = S; Worse = -

Key Criteria	Importance Rating	Nylon net bag	Stainless wire-mesh net bag	Crab snare	Chum Basket/Bait Cage	screw-top bait jar with holes	Draw String bag
Scent Diffusion	15	Datum	S	S	S	S	-
Bait Rentention	10		S	-	+	+	+
Entanglement/Snag risk	8		-	-	-	+	-
Ease of reload	2		S	+	+	+	+
Ease of cleaning	2		+	+	-	-	-
Durability	10		+	+	+	-	-
Environmental impact	8		+	+	+	+	+
Bait Amount	8		S	-	+	+	+
Hydrodyanmic drag	3		S	+	-	-	+
Camera FOV impact	10		S	+	-	-	-
Sum of Positives			3	6	5	5	5
Sum of Negatives			1	3	4	4	5
Sum of Sames			6	1	1	1	0
Weighted Sum of Positives			20	35	38	36	31
Weighted Sum of Negatives			8	26	23	25	45
TOTALS			**12**	**9**	**15**	**11**	**-14**

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