

HF Radar Calibration with Automatic Identification System Ships of Opportunity

**CODAR Ocean Sensors
Mountain View, CA**

Contract Start Date: September 21, 2011

Award Amount: \$399,883

Website: <http://www.codar.com/>

Problem- High frequency (HF) radar systems produce ocean current data by measuring the speed and direction of ocean currents in near real time.¹ The data, collected by over 300 HF radars worldwide, are used in a variety of ways, including: aiding oil spill response by using the current information to better predict the flow and location of contaminants for clean-up, improving search and rescue missions by narrowing the search area for missing vessels, and providing key information used in a range of oceanographic research. Data quality is critical in providing the most accurate HF radar data to its users, and radar system calibration helps ensure high quality data.



CODAR HF Radar Antenna. Photo Courtesy of CODAR Ocean Sensors

Prior to 2011, CODAR, who designs, manufactures, and supports over 90 percent of the national HF radar network systems in the United States, was conducting systems calibration through the use of transponders placed on small vessels. The vessels would travel in an arc around the the receiving radar antenna to calibrate the antenna response from all angles. While effective, this method was limited by the cost and availability of vessels to carry the transponders, time needed for the calibration process, and environmental

factors, such as weather and ocean conditions. Momentum for alternative methods for HF radar system calibration began building as system operators and technicians began discussing the potential for more efficient and cost-effective calibration methods while, simultaneously, oceanographic researchers at the University of California Santa Barabara (UCSB) became eager to exploit the Automatic Identification System (AIS) that they saw being used for vessel location onshore in their work.

Project- CODAR applied for and won an SBIR award to develop alternative HF radar calibration methods with support from UCSB. The team went on to show that by associating AIS vessel identifications (which provide ship positions) with vessel radar echoes in HF radar data, it is possible to reproduce the antenna pattern that was previously measured by transponders aboard ships. In their Phase II award, CODAR and UCSB operationalized their calibration methods. UCSB investigated methods that could filter the incoming AIS and vessel echo data, and CODAR developed software that could

¹ NOAA IOOS: <https://ioos.noaa.gov/project/hf-radar/>

match AIS data with radar signals and spectra. The resulting software product automates HF radar calibration for systems and allows for more continuous system calibration, which improves the accuracy of ocean current vectors.

Beneficiaries- The HF radar system calibration software benefits its users as well as stakeholders who are reliant upon the more accurate ocean current data for their work. Examples of beneficiaries include:

- **System Operators and Technicians** who can now more easily access and conduct quality control activities; reducing the time, cost, and planning considerations associated with previous calibration methods.
- **Scientists and Researchers** who can now access more accurate ocean current data for research, such as the study of harmful algal blooms.
- **Federal Government** who can now apply more accurate data to efforts such as:
 - *Ocean Current Forecasts.* Short-term ocean current prediction forecasts are generated that are used by a range of stakeholders such as the U.S. Coast Guard and NOAA Office of Response and Restoration (OR&R) (described further in bullets below).
 - *Search and Rescue Missions.* More accurate ocean current data can help search and rescue operations reduce search areas for vessels and people that have gone adrift; leading to more efficient and, potentially, more success search and rescues.
 - *Oil Spill Response.* Accurate, ocean current forecasts generated by the improved data can be used by entities, such as the NOAA OR&R and Coast Guard, to help oil spill responders better understand where the oil/contaminants may be headed; allowing spill response resources to be allocated more efficiently to address spill.
- **Public** who can now benefit from the range of downstream data applications implemented by the government and researchers (described above).
- **UCSB SBIR participants** who are now leveraging the expertise and knowledge of data-related radar algorithms gained from the SBIR work to improve the capabilities and data quality in the HF national network.

Ecosystem Service Benefits- The automated antenna pattern calibrations have made it easier for local system operators to keep up to date with calibration of the HF radar. This has resulted in more accurate ocean current data which aids the downstream applications that have implications for ocean ecosystems, such as:

- Reducing the quantity and severity of oil spill contaminants in the ocean that affect water quality, the lives of marine wildlife, and ocean habitat, such as spawning grounds for marine organisms.
- Monitoring harmful algal blooms
- Conducting ecosystem assessments
- Assisting in fisheries management

Economic Impacts- The SBIR award provided CODAR the opportunity to develop a beneficial community product that would not have otherwise been possible due to company resource constraints and the risk associated with the product development. The project led to a software prototype that laid

the foundation for a marketable product that continues to be refined and sold by the company. The results of the Phase II SBIR award also positioned CODAR for a Phase III grant that, ultimately, allowed the software to be disseminated and used by operators; expanding the product’s customer base. Today, CODAR has more than 150 licensed product users worldwide and will be releasing the second generation of their software product in Spring 2019.

The SBIR project has facilitated several internal benefits to CODAR that translate into economic impacts, including:

- Offering additional customer services in the form of analysis of the data generated by the software
- Hiring additional technicians to conduct the data analysis associated with new customer offerings
- Hiring a high-level software developer to focus on and continue working on the software initiated under the SBIR award
- Helping CODAR remain competitive in their niche market, which includes both domestic and international customers

Economic Impacts of CODAR SBIR Project on the State of California

Economic Impact (Based on Multipliers)					
Category of Final Demand	Amount (thousands)	Total Output (thousands)	Value-Added (thousands)	Earnings (thousands)	Jobs
Total Funding	\$444,121	\$853,512	\$466,638	\$239,648	3
Actual Sales	\$800,000	\$1,537,440	\$840,560	\$431,680	6
Anticipated Sales (all years)	\$225,000	\$432,405	\$236,408	\$121,410	2

The estimated overall economic impact to the state of California of CODAR’s HF radar calibration software can be seen in the table above. The table shows the economic impacts generated when the SBIR funding and product sales (column two) are multiplied by state-level Bureau of Economic Analysis (BEA) final demand multipliers. The resulting impact values show that the SBIR award of \$444,121 generated three new jobs and an additional \$466,638 dollars in Value-Added (similar to state Gross Domestic Product). In addition, the CODAR software sales of \$800,000 translates to an additional \$1.5 million in total output and an additional \$431,680 in earnings for the state of California.

NOAA Support- CODAR SBIR principal investigator, Chad Whelan, described the SBIR award program as a “great fit” for the project to develop alternative HF radar calibration methods. The CODAR-UCSB team was able to improve something for the community due to the financial resources made available through the SBIR award program. The NOAA technical lead at the Integrated Ocean Observing System Office brought an in-depth understanding of the relevant information to project discussions; providing feedback and prompting project considerations.

Developing Resilience to Ocean Acidification in Red Abalone Aquaculture

The Cultured Abalone Farm, LLC
Goleta, CA

Contract Start Date: June 20, 2016

Award Amount: \$399,987

Website: <http://culturedabalone.com/>

Problem- Ocean waters are becoming more acidic as they absorb increasing concentrations of atmospheric carbon dioxide—a process termed ocean acidification (OA). OA is proving detrimental to marine organisms, such as the red abalone. The state of California has witnessed diminishing populations of wild red abalone in the state’s coastal waters to the extent that is now illegal to harvest wild red abalone there. OA is also of concern to aquaculturists who rely upon ocean waters for the production of red abalone in their commercial fisheries.

Project- The Cultured Abalone Farm in Goleta, CA implemented a Phase I SBIR project that focused on understanding whether red abalone having higher nutrient and protein diets produced heartier offspring that could better endure future ocean acidification by looking at the genetic variation that occurs when feeding the abalone macro algae and red seaweed. By the end of Phase I, they were able to show that the altered diets do, in fact, shape red abalone OA-resistance, and this research was expanded



Larval development at the Cultured Abalone Farm hatchery. Photo courtesy of Cultured Abalone Farm

under a Phase II award. In Phase II, the awardees continued their research into the red abalone genome-level responses to ocean acidification; exploring whether wild red abalone off the coast of California growing in more acidic waters would be more likely to thrive in OA conditions than those abalone growing in less acidic conditions. Their research showed that abalone growing in more acidic conditions are more likely to thrive in OA conditions. In addition, Phase II work also engaged an evolutionary geneticist from the University of California, Davis to begin developing a reference transcriptome (i.e., a gene library) for red abalone.

Beneficiaries- The research conducted by the Cultured Abalone Farm benefits an array of stakeholders, including:

- **Red abalone conservation community** who can now use the information and research produced through the SBIR to help restore dwindling wild populations of red abalone.
- **Abalone aquaculture businesses** who can potentially use the ongoing research spurred by the SBIR to revive the domestic industry in California and provide similar support, as necessary, to international industry, such as that in China.

- **Consumers** who eat red abalone as a food source or utilize its shell for decorative art and artware may now have increased access to product.
- **Other species**, such as the white abalone, experiencing detrimental impacts of OA that may now be able to be revived using techniques developed for the red abalone.
- **Cultured Abalone Farm** who can now continue producing red abalone and is now at the forefront of this public-private research.

Ecosystem Service Benefits- The increased understanding of how to develop OA-resistant red abalone strains presents several ecosystem service benefits. Understanding how to make red abalone more resilient to OA can aid in the restoration of depleted wild red abalone populations, such as those in California. Red abalone serve the ecological function of stabilizing rocky reefs and kelp forests that are home to numerous marine organisms. They also serve as a food source for an array of marine animals such as otters, fish, lobsters and gastropods.² The research conducted by the Cultured Abalone Farm can also be leveraged to help support and maintain the health of other marine species, such as the white abalone.



Photo red abalone courtesy of Cultured Abalone Farm

Economic Impacts- The economic impacts associated with the development of methods for an OA-resistant strain of red abalone are currently limited to those generated from SBIR funding since the process to develop a patented process that can be sold to aquaculture operations and other interested parties is still in process. The estimated overall economic impact to the state of California of the SBIR Phase II funding can be seen in the table below. The resulting impact values show that the SBIR award of \$418,872 generated a total output of \$611,344 and \$250,611 in earnings for the state of California.

Economic Impacts of The Cultured Abalone Farm SBIR Project on the State of California

Category of Final Demand	Economic Impact (Based on Multipliers)				
	Amount (thousands)	Total Output (thousands)	Value-Added (thousands)	Earnings (thousands)	Jobs
Total Funding	\$418,872	\$611,344	\$377,739	\$250,611	4

Given that the SBIR work undergirds the ongoing development of a patented method for developing OA-resistant red abalone that is aimed for eventual sale, the economic impact values associated with this project may underrepresent the eventual, overall impact of this award.

NOAA Support- Lead Scientist for the Cultured Abalone Farm, Dan Swezey, conveyed that the SBIR Program has allowed the concept of understanding and exploring a possible OA-resistant strain of red abalone to become a reality. Through Phase I and Phase II awards, The Cultured Abalone Farm was able to generate research that has the potential to restore populations of red abalone in California and beyond; benefitting aquaculture businesses, consumers, and ecosystems alike.

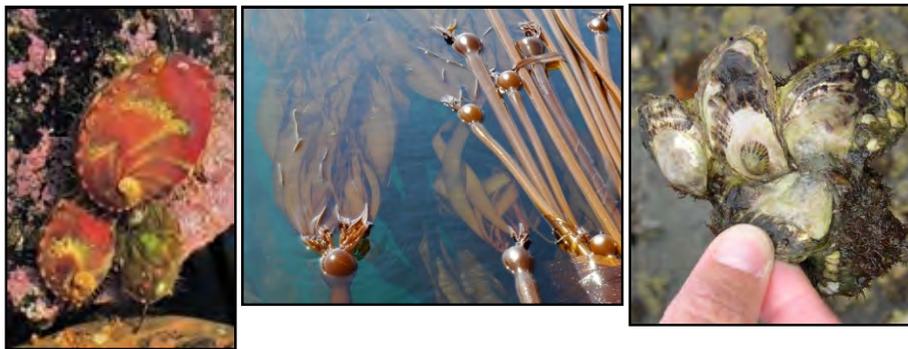
² <http://www.fishtech.com/facts.html>

Shellfish Research and Living Marine Resource Restoration in Puget Sound

Puget Sound Restoration Fund
Bainbridge Island, WA

CRADA Start Date: May 22, 2014
Website: <https://restorationfund.org/>

Problem – In the Puget Sound of Washington, Olympia oysters, kelp, and pinto abalone serve as ecosystem engineers; building and maintaining habitat critical for not only themselves, but numerous other species who rely upon the ecosystems that they create. Through their existence, these organisms also generate an array of benefits for humans that span from food production to employment to storm protection and recreation. Each of these critical organisms is teetering on the the brink of endangerment or disappearance in the Puget Sound. Currently in the Puget Sound, less than five percent of dense, Olympia oyster beds remain at the intertidal area; floating kelp beds have nearly disappeared from the southern portion of the Sound; and “Pinto abalone are considered functionally extinct in Washington waters”, decreasing 98 percent between 1992 and 2017.³



Pictured Left to Right: Pinto Abalone, Bull Kelp, Olympia Oyster. Photos Courtesy of Puget Sound Restoration Fund

Collaboration - In 2011, The Puget Sound Restoration Fund (PSRF) approached NOAA with the idea of expanding their hatchery capacity in order to increase their production of oyster seed, kelp, and abalone. PSRF’s request was timely, as NOAA’s Manchester station was re-integrating shellfish work as an area of interest, and a Collaborative Research and Development Agreement (CRADA) between PSRF, the NOAA Manchester Native Shellfish Hatchery, and the Northwest Fisheries Science Center Manchester Laboratory was established in 2014. Under the agreement, NOAA provides dedicated facilities having key attributes for project work (e.g., shellfish hatchery access with adequate flows of sea water) and technical expertise (e.g., species genetics) and PSRF is responsible for securing project staff and implementing project activities.

³ PSRF, 2018. <https://restorationfund.org/projects/pintoabalone>

Aiming to increase the scale of research and restoration activities focused on the Olympia oyster, pinto abalone, and kelp in the Puget Sound, PSRF and NOAA have focused project research and restoration activities on three areas:

- Producing Olympia oyster larvae and seed that is out-planted to restore native oyster beds.
- Establishing new pinto abalone operations at NOAA's Manchester Research Station to increase the number of abalone able to be produced and, subsequently, introduced into the wild.
- Establishing a kelp lab for further applied research.



Photo Courtesy of PSRF

Beneficiaries- The research and activities being conducted by PSRF benefit a range of stakeholders, including:

- **Native tribes** who can now access and plant native oyster seed that is a culturally significant source of food.
- **Commercial shellfish harvesters** who can now access and grow specific types of oyster seed that are central to their business.
- **Scientists, researchers, and academics** who are now provided surplus seed that would otherwise be unavailable to them for use in a variety of research projects, such as the Olympia oyster's impact on ocean acidification, testing oyster survival rates in various marine habitats, and studying oyster disease.
- **NOAA** who can now further address policy aims to "support aquaculture innovation and investments that benefit the Nation's coastal ecosystems, communities, seafood consumers, industry, and economy."⁴
- **Public** who can now access native oysters for a food source, gain additional employment opportunities created through the revitalized aquaculture fisheries, regain cultural heritage surrounding native oyster species, enhance and maintain ecosystems that support local tourism and recreation.

Ecosystem Service Benefits – A range of ecosystem service benefits have been generated by the CRADA work completed by PSRF.

- **Olympia oysters-** Since the inception of the CRADA in 2014, over 10 million oyster seeds have been produced and planted in priority areas, with 67 acres collaboratively enhanced in priority areas.

⁴ NOAA National Marine Aquaculture Policy (2011): <https://www.fisheries.noaa.gov/noaa-aquaculture-policies>

Olympia oysters are the only oyster species native to the coastal ecosystem of the Pacific Northwest region of the United States. The oysters provide critical ecosystem services such as helping regulate water quality, cycling nutrients, sequestering carbon, stabilizing and protecting coastline from storm surge, reducing marsh shoreline erosion, and creating habitat for sea grasses and fish alike.



Historic Olympia oyster bed pre-Statehood (left) and restored 10-acre Olympia oyster bed in Dogfish Bay (right) showing Olympia oysters as a dense, living structure. Photos courtesy of PSRF.

A thriving oyster population has the potential to support fisheries aquaculture for subsistence, recreational, and commercial uses, the development of non-food products such as fertilizer, building materials, jewelry, and other decorations.

- **Kelp-** The dedicated kelp lab space and research efforts established through the CRADA enabled PSRF to secure an additional 5-year grant worth \$1.5 million from Paul G. Allen to investigate seaweed cultivation as a potential strategy for mitigating ocean acidification through the removal of carbon dioxide (CO₂). Increasing levels of CO₂ in the ocean have been shown to negatively impact the health and development of certain organisms, such as the oyster's ability to develop a strong shell.⁵
- **Pinto abalone-** Operations made possible through the CRADA have tripled the production of pinto abalone when compared to pre-CRADA volumes. Pinto abalone are the only abalone species native to Puget Sound. The abalone graze on certain species of algae that forms on rocky reef habitat. The grazing, digestion and excretion of micro- and macro-algae clears habitat space for settlement of new organisms, improves nutrient cycling, and provides food to prey species.⁶

Economic Impacts – In addition to the range of ecosystem services bolstered by the research and activities conducted under the CRADA, the agreement has also generated economic benefits in the form of oyster product sales. PSRF indicated that product sales over the last year⁷ totaled \$25,000, with 100 percent of those sales attributable to the work completed through the CRADA. In addition, PSRF anticipates an additional \$50,000 in product sales over the upcoming year.

NOAA Support – PSRF Executive Director, Betsy Peabody described the CRADA with NOAA as being “life changing.” She articulated that NOAA has worked with PSRF step-by-step to accomplish a

⁵ Le, 2016. <https://www.seattletimes.com/seattle-news/studies-testing-kelp-to-ease-effects-of-ocean-acidification/>

⁶ PSRF, 2014. https://restorationfund.org/sites/default/files/2014_Kamtschatkana_Recovery_Plan.pdf

⁷ Approximately August 2017 to August 2018.

shared vision. NOAA's support for PSRF's work has come in several forms. NOAA has provided the facilities needed to conduct research and restoration activities, technical assistance critical to advancing the work being conducted, and an influx of resources as PRSF has grown, or outgrown various situations or circumstances, throughout their CRADA experience.

Saildrone: Unmanned Surface Vessel (USV)

Saildrone, Inc.
Alameda, CA

CRADA Start Date: June 20, 2014
Website: <https://www.Saildrone.com/>

Problem- Scientists and researchers have traditionally relied upon large research vessels for oceanographic data collection and monitoring activities. These vessels can be costly, require lead time for scheduling and planning voyages, and pose research restrictions regarding the range of possible observations and the ability to maneuver in tight spaces or through less-than-ideal weather and water conditions. The oceanographic data collected through monitoring and observations improve the scientific understanding of physical and biological aspects of the ocean, such as underlying ocean processes, ecosystem functioning, and organisms. The data also contribute to scientific disciplines whose work intersects with ocean processes, such as meteorology and climatology. The data have an array of practical applications, such as improving weather forecasts and aiding in species management.

Collaboration- The California-based company, Saildrone, sought collaboration with NOAA's Pacific Marine Environmental Laboratory's (PMEL) to maximize the scientific applications of the wind-powered, unmanned surface vessel that they had developed for use on land. PMEL could foresee the potential for the technology to expand NOAA's ocean observing research capabilities in a cost-effective manner, and after Saildrone was able to produce a prototype of an autonomous sailing drone, or "Saildrone," a collaborative relationship was born between the two entities. The goal of the collaborative research agreement (CRADA) was to combine NOAA PMEL's experience implementing large-scale observing networks with an enhanced version of a Saildrone able to attain high-quality scientific observations that would be accepted by the global scientific community.



A Saildrone with NOAA Research Vessel. Photo courtesy of Saildrone Inc

Today, the CRADA is an ongoing collaborative process between PMEL and Saildrone. The CRADA has resulted in multiple waves of technology/product development that focus on particular aspects of the Saildrone for NOAA's data collection or monitoring purposes. These waves of development include:

Wave 1 sensor data was validated through a side-by-side comparison with NOAA ship-based measurements. Results showed an outstanding correlation between the Saildrone data and ship-based measurements.

- **Wave 1-** Meteorological and oceanographic sensor package, where the focus was on the development of sensors to capture a range of ocean (e.g., ocean currents, pH) and atmospheric (e.g., wind speed, air temperature) measurements.

- **Wave 2-** Active acoustics, where the use of passive acoustics was developed and tested in the Bering Sea before the team shifted focus to active acoustics to monitor marine mammals.
- **Wave 3-** Carbon sensor, where the focus was on a high-precision carbon dioxide (CO2) sensor.
- **Wave 4-** Surface flux sensor to measure air and water turbulence.

With the potential for additional waves of product development, the Saildrone team conveyed that the future roadmap for sensor development will be driven, in part, by the Global Ocean Observing Network’s Essential Ocean Variables (EOVs), which help prioritize and maximize data across ocean observing platforms and networks.⁸

Like traditional research vessels, Saildrones collect high-resolution, science-grade data; however, they have a number of key characteristics that are advantageous when compared to their data collection counterparts, including:

- Lower operation cost
- Wind-powered propulsion
- Flexibility of deployment; less scheduling required
- Smaller vessel size allows for navigation in tight areas
- Not limited by weather or water conditions
- Real-time data transmission
- Continuous data collection made possible by solar powered battery recharge

Beneficiaries- The data collection capabilities of Saildrones benefit a range of stakeholders, including:

- **Emergency/Disaster responders** who can now detect oil spills without the use of planes or satellites.
- **Industry** who can now employ additional workers to manufacture Saildrones, which are made entirely in United States.
- **NOAA** who can now augment their existing data collection capabilities and assets in a cost-effective manner, which also frees-up other NOAA research vessels for other data collection efforts. In 2017, NOAA deployed 11 Saildrones alongside their 16 research vessels.
- **Public** who have experienced additional employment from product manufacturing, increased economic activity around Saildrone deployment hubs, and improved weather forecasting.
- **Scientific and Academic Researchers** who can now continuously collect data throughout the year across expanded ranges and in locations that could not be reached by larger research vessels. The various sensor packages also collect data that support a range of research, such as the use of the surface flux sensor data in studying the El Niño–Southern Oscillation (ENSO).



Photo of Saildrone Courtesy of Saildrone Inc

⁸ GOOS Essential Ocean Variables Webpage:
http://www.goocean.org/index.php?option=com_content&view=article&id=14&Itemid=114

Ecosystem Service Benefits- The data collected by Saildrones generates a variety of ecosystem service benefits. For example, the data can be used to enhance NOAA fisheries capabilities that might translate to the improved ability to manage fisheries for species health, preservation, or public consumption. The data improve geospatial coverage of carbon in ocean, which can be used to inform processes like ocean acidification and its impacts on resident plants and animals. In addition, Saildrones can augment the ability to detect oil spills; helping spur spill response to minimize negative to ocean organisms and ecosystems.

Economic Impacts- The development of the Saildrone has generated significant economic impacts for the company and the State of California that filter out to the broader country. Internally, the CRADA helped Saildrone increase private investment due to the perceived scientific rigor associated with NOAA’s involvement in product development; helping achieve over \$90 million in direct, private investment into the technology. The influx of product interest and sales, in turn, helped Saildrone expand their workforce from eight to over 100 employees since June 2014.

The manufacture of Saildrones, which occurs entirely in the United States, has also bolstered employment outside of the company. The product has created jobs stretching from advanced manufacturing to advanced engineering, and the economic impact trickles outward to supply chains across the nation. In addition, Saildrones have also increased the economic activity around deployment hubs from Alaska to Rhode Island.

Economic Impacts of CRADA-Related Saildrone Private Investment on the State of California

Category of Final Demand	Amount	Economic Impact (Based on Multipliers)			
		Total Output	Value-Added	Earnings	Jobs
Total Funding (millions)	\$95.2	\$184.2	\$90.3	\$48.2	752

The table above provides one example of the type of economic impacts the development of the Saildrone has had on the state of California. The table uses the financial input in column 2 (“amount”) and multiplies it by state-level Bureau of Economic Analysis (BEA) final demand multipliers to generate the economic impact values appearing in the latter part of the table. In other words, the table shows that \$95.2 million dollars secured by the company from third-party investors for product development generated 752 new jobs, \$90.3 million dollars in Value-Added (similar to state Gross Domestic Product), and an additional \$48.2 million dollars for the state of California. Similar economic impact estimates were also derived for Saildrone based on product sale and anticipated sale information. While these estimates have been excluded from the table to protect confidential business information, the resulting economic outputs generated for the state of California exceed \$2 million dollars for actual product sales and more than \$19 million dollars for anticipated product sales over the coming year.

NOAA Support- Saildrone credits the CRADA knowledge-sharing process with accelerating company research and development. The collaboration with NOAA has also added a layer of product legitimacy for investors, given the agency’s reputation for conducting rigorous science.

SeaTag: Design and Manufacture of a Family of Modular Archival Tags

Desert Star Systems, LLC
Marina, CA

Contract Start Date: August 15, 2008

Award Amount: \$392,039

Website: <http://www.desertstar.com/page/electronic-tags>

Problem- Understanding the location, behaviors, and movement of marine mammals can inform and improve fisheries management and species conservation strategies.⁹ The advent of electronic animal tags has allowed researchers to track the movement of marine mammals across broader expanses of the ocean and over longer periods of time than previously possible.¹⁰ The tags have increased the understanding critical habitats, such as spawning areas, for these mammals; collecting information on environmental factors, such as temperature and availability of food sources that impact species' habitats. At nearly \$4,000 each, the cost of pop-up satellite tags on the market was limiting product use. The application of the tag technology was confined to well-funded scientific studies, and even then, only a small population of mammals could be tagged, which led to imprecise data collection. In addition to the expense, tag longevity was also problematic. The power capacity of tags restricted the duration of use, and tags were used only once.

Project- Desert Star Systems used funding from NOAA's SBIR program to leverage an existing, unfinished pop-up satellite technology; transforming it into SeaTag™, a suite of four commercially available devices for tracking animals in the marine environment. SeaTag™ addresses the limitations of previous products by offering customers low-cost, reusable, and solar-based (providing unlimited charge) satellite tags. The full suite of available SeaTags™ have varying sensors, but each is equipped with:

- An accelerometer (measures activity of animal)
- Light sensors (allows for longitudinal locating via amount of daylight)
- Magnetic sensor (allows for latitudinal locating)
- Temperature sensor
- Depth sensors

The tag can communicate globally with product users through the use of the Argos satellite constellation. After a programmed amount of time,



Fish with SeaTag™ Modular Pop-Up Satellite Tag

⁹ Greene. 2009. Advances in Conservation Oceanography New Tagging and Tracking Technologies and Their Potential for Transforming the Science Underlying Fisheries Management, available at: https://eprints.soton.ac.uk/340095/56/22-1_greene.pdf.

¹⁰ Costa. 2012. New Insights into Pelagic Migrations: Implications for Ecology and Conservation. Available at: http://www.iab.uaf.edu/people/gbreed/gbreed_files/publications/costa_et al_annual_reviews_2012.pdf

the sensor detaches from the animal subject and floats to the surface, where it can be collected and reused.

Beneficiaries- SeaTags™ benefit a wide range of stakeholders:

- **Scientists and Researchers** who can now afford to use satellite tags in their studies and expand sample sizes due to lower tag costs.
- **Public, Environmentalists, and Non-Profits** who focus on animal welfare and endangered species benefit from the ability to track animals; helping monitor populations and continue to learn about various species.
- **Fishermen and Local Communities** who can use the tags to improve fishing businesses, preserve subsistence fishing grounds, and reduce illegal fishing, which also supports the regulatory efforts of local governments.

Ecosystem Service Benefits- SeaTags™ benefit a range of aquatic mammals by reducing the presence of vertical fishing line that can entangle and kill them. Data about the location and migratory pathways of the tagged animals can be used to inform where vertical fishing lines are placed; allowing for continued fishing and the increased safety and survival of the mammals. This use of SeaTags™ has been (and continues to be) used to benefit to the endangered the Northern Right Whale, where the estimated population is fewer than 550 for both species.¹¹

Economic Impacts- The SeaTag™ project propelled Desert Star Systems into the field of ocean smart sensors; attracting additional investments and increasing company employment and revenues. The work completed through the SBIR project generated multiple internships and training for new graduates and other young employees. The SBIR award dollars have helped sustain the small company, comprising upward of 20 percent of the company’s revenue stream at times.

Economic Impacts of SeaTags™ on the State of California

Category of Final Demand	Amount	Economic Impact (Based on Multipliers)			
		Total Output	Value-Added	Earnings	Jobs
Total Funding (millions)	\$0.5	\$0.9	\$0.5	\$0.2	4

The table above shows the economic impacts of the SBIR award funding for SeaTag™ products on the state of California. The table uses the financial input in column 2 (“amount”) and multiplies it by state-level Bureau of Economic Analysis (BEA) final demand multipliers to generate the economic impact values appearing in the latter part of the table. The resulting impact values show that the SBIR award of \$451,000 generated four new jobs and an additional 0.5 million dollars in Value-Added (similar to state Gross Domestic Product). Similar economic impact estimates were also derived for SeaTag™ based on product sale and anticipated sale information. While these estimates have been excluded from the table to protect confidential business information, the resulting economic outputs generated for the state of California are over \$6.5 million dollars and nearly 30 jobs for actual product sales. Anticipated product

¹¹ NOAA Fisheries estimates the population of Northern Pacific Right whales to be fewer than 100 and the population of the North Atlantic species to be approximately 450 (for a combined total of 550 or fewer). Sources: Northern Pacific Population: <https://www.fisheries.noaa.gov/species/north-pacific-right-whale>; Northern Atlantic Population: <https://www.fisheries.noaa.gov/species/north-atlantic-right-whale>

sales over the coming year are estimated to yield nearly \$2 million dollars for the state of California and an additional eight jobs.

NOAA Support- Desert Star System credits the NOAA SBIR Program with providing them with extra support needed to make SeaTag™ technology possible. Desert Star founder, Marco Flagg, spoke to the fact that ocean technology takes a long time to mature, and as a small company, an investor who was willing to wait for financial returns over a longer time horizon than the private sector or “angel” investors is valuable. NOAA is comfortable with receiving benefits or returns over long time horizons because they have a continued interest in the impacts and benefits that these types of product generate over time for stakeholders. Today, the SeaTag™ products developed through the SBIR award continue to generate a strong revenue stream for the company while promoting a variety of product uses that benefit a range of diverse stakeholders and wildlife.