



NOAA Topic Specific Scouting

yet2 Buoyless Gear Location Marking Project

Pivot Report

October 21, 2020

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Executive Summary

Project Objective

- **Identification** of technologies/companies that have the potential/expertise to develop and commercialize a Buoyless Underwater Object Location Marking System.
- **Assessment** of the most promising potential solution providers and **interviews** with potential partners.

Results to Date

- *yet2* has sent 41 relevant targets to NOAA to be reviewed.
 - Looked at Ropeless Fishing Systems, commercially available technologies/systems and novel academic research of Underwater Communication, Positioning, and Networking systems, and its individual components.
 - Reviewed acoustic, optical, and electromagnetic systems, novel methods, modems, and power transfer techniques.
- NOAA reviewed and provided feedback on all 41 targets and has identified 39 companies with relevant expertise developing and commercializing underwater Communication & Positioning Systems.
- Important results to date:
 - NOAA contacted and invited all in scope and relevant targets to the Ropeless Consortium Annual meeting.
 - *yet2* gained insights on the state of the art of Underwater Communication And Location Systems to inform NOAA, who will use this information to work on the specifications for a Bouyless Gear Location Marking System.

General Observations and Next Steps

General Observations

Pricing

While there are many companies with capabilities and existing products around NOAA's desired system, **most are not within the desired cost range.**

- A traditional system for monitoring high-value assets such as underwater autonomous vehicles, cost upwards of \$15,000.
- Some researchers have built low cost devices (\$100-1000) from raw materials, but it does not appear that these devices are being manufactured on a commercial scale.

Underwater Communication Technique

Acoustic technology is the most likely to be used for these devices.

- Acoustic devices are the most widely used and commercially mature, and therefore, will likely be lower cost to develop.
- There are other emerging forms of underwater communication, such as optical and acoustic-RF; however, these are early stage and will not offer any cost or performance benefits in the near term.
- *yet2* recommends to stay abreast of developments in other Underwater Wireless Communication techniques, including optical and electromagnetic, that could provide benefits to buoyless gear location marking in the future.

Signal Processing

Signal processing is an emerging area of research to improve localization accuracy, reduce power needs, increase range, and reduce reliance on expensive components.

Customization

Many of the companies presented by *yet2* also offer customized products and engineering services. These companies will likely be willing to develop a low-cost device once the specifications have been agreed upon.

General Observations and Next Steps

Next Steps and *yet2* recommendations

Underwater Networks

- Most commercially available solutions that detect and track the location of underwater objects are mainly focused on finding one high-value object at a time instead of hundreds of relatively low-value objects. However, solutions that provide underwater networking capabilities (e.g. Beringia, W Sense, Underwater Technologies Center, Subnero) aim to connect and locate numerous modems through underwater networks.
- *yet2* recommends to source insights from companies with underwater networking capabilities as they could provide a different point of view.

Scale up capabilities

- *yet2* recommends to factor in the company's capabilities to build in large quantities. However, this should not be the only or main factor, but one of the factors to consider.
- *yet2* recommends to consider different relationships between inventor/designer and manufacturer (e.g. small startups could partner with big manufacturers).

Incentives

- It is likely that large companies will be willing to dedicate resources to develop and commercialize a Buoyless Gear Location Marking System without any incentive. However, this might not be the case for small and medium sized companies, where resources might be more limited, unless an incentive is given.
- *yet2* recommends NOAA to consider developing a strategy around Intellectual Property (e.g. open source design).

Potential Paths forward once NOAA has decided on the specifications

- *yet2* recommends NOAA to have conversations with companies identified in this search to gain insights about tradeoffs and refine specifications.
- Potential funding mechanism could include grants to universities for open source design, RFP for large companies, SBIR for startups, or running a prize challenge for design ideas.

Acoustics

Positioning & Communication

Acoustic solutions have the capability to communicate with underwater devices to detect and track their location, even if they move beyond their initial deployment location, and most of their features can be customized to meet NOAA requirements. Factors that can be customized include the range of communication (but it would impact the size of the transducer), the software layer (can be modified to work with other vendors), and the underwater device/modem (different types of data can be sent, including digital, text, images, etc. but the more data that is sent, the higher the power required). *yet2* reviewed and identified relevant underwater acoustic positioning systems including Long-baseline (LBL) systems (e.g. W Sense), Ultra-short-baseline (USBL) systems (e.g. Sonardyne, Evologics, ixBlue, etc.), Short-baseline (SBL) systems (e.g. Kongsberg), and Autonomous Smart Buoys (ASB) systems (e.g. Beringia).

Networking

Solutions that provide underwater networking capabilities (e.g. Beringia, W Sense, Underwater Technologies Center, Subnero) aim to connect and locate numerous modems through underwater networks. Fish tracking systems (e.g. InnovaSea/VEMCO) operate in a similar manner to simultaneously track large numbers of underwater animals in real-time. Current limitations include the need for autonomous robots or autonomous smart buoys to emulate the function of satellites in the water surface and establish a baseline for precise underwater positioning.

As NOAA moves forward with deciding on the specifications of the device, several points from this project may offer insights of where to focus potential solution providers to fill gaps:

Specification	yet2 Recommendation for Initial Specs	yet2 Insights	Priority of Gap or Focus Area
Cost	~\$300-\$1000	Some devices are under \$500, but these were typically handmade from raw materials for research purposes. Getting below \$1,000 will be challenging, yet feasible, for the commercial sector based on info yet2 has collected.	High – most significant area that yet2 would recommend as a focus area. Approaches such as material (piezoelectric and housing) innovations and signal processing/algorithms could reduce costs.
Range	1000+ meters	Most commercial solutions are targeting a communication range of 300-1000 meters. The range is highly dependent on power supply.	High – are there other ways to boost range that are low power?
Frequency of Use	Ultra-low-power listening mode + interrogate/respond	Listen-and-respond will be more efficient than random ‘pings’. While this is not a novel concept, finding a low cost, ultra low power way listening system will be a challenge for innovators and industry.	High – many groups are working on a low-power listening mode for IoT, and some of these methods may translate into underwater communication.
Power Source	Replaceable (alkaline); rechargeable (Li-ion) batteries	See next slide	Medium – there are not viable near-term solutions, but better energy storage in the future could boost range and performance.
Communication Method	Acoustic	Acoustic devices are the most widely used/commercially mature, and therefore, will be lower cost to develop. Optical and acoustic-RF method are too early stage.	Low – acoustic is the most promising solution for now.
Depth/Housing	300+ m	The depth rating, and required housing, has not been a major issues for companies. Housings rated to specific depths are widely available. Range, rather than the depth, is often the limiting factor.	Low – while there may be some innovation around low-cost housings, innovations in this area are typically working at depths that NOAA does not need.
Size	<12”x6”	Size was not a significant problem for most solutions. The battery pack may be the most significant size issue.	Low –existing devices would not be burdensome on a trap. However, consideration may be given to placement (e.g. floating above trap).
Unique ID	Required	Most already offer this as an option and include a software component.	Low – currently standard without much innovation occurring in this area.

Power

Most of the current systems and technology are using commercial-off-the-shelf (COTS) alkaline or Lithium Ion batteries. The size and lifetime of the battery is highly dependent on how often the device has to respond, or 'ping', and at what range (i.e. it will take less power to send a signal 10m vs. 100m).

Due to cost, these COTS batteries will likely be the best option for NOAA and partners to pursue in the short and medium term. However, in the long term, NOAA should continue to monitor the developments in the following fields:

- **Energy Harvesting** – These systems are able to harvest energy from their environment, and therefore do not need replacement batteries or recharging. While the technology for underwater sensor energy harvesting is sparse and early stage, this could potentially reduce the user friction of battery replacement and recharging, while also allowing devices to operate continuously. Solutions in this area range from piezoelectric/vibrational energy, solar/optical energy, to thermal gradient energy.
- **Signal Processing** – Several organizations are working to more efficiently and effectively process outgoing and incoming signals. This research is being done primarily to increase data transfer rates, but there are also implications for this technology in terms of lowering cost and decreasing the power necessary for a device to send and receive signals.
- **Supercapacitors** – While the technology reviewed by yet2 exclusively used batteries, supercapacitor technology might be a viable option in the future. Supercapacitors are capable of high energy output in short durations, and thus may be ideal for sending out high-power signals intermittently. Additionally, hybrid battery-supercapacitor technology is emerging for other applications, and may be applicable for underwater technologies in the future.

Helpful resources for recent advancements in this area include:

- [Battery-Supercapacitor Hybrid Devices: Recent Progress and Future Prospects](#) (2017)
- [Integration of Battery and Super Capacitor for Energy Storage System](#) (2017)
- [A Novel Flexible Hybrid Battery–Supercapacitor Based on a Self-Assembled Vanadium-Graphene Hydrogel](#) (2020)
- **Emerging Battery Chemistries** – Alkaline and Lithium Ion batteries currently dominate underwater devices. However, new battery chemistries are emerging, such as those using Silicon, Sulfur, Carbon, etc. These batteries often offer advantages in terms of cost of materials, safety, and weight. However, many are still early stage. Most of these chemistries are being initially targeted at the automotive market, but in the future may be able to scale down for underwater IoT devices.

Ropeless Fishing System

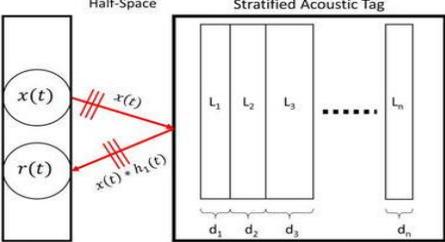
Surface Marking

Current Ropeless Fishing Systems, including Desert Star Systems and Ashored Innovations, log trap surface deployment locations and update them to a cloud server. Hence, these systems currently rely on the surface deployment location and don't account for factors, such as storms or currents, which move gear beyond their initial deployment location. [As of 2020](#), DSS also offers Acoustic Gear Marking used in conjunction with virtual gear marking to help find lost gear, or for an inspector to cross reference virtual gear markings and actual locations. [As of October 2018](#), Ashored Innovations is working on a talkback feature via acoustics to tell a nearby vessel where a lost trawl is if in a listening range if the buoy and trap were to be pushed off its original location. *yet2* recommends to stay abreast of developments in these companies regarding their acoustic capabilities.

Acoustics

Edgetech's 5112 Ropeless Fishing System (RFS) includes the Trap Tracker application, which virtually marks trap and trawl lines, records the positions and catch information and uploads it to a cloud database to help other fishers and law enforcement know where traps are located. Commands from the Trap Tracker application are sent by Bluetooth to the deck box and transducer that sends the commands by an acoustic signal to the 5112 release mounted in the release cage. An in-range RFS receives the command, acts, and replies with information to the Trap Tracker phone/ tablet application. Commands include deploy, recover, ID information and status information. Additionally, a range responder helps relocate trawls and cages. Currently, there is no indication that an updated location is reflected on the Trap Tracker application. *yet2* recommends to keep track of EdgeTech's developments.

List of other Targets reviewed and Rejected by yet2

Organization	Technology Description		Why Not Presented
<p>Georgia Institute of Technology Link</p>	<p>Research from Georgia Tech titled "Passive underwater acoustic tags using layered media" presents a passive underwater marker made of different horizontally stacked acoustically reflective materials. A marker's characteristic acoustic signature can be detected by AUVs as acoustic backscattering upon tag insonification, and hence be used for navigation purposes. The acoustic tags are low cost -designed are composed of layers of common plastics (high density polyethylene, polycarbonates, poly vinyl chloride, acrylic, etc.), so that acoustic impedances are comparable to that of water and the other layers present in the tag.</p>		<p>Used as unique acoustic identifier, not for localization.</p>
<p>ATTACH Link</p>	<p>The ATTACH (Acoustic Tagging Technologies Applied to Cables and subsea Hardware) project was a three-way collaboration between Subsea Asset Location Technologies (SALT) Ltd., Precision Acoustics Ltd. and the University of Birmingham. They conducted a feasibility study to identify remote-sensing, acoustical methods of labelling high-value subsea energy assets by designing synthetic sonar targets that float above the asset and are significantly easier to detect using a sonar system.</p>		<p>Using technology for labelling and ID rather than localization</p>
<p>MIT Link</p>	<p>MIT researchers have created a battery-free underwater communication system that uses near-zero power to transmit sensor data. They are presented the system at the SIGCOMM conference in 2019 and won the conference's "best paper" award. In the researchers' system, a transmitter sends acoustic waves through water toward a piezoelectric sensor that has stored data. When the wave hits the sensor, the material vibrates and stores the resulting electrical charge. Then the sensor uses the stored energy to reflect a wave back to a receiver.</p>		<p>Energy harvesting too early stage for near-term solutions and likely too expensive for medium-term solutions.</p>
<p>MIT Link</p>	<p>In a paper being presented 2018's SIGCOMM conference, MIT Media Lab researchers designed the "translational acoustic-RF communication" (TARF) system that is able to operate through the air-water barrier. An underwater transmitter directs a sonar signal to the water's surface, causing tiny vibrations that correspond to the 1s and 0s transmitted. Above the surface, a highly sensitive receiver reads these minute disturbances and decodes the sonar signal.</p>		<p>Early stage; likely targeting for aerospace-to-subsea communications</p>
<p>RESQUINT Link</p>	<p>Resquint is a floatation device that is mounted to fishing gear like lobster traps and crab pots. If a trap goes astray and remains under water for a longer period of time, Resquint is automatically released and floats to the surface.</p>		<p>Similar to systems NOAA is already aware of</p>
<p>PropSpeed Link</p>	<p>Foulfree™ is a foul-release coating that protects transducers from marine growth to ensure accurate signal transmission and sensitivity for a year or more. Airmar certifies that the application of Foulfree™ coating on its transducers results in no loss in transducer performance.</p>		<p>Potentially an add on to a solution once developed</p>

Technology Matrix

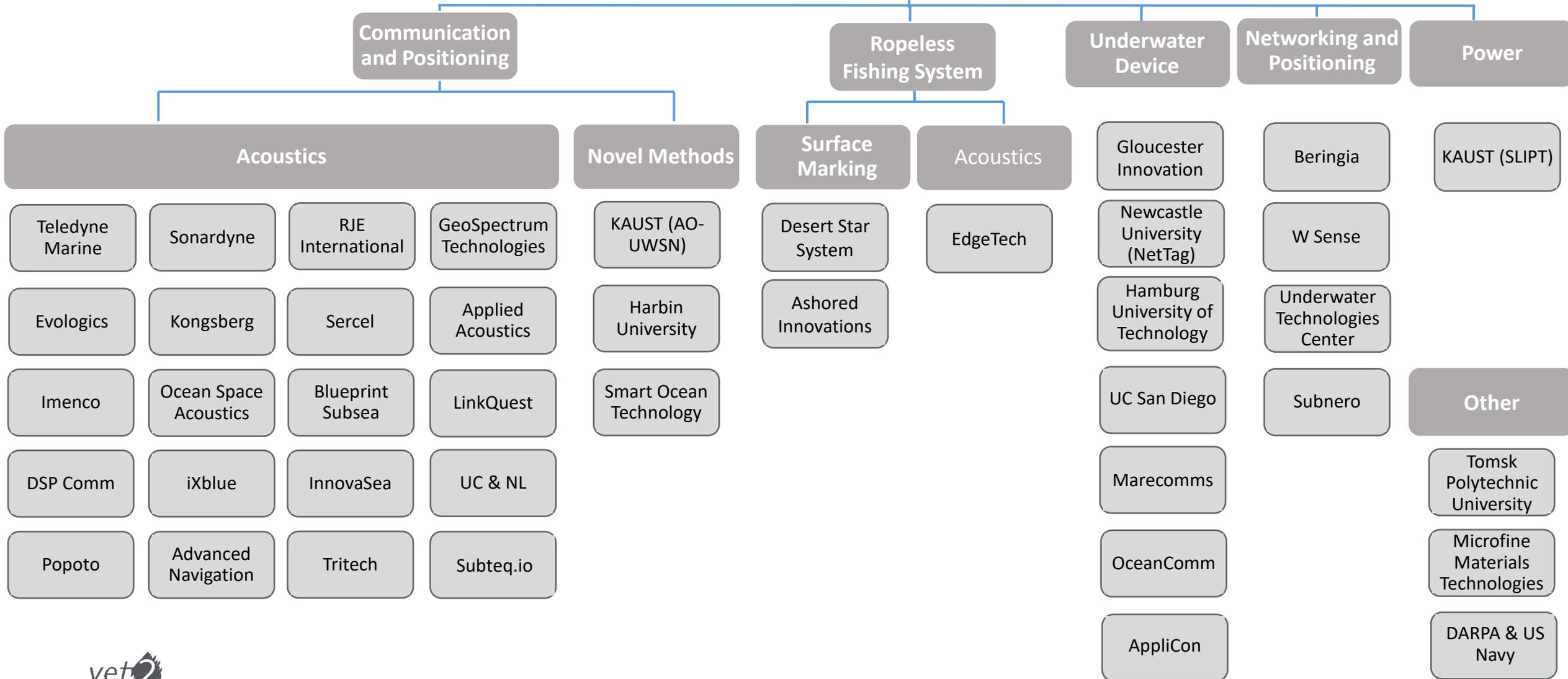
Please refer to Excel Document for full table.

Name	Website	Location	Technology	Depth Rating (m)	Battery Life (hr)	Location Accuracy	Price	Communication Range	Communication Method	Method to View Gear Location	Interoperability	Data Transmission Capability	Customization Abilities	Number of Employees	Founding Date
Advanced Navigation	https://www.advnav.com	Australia	Acoustic positioning transponder that operates with the Subsonus USBL	up to 2000m	18 months	TBD	\$2430; volume discounts available	up to 1000m	USBL	Surface Unit	TBD	TBD	Yes	56	2012
AppliCon	http://www.applicon.com	Italy	SeaModem, an acoustic modem that allows underwater digital communication and networking	400m	TBD	TBD	TBD	In development	Acoustics	In development	Supports the JANUS standard	In development	Yes	TBD	1969
Applied Acoustics	https://www.appliedacoustics.com	UK	Easytrak, an Ultra Short Baseline (USBL) underwater positioning and tracking system	Different options	Different options	TBD	TBD	Different options	USBL	Different options	Compatible with almost all industry standard tracking systems	TBD	Yes	16	1989
Ashored Innovations	https://www.ashoredinnovations.com	Canada	'rope on-command' (ROC) fishing system to minimize the risk of whale entanglements	TBD	TBD	TBD	TBD	TBD	Acoustics	TBD	TBD	GPS location is recorded and uploaded to a cloud server	N/A	2-10	2018
Beringia/Dive NET	https://www.beringia.com	USA	Compact acoustic network modems that claim to be the smallest in the world	up to 300m	TBD	TBD	TBD	up to 2000m	Acoustics	Separate Display	TBD	long range digital acoustic communication	Yes	TBD	2018
Blueprint Subsea	https://www.blueprintsubsea.com	UK	Suite of products built around a robust broadband spread spectrum signaling scheme	up to 2000m	TBD	0.5m	\$15,000	up to 2000m	USBL	Chart Plotter	TBD	Windows Software Application	Yes	9	2006
DARPA & US Navy	N/A	USA	Positioning System for Deep Ocean Navigation (POSDON) program	TBD	TBD	TBD	TBD	TBD	Acoustics	TBD	TBD	TBD	TBD	DARPA: 517	N/A

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Buoyless Gear Location Marking



Technology Description

[The Ranger 2](#) is a system made up of software, a vessel-mounted transceiver and in-water transponders. It provides Underwater Tracking, Dynamic Positioning, and Telemetry. It comes with a list of standard features, the 6G (sixth generation) acoustic hardware platform and Sonardyne Wideband 2 digital signal architecture, which work together to deliver the best possible Ultra-short baseline (USBL) positioning performance and operator experience. It can track equipment over thousands of meters away in any direction, updating the position of every target, every second.



[The Marker 6](#) is a low-cost acoustic positioning solution where compact design and deep water are necessary operational factors.

The Marker 6 enables targets such as underwater structures to be marked unambiguously and later relocated using a Sonardyne USBL system. The Marker 6 incorporates Near Field Communications (NFC) providing the ability to enter Marker 6 into a storage mode when not in use, thereby significantly increasing the overall battery endurance. Sonardyne Wideband acoustic signal processing offers improved performance in challenging conditions such as at long range. The signal encoding also reduces the interference both on and by adjacent Sonardyne and other acoustic positioning systems.



Depth Operating Range: customizable, recommended system up to 4,000 meters.

Comparative Value Proposition

- Sonardyne claims to have an unrivalled portfolio of acoustic and non-acoustic technologies for use in the most challenging marine environments.

Ranger 2 USBL System

- Wide range of customization options at the investment level needed.
- Simple software compatible with all makes of Dynamic Positioning systems.

Marker 6 Transponder

- Low-cost, compact, and with a rugged design.
- Alkaline or Lithium battery pack with 12 months/33 months listening life.
- Depth rated to 4,000 meters.

Commercial Information

Sonardyne is an independent provider of marine technology solutions globally, spanning all marine markets. Their main expertise is in acoustic technologies, but the company also has various research programs in sonar imaging, optical communications and inertial navigation technologies. Company claims to be able to develop a solution tailored specifically for this project, and to reduce cost as much as possible.

TRL: 8/9 – commercially available with a wide range of customization options.

Partnering & Deal Potential: TBD.

NOAA Use Case: portfolio of acoustic and non-acoustic technologies with customization capabilities for underwater communication and positioning.

Updates IR2

What are the minimum requirements for a system that meets NOAA requirements?

Sonardyne is eager to provide a proposal for this project once the following questions are answered: “What is the maximum depth requirement and does NOAA need an actual position (USBL) or would a dunker system (range) be acceptable?”

Does Sonardyne provide an API to integrate with other software? Can the user interface be customizable?

Sonardyne has the capabilities to customize the software completely and to make it integrate with any other software. However, the more integrations it has, the higher the price will be.

Does Sonardyne’s system have the capabilities to update locations of gear that is located on the seafloor? (e.g. update location when a vessel goes over gear)

Yes, Sonardyne could perform any sort of firmware and hardware modifications to update location of gear and to allow the underwater beacon to store information such as ID number, date deployed, etc.

Price

Sonardyne offers discounts for large orders and could therefore explore how to decrease the price of the system, and each individual component. Company could give an estimated price on proposal.

Past Experience

“The UK government is looking at similar issues with their fishing industry. Reading through the proposal, the University of Plymouth is taking the lead on this one with Sonardyne working on the design and manufacturing. The system being requested/proposed in the UK is an acoustic release type marker beacon with rope canister kit. So similar but not the same requirement as NOAA.”

Hampshire, UK; office in Houston, TX, USA.
Founded 1971.

<https://www.sonardyne.com/>

Updates IR2

Our Work in Academia and Ocean Sciences

Sonardyne has been working with the ocean sciences community for over 30 years. This is a link for our Ocean Sciences brochure:

https://issuu.com/sonardyneinternationaltd/docs/sonardyne_ocean_science_brochure which shows the numerous areas where we work with that community. The picture to the right shows many of our larger more prominent customers but we also work with a number of smaller academic universities. We would be more than happy to provide a list of customers references.

Marking and Relocation Systems

We have been supplying relocation systems to the ocean science community for over 20 years. The original relocation system comprises small long-life deep-water (4000m) acoustic marker beacons and a simple transceiver which allows the user to 'home into' the marker beacon subsea. The number of deep-water markers manufactured and supplied are in the hundreds. A shallow-water (500m) derivative of the deep-water marker beacon is our 7815 TZ/OBC transponder used for positioning geophones/hydrophones used for seismic surveys. Sonardyne has manufactured and supplied thousands of these units to our customers. Sonardyne offers simple topsides for both of these transponders which allow for either ranging or ranging and direction (left/right/straight) as well as more complex USBL systems for relative or real-world positioning.

Custom Engineering

With Sonardyne's in-house engineering department we are able to offer our customers 1.) tailor-made solutions for your project 2.) low risk and cost effective 3.) Built on over 40 years of subsea experience 4.) Full service capability; design, prototyping, manufacture, testing and training 5.) All under one roof; software, hardware, firmware and third party integration. Not every situation can be resolved with the same solution. We understand that sometimes our clients' projects require a more customized approach, rather than a standard off-the-shelf solution.

For the last decade we've continually invested in developing and transforming our capabilities and methods of working in system engineering, product design and custom solution delivery. We're an agile organization and all parts of the company have been touched by this process, from how we capture users' requirements to through-life project management, materials control and custom manufacture. The result? A team of experienced people who have tried and tested technologies at their fingertips, with a proven portfolio of hardware and software pieces that can be fitted together seamlessly to build custom engineered systems that meet your needs. We have extensive experience in working with clients to design, develop and deliver systems that meet their specific operational requirements through custom engineering.



Technology Description

EvoLogics offers highly flexible and cost-effective solutions for multiple underwater communication, positioning, navigation and monitoring applications.

Each product is available in a variety of configurations to offer the best-fit solution for a particular scenario. Company offers a selection of short- mid- and long-range devices for shallow or deep-water applications. Moreover, EvoLogics' new underwater acoustic positioning software, the [SiNAPS](#), provides easy-to-use display features for real-time tracking of multiple targets, and supports interfacing with external instruments.

EvoLogics developed the S2C (Sweep Spread Carrier) technology - a reliable acoustic telemetry that provides an independent bidirectional data link along with positioning, broadcasting and networking capabilities - tracking targets and exchanging data with them at the same time does not require switching between modes of operation.

Building upon eight years of studies on the physics of dolphin communication, modems built on S2C technology continuously spread the signal energy over a wide range of frequencies and adapt the signal structure so that the multipath signal components do not interfere with each other. At the receiver end, advanced signal processing collects the energy and converts the received signals into narrow-band signals. This allows to significantly depress multipath disturbances and provides a substantial gain, enabling successful decoding of signals in harsh environments even when they are heavily masked by noise.

Depth Operating Range: different options available, ranges up to 10,000m.

Comparative Value Proposition

- Whole **ecosystem of products** including several series of underwater acoustic modems, underwater positioning systems, an advanced framework for developers, as well as novel robotic solutions and innovative R&D projects.
- **Space-, energy- and cost-saving** solutions.
- S2C system **overcomes common challenges in subsea communication**: no data lost, no delays, high transmission quality and above-average transmission speeds.
- **Limitations**: out of [four patents granted](#) to EvoLogics, one is still [active](#) - release apparatus for a load on a device and underwater device.

Commercial Information

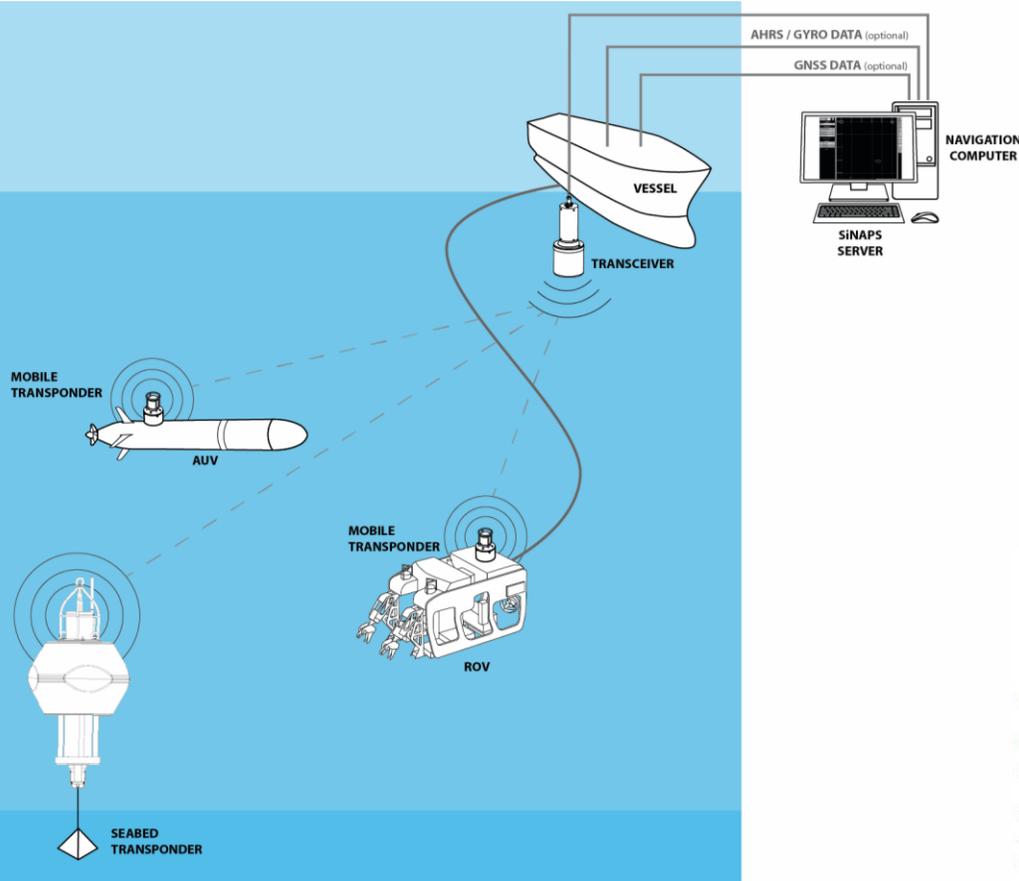
EvoLogics is made up of a group of scientists and R&D experts, who develop innovative technologies for maritime and offshore industries through interdisciplinary cooperation between engineering and life sciences. Company designs and manufactures wireless underwater communication systems based on bionic concepts, combining engineering with ideas found in nature. The key clients are offshore companies, fisheries, commercial service providers, state- and privately-funded research facilities and universities.

TRL: 8/9 – commercially available with customization options.

Partnering & Deal Potential: EvoLogics exports to international markets both directly and through an established distribution network.

NOAA Use Case: customizable ecosystem of products for underwater positioning and communication.

Additional Information



Use case: A USBL transceiver is mounted on a Vessel and uses acoustic signals to determine the distances and bearings to the tracking targets. The USBL transceiver measures the time from transmission of its acoustic interrogation signal until an acoustic reply from the Transponder is detected and converts it to distance to the Transponder. The customer's Navigation computer is interfaced with the USBL transceiver and the external instruments and is connected to the local computer network. The SiNAPS, is installed on the Navigation computer.



S2C R 18/34 USBL

High-speed device for short-range applications in shallow waters.

Frequency: 18 - 34 kHz
 Acoustic Connection: up to 13.9 kbit/s
 Operating Range: 3500 m
 Directivity: horizontally omnidirectional



S2C R 18/34H USBL

High-speed device for short-range applications in shallow waters.

Frequency: 18 - 34 kHz
 Acoustic Connection: up to 13.9 kbit/s
 Operating Range: 3500 m
 Directivity: hemispherical



S2C R 7/17 USBL

High-speed device for short-range applications in shallow waters.

Frequency: 7 - 17 kHz
 Acoustic Connection: up to 6.9 kbit/s
 Operating Range: 8000 m
 Directivity: hemispherical



S2C R 7/17D USBL

High-speed device for short-range applications in shallow waters.

Frequency: 7 - 17 kHz
 Acoustic Connection: up to 6.9 kbit/s
 Operating Range: 10000 m
 Directivity: directional, 80 degrees

Updates IR2

Can EvoLogics' products pass information from the seafloor to the database, not just provide the location (e.g. a unique identifier, name of fisher, type of gear, date deployed, etc.)?

Yes, apart from communicating the location, EvoLogics' acoustic modems can transmit any type of digital data including text and images. It could even communicate if there is a fish inside of the trap. The limitations are usually the available bandwidth and the power consumption.

Does EvoLogics provide an API to integrate with other software? Can the user interface be customizable?

Yes, EvoLogics software can be integrated with other systems, it can also run on an embedded system. The user interface is completely customizable.

Past Experience

EvoLogics has already created similar systems that have the capabilities of the system that we want, therefore, they claim that technologically they can develop the system that NOAA wants. However, they anticipate the battery life of the underwater device to be one of the main challenges.

- To reduce power consumption the device is always in passive mode and it can be programmed to switch off by itself, so it only activates to 'listen' in pre-defined periods of time. The longer the device is idle (not listening), the lower the power consumption will be.

Price

EvoLogics would be happy to provide a price estimate. In order to provide it the following information is required: maximum water depths and maximum range. Any further information provided could help EvoLogics create a more accurate estimate: e.g. minimum amount of bites needed in the underwater device (how much information does it need to hold?)

From EvoLogics

- "The persons that have worked with our modems at NOAA before are Byron Kilbourne (byron.kilbourne@noaa.gov) and Eric Breuer (eric.breuer@noaa.gov). We actually worked with Eric Breuer's team very closely during the initial phase to optimize the wake-up module solution to their needs, so that they are able to connect two sensors independently to the modem and each will be able to start a communication.
- For an example of things that are possible, our acoustic modems have been used in the fishing industry to send pictures in near real time to the vessel's bridge and allow fishermen to see the catch in real time: <https://fiskerforum.com/live-camera-feed-from-the-trawl-becomes-a-reality/>
- Some applications where our systems are frequently used include underwater autonomous observatories, transmitting sensor data to the surface on demand / schedule and autonomous vehicles both for positioning and transmission of sensor data / commands."

Thousand Oaks, CA, USA.

Founded 1960.

<http://www.teledynemarine.com/>

Technology Description

Teledyne claims to have been working in a bouyless gear location marking solution for many years now. Company is working with different partners, but as of July 2020, their most developed solution, working alongside Smelts, consists of only one device that is used for communicating and tracking location as well as for the retrieval of the trap. Solution is based on Teledyne's Compact Modem and Topside solutions:

[The UTS-9400 Universal Top Side](#) is a complete single-unit acoustic deck unit for any level of user. The UTS delivers a user-friendly interface, with intuitive communication, command and control features. The UTS uses advanced ambient acoustic condition analysis to ensure commands get through in even the most challenging environments

[The Releaseit Shallow Water Deck Unit](#) is a lower-cost turn-key option for shallow water applications up to 500m water depth.

[The Compact Modem](#) is an acoustic modem for shallow to mid-water applications. Its alkaline or lithium battery life depends on how often the modem is interrogated. Standard modem's battery lasts days to weeks – capability to supply power underwater is feasible. Although Teledyne hasn't applied the JANUS protocol in this application, the modem is fully compatible with the JANUS interoperability standard.

Depth Operating Range: different options available, recommended system up to 2,000 meters.



Comparative Value Proposition

- Complete line of underwater locator products with customization options

Universal Top Side

- Used to operate all standard acoustic releases and to control and communicate with Teledyne Benthos' full line of acoustic modems and positioning products.
- Portable or rack mount configurations available
- Software/firmware upgrades available to improve current system.

Compact Modem

- Reliable, light-weight, and affordable modem depth rated to 2000m.
- **Limitations:** battery life of days to weeks, option to supply power underwater.

Commercial Information

Teledyne Marine is a group of subsea technology companies. Teledyne Marine has evolved into to bring Imaging, Instruments, Interconnect, Seismic, and Vehicle technology together to provide total solutions to customers. Company has collaborated to create the JANUS standard.

TRL: 8/9 – commercially available with customization options.

Partnering & Deal Potential: Teledyne provides its modem and underwater communication expertise to [Smelts](#), creators of a patent pending ropeless lobster retrieval and marking technology. Teledyne claims to be working with more companies in similar projects.

NOAA Use Case: Customizable underwater locator products with proven communication and positioning systems technologies.



Technology Description

RJE has over 25 years of experience blending technology and science to create products for underwater markets– acoustic pingers, transponders and more – and relocation systems for subsea industry.

RJE's acoustic beacons & transponders are available in a wide variety of options to meet any requirement. With different frequencies, activation methods, and battery life options and more. Company claims to have solutions for any marking and relocation situation. These acoustic pingers mark and relocate equipment and locations underwater, and receivers & interrogators can be mounted on subsea vehicles, used from the surface, or operated by a diver.

The [STI-350 Surface Acoustic Receiver](#) is designed for small boat operations, the STI-350 uses a directional hydrophone and adjustable staff assembly to locate underwater locations or targets marked with an acoustic beacon or ATT-400 transponder.



The [ATT-400EL Long Life Acoustic Target Transponder](#) is small and easy to deploy for up to 18 months in depths of 1000m. When interrogated by the STI-350, DTI-300 or VADR series acoustic receivers, the ATT-400 provides range and bearing up to 750 meters away. The ATT-400 can also be programmed to operate as a free-running pinger.



Depth Operating Range: different options available, ranges up to 6000m+.

Comparative Value Proposition

- RJE International **specializes in customization** and claims to be able to create a pinger/ transponder for any specific task.
- Company **supports the whole product development process:** product design, development, evaluation and marketing.
- Claims to have experience developing products to meet the most rigorous demands of the subsea world.
- Customers include the US Navy, Army, Air Force and all major branches of the U.S. Government.

Commercial Information

RJE International develops, manufactures, and supplies diver sonar and navigation platforms, underwater acoustic relocation products, and wireless underwater communications. RJE offers product design, development, evaluation and marketing for military divers, offshore and marine scientific communities, search and rescue teams, and more. Customers include the US Navy, Army, Air Force and all major branches of the U.S. Government, as well as most major foreign governments and commercial customers in over 50 countries worldwide.

TRL: 8/9 – commercially available with customization options.

Partnering & Deal Potential: TBD.

NOAA Use Case: completely customizable products and systems for underwater positioning marking.



Technology Description

KONGSBERG offers two different lines of Acoustic underwater positioning and navigation systems:

HiPAP - High precision acoustic positioning system

The [HiPAP family](#) was first developed with a focus on the Super Short Base Line (SSBL) principle. The main advantage of the SSBL principle is that it only requires installation of a single vessel-mounted transducer and one subsea transponder. The unique transducer technology and advanced digital signal processing was found to be the ideal solution for obtaining the optimal position accuracy required in any water depths. All HiPAP models operate the latest acoustic protocol for positioning and communication, [Cymbal](#).

μPAP - Small and portable acoustic positioning system

μPAP is a small and compact acoustic positioning system for operation from a surface vessel to track ROV's, tow fish, divers and any other subsea target at ranges to several thousand meters. The system operates in SSBL (specifically Ultra-Short Baseline) mode where it measures the distance and direction to subsea transponders and computes a 3D position in local coordinates or in geographical coordinates. μPAP is designed to be a portable system for easy installation on the vessel or other surface unit.

Example Applications

A transponder is deployed at the seabed, on a submerged structure. Vessel operators then want to know the position of this transponder. the HiPAP system operating in SSBL mode gives the operator this information with the simple push of a button. The HiPAP system will then display the transponder position relative to the vessel or geographically, in numerical coordinates. It will also send the coordinates via serial line or ethernet to external equipment.

Depth Operating Range: claims to work in any water depth.

Comparative Value Proposition

- **Completely customizable** positioning system:
 - Two product lines (HiPAP and μPAP)
 - Three different principles for measurements and calculations (Super Short Base Line, Long Baseline and Multi-User Long Base Line)
- Experience creating products on- and offshore, for merchant marine, subsea, navy, coastal marine, aquaculture, and more.



Example Transponder Range

Commercial Information

KONGSBERG is a global technology corporation delivering mission-critical solutions with extreme performance for customers that operate under extremely challenging conditions. The group has fulfilled demanding customers' needs and adapted to changing market conditions throughout its 200-year-old history. KONGSBERG develops technology from the bottom of the sea, to outer space, translating innovations from one business area to the other.

TRL: 8/9 – commercially available with a wide range of customization options.

Partnering & Deal Potential: life cycle management service will assist customers throughout all the phases, from design to commissioning and during the operational lifetime.

NOAA Use Case: two product lines for underwater positioning and communication.

Imenco Nautronix

Aksdal, Norway; office in Broussard, LA, USA.
 Founded 1979.
<https://imenco.no/area/all/subsea-acoustics>



Technology Description

Imenco Nautronix offers a [range of acoustic pingers and receivers](#) for easy marking and location of subsea structures.

Various frequencies, battery life and acoustic power are available depending on project requirements and can be deployed via a surface vessel, remotely operated vehicle (ROV) or diver.

Acoustic pingers

Easy to use, battery operated units with saltwater contacts. The pinger is activated on deployment of the unit and outputs a standard tone at a fixed frequency, duration and repetition. Various battery lives are available depending on required duration. Capability for passive mode listening TBD.

Acoustic receivers

High sensitivity, easy to use omni-directional and directional units. These can be used from a surface vessel, deployed on an ROV or hand held by a diver. All pinger receivers have an internal battery making them portable and deployable on various surface systems.

[Subsea Power Systems and Battery Pack](#)

Multiple battery chemistries available to suit application requirements including rechargeable and single use. Multiple housing materials available to suit planned deployment depth.

Depth Operating Range: claims to work in any water depth.

Comparative Value Proposition

- **Bespoke and customized solutions** to suit any project requirement.
- Imenco specializes in developing products and services in subsea operations.
- Claims to have specialist knowledge in acoustics communication and positioning for offshore subsea applications.
- Imenco **develops products for fishing vessels**, offshore surface vessels, marine research vessels, naval surface vessels, submarines and many others.

Commercial Information

Imenco is an engineering company and was for the first 20 years engaged in a variety of subsea projects. Throughout the years Imenco has grown through the development of own solutions and through the acquisition of other companies. Imenco claims to have a leading position within Subsea Camera Technology, Subsea Lifting & Handling, Subsea Mechanical Solutions, and Subsea Acoustic Communication & Positioning.

TRL: 8/9 – commercially available with customization options.

Partnering & Deal Potential: TBD.

NOAA Use Case: bespoke and customized solutions for underwater positioning.

Nantes, France; office in Houston, TX, USA.
Founded 1956.

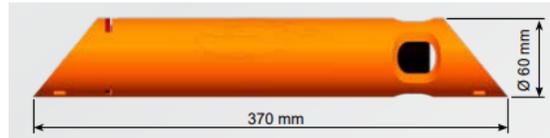
<http://www.sercel.com/products/Pages/GeoTag.aspx>



Technology Description

GeoTag is an acoustic positioning system that has been designed to work with any ocean bottom down to 500 meters deep.

The small and lightweight GeoTag is an **acoustic transponder** enabling accurate positioning measurement of objects on the seabed by measuring ranges from the surface transceiver. Its specific design allows easy installation on any cable or node.



The GeoTag **transceiver** on the vessel interrogates the GeoTag transponders located on the seafloor. The GeoTag transceiver is connected to the navigation system through a junction box.



The GeoTag **Programming and Test Equipment** is an autonomous device powered by a Li-Ion battery. It is used to program the addresses of the transponders before deployment.



Depth Operating Range: 500m, specifications [here](#).

Comparative Value Proposition

- **Compact and lightweight** underwater positioning system that allows for rapid maintenance such as battery replacement.
- Transponder has a **battery life of 6 months and a unique ID**.
- Customers include the scientific community and the military.
- Company offers **manufacturing services to meet customers most demanding applications**, specific products TBD.
- **Limitations:** Sercel focuses on seismic acquisition but the GeoTag system claims to be designed to locate any underwater object.

Commercial Information

Sercel designs and manufactures seismic acquisition systems with technology that is built to handle the toughest challenges. The company's products include underwater acoustic communication & positioning systems, passive acoustic monitoring & marine mammal detection systems, ocean bottom seismometers, mooring monitoring beacons, acoustic transducers & hydrophones. Sercel, in partnership with SHIP AS A SERVICE, provides a [marine test center](#) to help achieve in-sea equipment project goals: from testing and validation through to qualification.

TRL: 9 – commercially available.

Partnering & Deal Potential: TBD.

NOAA Use Case: system for underwater positioning, customization options TBD.

Beringia

Los Angeles, CA, USA.
 Founded 2018.
<https://www.divenetgps.com/>



Technology Description

DiveNET: Sealink compact acoustic network modems claim to provide industry-leading performance in a compact, low power demand solution.

Sealink modems are designed to enable subsea wireless data networking capabilities with cost-effective, long range digital acoustic communication. This line of compact acoustic modems are based on a common, patent-pending design featuring a transceiver element acting as a housing containing all of the electronic components within and covered by a molded thermoplastic membrane. Further details about patent TBD.

	Sealink C (Command modem)	Sealink S (Streaming modem)	Sealink M (Micro modem)
Dimensions (mm)	64 x 62	64 x 62	40 x 45
Max Depth (m)	400	400	300
Acoustic Range (m)	8,000	8,000	1,000



Company also offers **DiveNET: GPS** a portable, self-contained wireless wide-area underwater GPS navigation system. DiveNET: GPS provides 3D coordinate positioning for an unlimited number of divers and/or submersible systems inside a coverage area up to 2,000 meters in diameter. DiveNET: GPS is depth rated for up to 300 m.

Comparative Value Proposition

- **Compact, low power demand and affordable** solution.
- Claims that its acoustic modems are the **smallest in the world**.
- **Customization options** available.
- Current applications include acoustic GPS navigation, data and voice communication, and Subsea Internet of Things (SIoT) connectivity.
- **Limitations:** Sealink working area of 8,000 m x 8,000 m. GPS employs four hand-portable Autonomous Smart Buoys (ASB), deployed roughly around a dive site to emulate the function of satellites on the water surface and establish a long baseline for precise underwater positioning.

Commercial Information

DiveNET Subsea Wireless is a family of hydroacoustic solutions built around a common, patented technological platform. The DiveNET series features evolving capabilities aimed to empower diver and robotic underwater exploration.

Beringia Enterprises LLC is the exclusive supplier of DiveNET Subsea Wireless solutions for through-water acoustic GPS navigation, data and voice communication, and Subsea Internet of Things (SIoT) connectivity.

TRL: 8/9 – commercially available with customization options.

Partnering & Deal Potential: TBD.

NOAA Use Case: subsea connectivity solutions with customization capabilities.

Ocean Space Acoustics

Trondheim, Norway.
 Founded 2018.
<https://www.osac.no/>

Technology Description

PingMe is a device for tagging gear and objects under water, and it consists of three units:

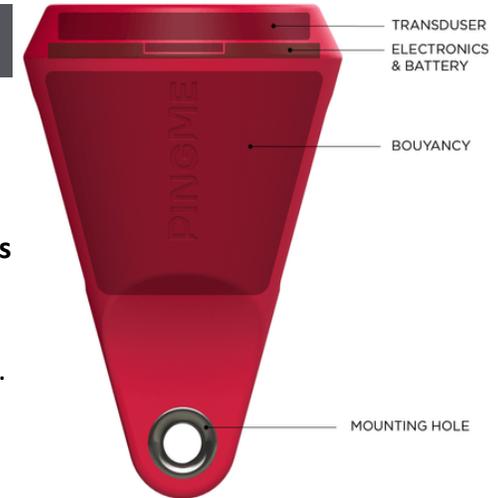
- **PingMe transponder:** A small device attached to gear/objects that can be identified and located underwater. The transponder is **passive and reflects the sound waves originating from standard sonar**. The reflected signal is encoded with a unique identity so that the sonar, with PingMe software integrated, can identify the transponder and calculate its position. This information might be encrypted if the information is to be transferred to the cloud.
- **PingMe Software:** A software module integrated in the boat's existing sonar system or as a stand-alone system. The software allows **communication with the transponder to determine location and ID**.
- **PingMe Service in the cloud:** Management tool for the authorities.

Depth Operating Range: 1000+ m



Comparative Value Proposition

- Primarily developed **for fisherman** with the goal of being **low cost and easy to install**.
- Works with **standard sonar**.
- Information is **encrypted and each sensor has a unique ID**. Information can be shared if needed.
- 5 - 10 year lifetime of device; battery life TBD.
- Range of more than 1000m.



Commercial Information

PingMe is being developed by Ocean Space Acoustics AS (OSAC) in collaboration with Norwegian fishermen and SINTEF (Norway's largest research institute). They claim that the basic technology behind PingMe would be ready in 2019. Transponders, software and services that make the solution user-friendly and robust will be available in the market in 2021/2022.

TRL: TBD – claim to be going to market in 2021/2022.

Partnering & Deal Potential: TBD, currently collaborating with fisherman and SINTEF.

NOAA Use Case: Device to attach to lobster traps for location tracking.



Technology Description

The SeaTrac X100 series of **Micro-USBL (ultra-short base line) tracking and data modems** are a suite of products built around a robust broadband spread spectrum signaling scheme. These multi-purpose acoustic transponder beacons are capable of **simultaneously tracking asset positions and undertaking bi-directional data exchange**.

- X150 USBL Beacon - A multi-purpose USBL acoustic transponder beacon
- X110 Modem Beacon - An acoustic transponder beacon and data modem
- X010 Modem Beacon - A miniature and lighter weight version of X110 beacon

Each beacon is configured by the user with a **unique identification-code** that allows up to 14 beacons to exchange acoustic data messages or broadcast to all other beacons in the network. Messages are exchanged by a request/response process and when complete the sending beacon is able to obtain a range measurement to the remotely interrogated beacon.

Blueprint Subsea has also developed **PinPoint, a Windows software application** that allows users to track up to 14 SeaTrac acoustic beacons.

Depth Operating Range: Up to 2000 m



Comparative Value Proposition

- Each beacon is configured by the user with a **unique identification-code** and features bi-directional data and information exchange with up to 14 other beacons.
- Positions are **computed within the beacon**, so no additional hardware is required.
- Each beacon is fitted with an environmental pressure and temperature sensor that allow the depth of each beacon to be calculated and monitored. When used as part of a tracking system, the remote beacon's depth information can be transmitted and used as part of the position solution, **improving vertical accuracy**.

Commercial Information

Blueprint Subsea designs and manufactures products for the offshore, subsea and commercial diving markets for an affordable cost. They have offices in the UK and South Korea. [Cardinal Point Captains \(CPC\)](#) is the distribution company for Blueprint Subsea's SeaTrac products.

TRL: 9 – commercially available.

Partnering & Deal Potential: TBD, customization abilities TBD.

NOAA Use Case: Beacons and modem for locations.



X150 USBL Beacon

A multi-purpose 'ultra-short base line' acoustic transponder beacon, capable of tracking the position of up to 14 other SeaTrac beacons, and data exchange.



X110 Modem Beacon

An acoustic transponder beacon and data modem, capable of reporting an asset's position to X150 beacons building data networks of acoustic nodes.



X010 Modem Beacon

A miniature and lighter weight version of our X110 beacon, the X010 is suitable for mounting on divers and small ROV's.

Type	Acoustic Positioning Output	Acoustic Ranging Output	Pressure Sensor Rating	Weight
USBL Modem	Yes	Yes	100m (std) 300m, 1000m, 2000m (options)	720g (air) 530g (water)
Transponder Modem	No	Yes	2000m (std) 100m, 300m, 1000m (options)	690g (air) 500g (water)
Transponder Modem	No	Yes	300m	300g (air) 170g (water)

X150 USBL Transponder Beacon Specs

SPECIFICATIONS

LINKS

Dimensions...

Length (excluding connector)	132mm (5.2")
Length (including connector)	160mm (6.3")
Diameter	55mm (2.16")

Weight...

In air	708g (1.56lbs)
In fresh water	508g (1.12lbs)

Housing...

Depth Rating	2000m (other depth rating available)
Construction	316 Stainless Steel
Operating & Storage Temperature	-5°C to +35°C (23°F 95°F)

Electrical...

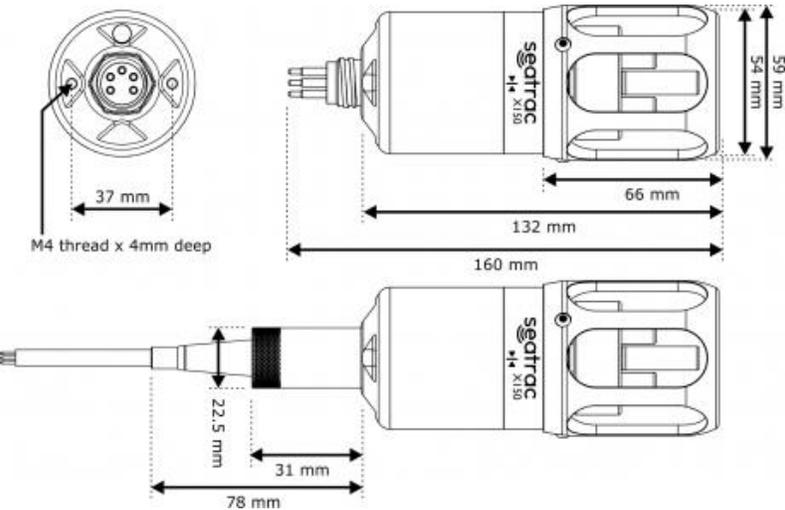
Connector	Teledyne Impulse MCBH-5-MP (5-way)
Communications	RS232 Main serial port (Aux serial port and RS485 operation available on request)
Supply Voltage	9V to 28V DC
Power Consumption	Less than 10W when transmitting, approx 0.5W when idle
Integrated Sensors	Pressure, Temperature, 9-DOF AHRS, Supply Voltage Monitor
Indicators	Red/Green visual status LED

Acoustic...

Remote Ranging	Yes
Remote Positioning (USBL)	Yes
Acoustic Range	1km radius horizontal, 1km vertical
Range Resolution	±50mm (dependant on VOS accuracy)
Angular Resolution	±1°
Velocity-of-Sound Range	1300ms-1 to 1700ms-1
Beacon Velocity	Active Doppler compensation, up to 15kts (28kph)
Communications	Broadband spread spectrum encoding, 24-32kHz, 100 baud. Multi-tiered Acoustic Protocol Stack.
Packet Addressing	15 unique beacon identifiers, and broadcast to all capability.
Transmit Sound Pressure Level	~172dB re 1uPa @ 1m

Applications...

Supported Software Platforms	SeaTrac NavPoint Software, SeaTrac Utilities Software
Developers/Integrators	SDK, including ASCII based serial command interface with Application level and Acoustic Protocol Stack level commands for third party integration.



Technology Description

DSP Comm has a proprietary Digital Spread Spectrum algorithm that enables modems to compensate for the Doppler effect and severe reverberations in the underwater channel, allowing data to be transmitted reliably in practically any sea state.

[Aquacommm](#)

Underwater wireless communication systems for underwater connectivity. Highly reliable underwater wireless communications, low power consumption, flexibility in design and integration. Aquacommm claims to provide systems at a cost-effective price point.

[Aqua Network](#)

Modems are standard AquaComm underwater modems with added networking capability. This allows for IOT underwater and to deploy numerous underwater sensors nodes in a network configuration. For low power consumption, network nodes can be in a low power receive state until woken up by a broadcast.

[Aqua Case](#)

Underwater pressure housing designed and manufactured with precision engineering. AquaCase housings are purpose built to house Aquacommm underwater modems for harsh environments. The housings can be tailored to customer needs and have a modular design to add battery extensions.

Depth Operating Range: 200m, 1000m, 3000m.



Comparative Value Proposition

- Modems use **10-20 times less power** than competing products
- Small form factor, lightweight: **less than half the size** of competing modems
- Networking API: networking option **allows third parties to interface** and implement networking layer easily.
- Housing has a **modular design to add battery extensions**.
- As of Feb 2019, the price of the underwater acoustic modem was [under USD1,000](#). "This price is for small quantity and we can offer even more attractive price breaks for serious developers of solutions and products."

Commercial Information

Aqua Comm is used in numerous solutions today by original equipment manufacturers (OEMs) and other organizations globally. Some areas of applications include Submersible retrieval buoys, Diver location and positioning, Underwater asset monitoring and location-based services, and Wireless underwater lift bags. Company works with the oceanographic instrumentation, oil and gas, defense, environment monitoring, aquaculture, and diving industries.

TRL: 7/8 – products tailored to client’s needs.

Partnering & Deal Potential: TBD.

NOAA Use Case: underwater wireless communication systems tailored to customer’s needs.

Saint-Germain en Laye, France.

Founded 1998.

<https://www.ixblue.com/application/subsea-positioning>

Technology Description

USBL Positioning and Communication

Complete USBL offer with track record of successful use from very shallow water (15 m) to greater depths (10,000 m). Gaps Series and Posidonia are based on an open architecture with serial and Ethernet connectivity and Web control command. All USBL are compatible with third-party equipment.

Gaps Series

Gaps Series has been designed to provide accurate location, positioning and tracking of subsea assets, from ultra-shallow to deep water depths. Both Gaps USBL systems are easy to install and operate. In one single step, that is to turn on the system after installing it, the user is ready to operate.



Comparative Value Proposition

- Gaps M5 is a compact, export-free, cost-effective and omnidirectional USBL system.
- Low power consumption with off-the-shelf batteries.
- Full range of transponders for all applications, option available for user configuration.

Commercial Information

iXblue specialized in the design and manufacturing of advanced marine, photonics and autonomy technologies. The group in-house expertise includes innovative systems and solutions devoted to inertial navigation, subsea positioning, underwater imaging, as well as shipbuilding and test & simulation. iXblue technologies support Civil and Defense customers in carrying out their sea, land and space operations with maximum safety, efficiency and reliability. iXblue conducts its business in over 60 countries.

TRL: 8/9 – commercially available products with customization options.

Partnering & Deal Potential: TBD.

NOAA Use Case: different underwater positioning product lines.

	Gaps M5	Gaps M7	Posidonia (deployable antenna)	Posidonia (flush antenna)
Range nominal (M)	995	4,000	10,000	10,000
Accuracy (% x range)	<0.5	0.06	0.1	0.1
Operating frequency (kHz)	20~30	20~30	14~18	14~18
Antenna aperture (DEG)	200	200	70	100
Data telemetry	yes	yes	no	no
Material	Carbon fiber	Carbon fiber	Stainless steel	Stainless steel
Size (MM)	Ø 296 x 520.8	Ø 295 x 638	Ø 580 x 420	Ø 800 x 320
Related transponder	iXblue MF range Canopus Third-party transponder	iXblue MF range Canopus Third-party transponder	iXblue LF range	iXblue LF range

Boston, MA, USA.

Founded 2014.

<https://www.innovasea.com/fish-tracking/>

<https://support.vemco.com/s/>

Technology Description

VEMCO (acquired by InnovaSea) Positioning System (VPS) is an ultrasonic aquatic fine-scale positioning system used for tracking fish, other aquatic animals, or underwater objects.

The system consists of underwater acoustic transmitters and receivers that are deployed by the customer, and a receiver data processing service provided by VEMCO. Transmitters are deployed on the animals or objects being tracked, and receivers are deployed at fixed stations in the area of interest to detect and record their transmissions. Further information TBD.

Coded Tags

Coded tags are transmitters that transmit a unique animal ID and, optionally, sensor data. Coded tags are used primarily for passive monitoring and fine-scale positioning studies, where large numbers of animals are being tracked simultaneously and identification of individual study animals in real-time or during post-study data analysis is of importance.

Depth Operating Range: TBD.



Comparative Value Proposition

- **R&D capabilities** to develop new products.
- **Large amount of transmitters** are used for underwater tracking and positioning.

Commercial Information

Innovasea provides end-to-end solutions for fish farming and aquatic species research – including quality equipment, consulting services, and platforms and products that deliver data, information and insights. In 2019 InnovaSea [acquired Amirix Systems](#), parent company of Canada-based Vemco. Vemco and HTI-Vemco offer fish tracking and monitoring solutions for fisheries researchers worldwide. Product lines are based on using acoustic telemetry to communicate wirelessly under water.

TRL: TBD.

Partnering & Deal Potential: TBD.

NOAA Use Case: wide range of transmitters and receivers for underwater positioning.

Underwater Technologies Center

Omer, Israel.
 Founded 2003.
<https://www.utc.co.il/>



Technology Description

UTC develop the Underwater Digital Interface (UDI) based on a system of networks. On the original UDI each network links 14 underwater devices and a boat unit supports up to four networks using four different frequency ranges.

[UDI OEM](#)

At Underwater Technologies Center (UTC), mechanical, electronics, software and acoustics engineers, physicists and technicians, all work together to build products to spec by fostering innovative technologies through new ideas, concepts, design, development, and ultimately commercialization.

[UDI AM](#)

UTC has vast experience in designing different acoustic modems. OEM modems serve in a range of underwater communication systems.

The modems have been designed for high performance in challenging underwater environments. There are two families of modems, specifically designed for shallow water and long range. In addition, all modems can be connected through networks that contain 14, 28 or 56 addresses and network protocol; thus providing a complete underwater network ready to accept different software applications.



Depth Operating Range: TBD.

Comparative Value Proposition

- Modems have been tested and in use for over 10 years, in underwater data communications in thousands of devices.
- Option to design a product from **idea stage all the way to commercialization.**

Commercial Information

Underwater Technologies Center is mostly known for its diver detection systems, but also offers acoustic releases, and wireless underwater digital acoustic communication systems. Current applications include underwater communication, sonar, acoustic release, parametric arrays, and tracking systems. Products are based on a [patented technology](#) of underwater communications.

TRL: 7/8 – products tailored to client’s needs.

Partnering & Deal Potential: [Chase Supply](#) is UTC’s U.S. distributor.

NOAA Use Case: company with product development capabilities and extensive knowledge of underwater communications.

Technology Description

Newcastle University is working on a **low-cost, miniature transponder for the NetTag project** to reduce ghost fishing and marine litter.

Newcastle University's recent research has focused on miniature devices, around the size of a matchbox, that consume milliWatts when receiving signals and less than 1 Watt of power when transmitting. A unit on board the surface vessel will send out interrogation signals and any tagged gear within a range of 3km will send a reply. They are able to send data reliably up to 3km range at a rate of 500 bits per second. They are aiming for the device to be manufactured for £50-100.

Related research from the group:

- [In-Band Full-Duplex Interference for Underwater Acoustic Communication Systems](#) (2019) - Adaptive self-interference cancellation (SIC) method for in-band full-duplex underwater acoustic (IBFD-UWA) systems along with a model for the self-interference (SI) for shallow-water acoustic channels.
- [Multi-User Broadcast Acoustic Positioning System](#) (2019) - Multi-user underwater acoustic positioning network based on the continuous broadcast of low power, spread spectrum signals from 3 or more surface nodes synchronized by GPS.
- [Low Energy, Passive Acoustic Sensing for Wireless Underwater Monitoring Networks](#) (2019) - Vessel detector is based on the principles of the Detection of Envelope Modulation on Noise (DEMON) algorithm and tested with acoustic underwater wireless network to the end-user.



Comparative Value Proposition

- Newcastle University is **leading the development of the underwater communication and tracking sensors** for the NetTag project.
- The researchers have focused on **lowering the cost of the device to £50-100**.
- **Minimal energy consumption** such that they devices can last for months.

Commercial Information

This research was conducted by the Sensors, Electromagnetics and Acoustics Lab (SEALab) at Newcastle University, led by [Jeffrey Neasham](#). They focus on research in wireless sensor systems and communications for extreme environments. They have worked in underwater communications technology for over 25 years and their previous technologies are incorporated in over 2000 devices in use around the globe for underwater vehicle navigation, diver tracking/messaging and marine monitoring.

In addition to Newcastle University, the NetTag project includes: [CIIMAR](#), [Univ. de Aveiro](#), [INESC TEC](#), [Univ. de Santiago de Compostela](#), [APMSHM](#), [Arvi](#), and [Euronete](#).

TRL: TBD, appear to have prototype.

Partnering & Deal Potential: In addition to the NetTag project, the SEALab team is also collaborating with Heriot-Watt University and the University of York to develop large-scale smart sensing networks in called USMART, as well as a project with marine biologists to monitor marine mammal distributions and the impact of wind farms.

NOAA Use Case: Low-cost transducer for fisherman.

Technology Description

In August 2020, GeoSpectrum Technologies announced the introduction of the **C-Bass family of compact Very Low Frequency (VLF) long-range acoustic underwater transducers.**

The C-BASS VFL electrodynamic sound projectors are small in size and weight but still maintain the high-power and frequency range (bandwidth) of legacy systems. Its ranges exceed 1,000 km and it is capable of effectively operating under ice. C-BASS transducers are available in a variety of sizes and configurations, including a 20 cm diameter configuration.

Series	M72-225	M72-325	M72-500	M72-1000
Diameter	8.5 in	12.9 in	18 in	38 in
Mass	8 kg	20 kg	100 kg	300 kg
Thickness	7 in	7 in	8 in	8 in
SPL at f_{res} [dB re 1 μ Pa @ 1 m, continuous]	175 dB	180 dB	190 dB	195 dB
Efficiency at f_{res}	10%	10%	9%	6%
Depth Rating Without Pressure Compensation	30-100 m	10-60 m	5-30 m	—
Depth Rating With Active/Passive Pressure Comp.	>1,000 m	>1,000 m	>1,000 m	>1,000 m
Resonant Frequencies	250-500 Hz	160-400 Hz	75-200 Hz	15-100 Hz



Comparative Value Proposition

- C-BASS VFL underwater transducers claim to be **less expensive, lighter, smaller, more efficient, and have a broader bandwidth** than similar communication devices.
- The **omni-directional** C-BASS can be used individually or in arrays to produce high-power sources with or without directivity.
- Claim that it can be used for **underwater navigation through a network of beacons.**
- In November 2019, Geospectrum [announced](#) the **successful deployment** of their M72-1000 C-Bass VLF device in the Arctic Ocean as the active component for low frequency thermometry experiments, in partnership with the Coordinated Arctic Acoustic Thermometry Experiment (CAATEX).

Commercial Information

GeoSpectrum Technologies, an Elbit Systems’ subsidiary, specializes in underwater acoustic transducers and systems. GeoSpectrum supplies its products to the defense and homeland security, oil and gas, and environmental sectors. They produce standard products, but also **customize products for specific requirements** “at short notice and at affordable prices”. They also provide **consulting services and have designed transducers for a number of customers for their own manufacture.**

TRL: 9 – commercially available.

Partnering & Deal Potential: TBD, provide customized products and consulting/design services.

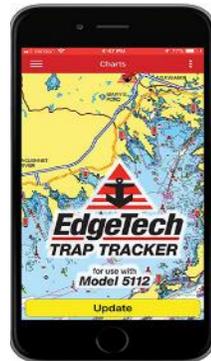
NOAA Use Case: Transducers and sound projector technology.

Technology Description

Edgetech offers a variety of subsea acoustic products, including their **5112 Ropeless Fishing System (RFS), tracking app, and transponder.**

The RFS consists of a Release cage with the appropriate line and floatation cover with an integrated **EdgeTech 5112 rugged acoustic release and transponder, a BLEAT (Bluetooth® Low Energy Acoustic Transceiver) Deck Box unit or Portable BLEAT deck box with hullmounted or portable dunking transducers, and the EdgeTech Trap Tracker application.** Commands from the Trap Tracker application are sent by Bluetooth® to the BLEAT deck box and transducer that sends the commands by an acoustic signal to the 5112 release mounted in the release cage.

Edgetech also offers the **Coastal Acoustic Transponder (CAT)** for use as an underwater instrument location and positioning aid. Operational depth is up to 3500m.



Comparative Value Proposition

- Battery life of up to 1 year, 3000 replies via communication with computer, or 100 releases.
- Made of an aluminum-nickel alloy to resist corrosion while underwater.
- Edgetech Trap Tracker App virtually marks trap and trawl lines, records the positions and catch information and uploads it to a cloud database to help other fishers and law enforcement know where traps are located.
- Ropeless fishing system that allows fisherman to still use their own lobster traps.

Commercial Information

EdgeTech is a manufacturer of underwater technology solutions. The company offers products which include: side scan sonars, sub-bottom profilers, bathymetry systems, AUV and ROV-based sonar systems, combined and customized solutions. In addition to the full line of underwater survey products, EdgeTech provides USBL systems, transponder beacons, deep sea acoustic releases, shallow water and long life acoustic releases, MRUs and customized underwater acoustic command and control systems.

TRL: 8/9 – commercially available.

Partnering & Deal Potential: TBD.

NOAA Use Case: Systems for ropeless fishing & other forms of underwater acoustic positioning.

Specs for 5112 RFS


KEY SPECIFICATIONS
MECHANICAL SPECIFICATIONS

Release mechanism	Motor driven push off mechanism
Release load rating	112kg (250 lbs)
Lift load rating	225 kg (500 lbs)
Depth rating	500 meters (1,640 ft)
Length	35.5 cm (14 in)
Diameter	12 cm (4.75 in)
Weight in air	10 kg (22 lbs)
Weight in water	8.6 kg (19 lbs)
Exposed materials	Nickel Aluminum Bronze Alloy, Buna-N, ULTEM, and Nylon

ELECTRICAL SPECIFICATIONS

Command Frequencies	17.5 kHz to 18 kHz
Command Codes	XACS (Expanded Acoustic Command System, over 1 billion unique codes)
Transmit Source Level	178 dB re 1 μ Pascal-meter
Receiver Sensitivity	-78 dB re 1 μ Pascal-meter
Battery Life Alkaline	(replaceable 9 volt alkaline) 1 years & 3,000 replies & 100 releases



Technology Description

Popoto offers underwater acoustic products including acoustic modems, transducers, and development kits.

The [PopotoSlim](#) delivers subsea communications, flexible, programmable interfaces and small size (110mm x 30mm x 33mm). Retail price of \$2,000 and discount pricing for large quantities. Company claims that their price point for acoustic communications allows new ocean solutions previously thought impossible. Modem has an easy to use **implementation of the JANUS standard**. It is off-the-shelf and available as an OEM boardset for manufacturers or as a complete standalone solution for ship board or submerged operation.

The [Popoto Modem Enclosure](#) is available as a compact Aluminum housing, deployable up to 2,000m or as a large shallow water housing good up to 200m.

The [top-side interface](#) to the Popoto Integrated Voice and Data Modem is available with 20-35 KHz Transducer.

Depth Operating Range: 200m-2,000m



Comparative Value Proposition

- Compact, modular, and API driven modem for **custom solutions or off the self products**.
- Discount pricing for large quantities: 10% discount for 10 or more and 20% discount for 20 or more. Discount for larger quantities TBD.
- Customization options and products used by OEM.

Commercial Information

Popoto Modem (a brand of delResearch LLC) is made up of professionals in acoustic communications, embedded hardware and software, and digital signal processing. Popoto Modem's product portfolio provides OEM and end user solutions for different sub-sea communications needs. Current applications TBD.

TRL: 7/9 – option for customization or commercially available products.

Partnering & Deal Potential: TBD.

NOAA Use Case: product portfolio for underwater communication needs.

Technology Description

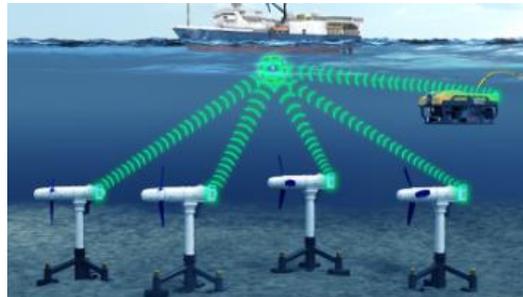
Advanced Navigation offers the [Subsonus Tag](#), an acoustic positioning transponder that operates with the Subsonus USBL. Device has an integrated battery, wireless charging and a pressure tolerant display.

Long battery life: its acoustic processing architecture allows it to achieve a battery life of up to 18 months in slow update applications.

Multi-track technology: up to 65,000 Tags can be tracked by one surface Subsonus unit.

Depth Operating Range: Acoustic tracking range of up to 1,000 meters and tag is depth rated to 2,000 meters.

Applications include subsea asset tracking, remote sensing, vehicle tracking, and diver tracking.



Comparative Value Proposition

- **Claims to have the highest battery density on the market, offering up to 18 months on one charge;** transmit power is configurable which allows extra battery life to be achieved when operating at close range.
- **Up to 65,000 Subsonus Tags can be deployed in the same area** and tracked using one surface Subsonus unit; each tag has a unique address.
- AI algorithm allows Advanced Navigation's products to be much smaller, more accurate, more reliable and significantly cheaper than incumbent products.
- **Limitations:** retail price of \$2,430 – volume discounts available. Customization options TBD.

Commercial Information

Advanced Navigation was founded to commercialize thesis research into AI neural network based inertial navigation. Company builds ultra-precise, AI-based navigational technologies and robotics based on an AI algorithm that allows them to be much smaller, more accurate, more reliable and significantly cheaper than incumbent products, making transformative new technologies possible for the first time, including self-driving cars, robotics, autonomous drones and submersibles, as well as new capabilities in aerospace, automotive, defense, marine and subsea.

TRL: 9 – commercially available. Customization options TBD.

Partnering & Deal Potential: company collaborates with Australian universities to develop new and groundbreaking product capabilities. Current clients include NASA, Boeing, Airbus and Tesla.

NOAA Use Case: acoustic positioning system based on novel AI algorithm.

Technology Description

Researchers at King Abdullah University of Science and Technology (KAUST) propose a **novel localization** method for energy harvesting **hybrid acoustic-optical underwater wireless sensor networks (AO-UWSNs)**.

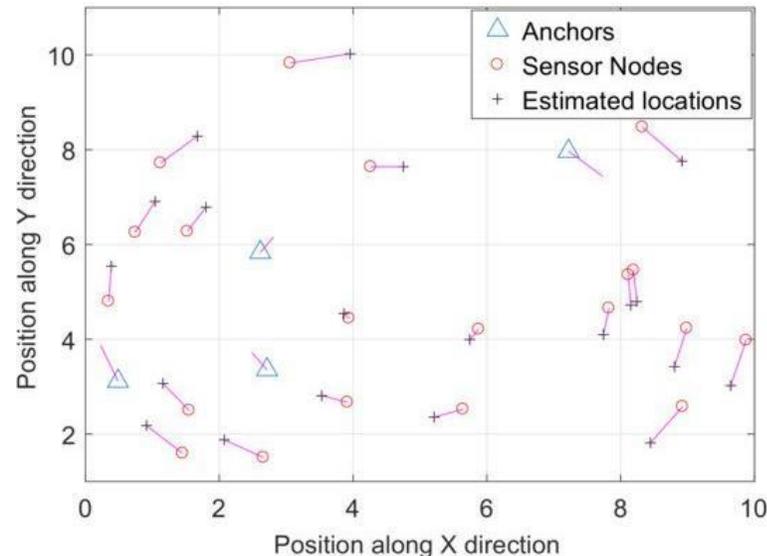
AO-UWSN employs **optical communication for higher data rate at a short transmission distance** and employs **acoustic communication for low data rate and long transmission distance**. A hybrid received signal strength (RSS) based localization technique is proposed to localize the nodes in AO-UWSNs. The proposed technique combines the noisy RSS based measurements from acoustic communication and optical communication and estimates the final locations of acoustic-optical sensor nodes. In the fully connected network, each sensor node is able to communicate with close and distant neighbors using optical and acoustic channels, respectively. Every sensor node shares its neighborhood information with the surface buoy.

This research is from the paper: [Energy Harvesting Hybrid Acoustic-Optical Underwater Wireless Sensor Networks Localization](#) (2018).

Other recent papers from this group include:

- [A software-defined opto-acoustic network architecture for internet of underwater things](#) (2019)
- [Analysis of 3D Localization in Underwater Optical Wireless Networks with Uncertain Anchor Positions](#) (2019)

Depth Operating Range: TBD



Comparative Value Proposition

- AO-UWSN's hybrid system employs **optical communication for high data rate at a short transmission distance** and employs **acoustic communication for low data rate and long transmission distance** to accurately locate the sensors in the network.
- The efficiency of the localization technique **improves with the energy harvested from the aquatic environment**.

Commercial Information

This research is led by Nasir Saeed in the Department of Electrical Engineering at King Abdullah University of Science and Technology (KAUST). This work is supported by the KAUST-MIT-TUD consortium.

TRL: 2/3 – Early stage research.

Partnering & Deal Potential: TBD, located in Saudi Arabia.

NOAA Use Case: Localization of sensors that is optimal for energy harvesting as well.

Technology Description

Researchers at King Abdullah University of Science and Technology (KAUST) are investigating the use of **simultaneous lightwave information and power transfer (SLIPT)** configurations for transmitting energy and data to underwater electronic devices.

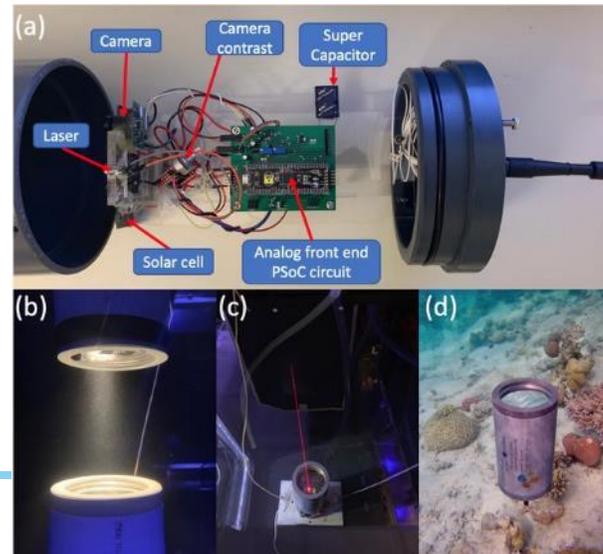
Using surface buoys or drones equipped with lasers, **power and data can be sent and received between sensors on the ocean floor**. The lasers will be able to connect and power underwater robots and devices simultaneously. Return data will be transmitted to the surface vessel, which then communicates via RF (radio) to land bases or data centers.

The KAUST team is now finding ways to overcome the effects of turbulence on underwater reception and looking into the use of ultraviolet light for transmissions that face underwater obstructions. **They are also developing underwater optical positioning algorithms that could help locate relay devices to extend the communication ranges of IoUT devices.**

Research in this field could ultimately lead to the deployment of self-powered underwater sensors for tracking climate change effects on coral reefs, detecting seismic activity, monitoring oil pipelines, and even small autonomous robots for more accurate and extensive underwater search and rescue operations.

Paper: [Toward Self-Powered Internet of Underwater Things Devices](#)

Depth Operating Range: Currently can only transmit over several meters.



Comparative Value Proposition

- Underwater **optical communication** provides a large bandwidth for reliably **transmitting information and energy over several meters**.
- Completed experiments:
 - Charged and transmitted instructions across a 1.5-metre-long water tank to a solar panel on a submerged temperature sensor.
 - Charged the battery of a camera submerged at the bottom of a tank filled with Red Sea water via its solar panel within an hour-and-a-half by a partially submerged, externally powered laser source. The fully charged camera was reportedly able to stream one-minute-long videos back to the laser transmitter.
- **Limitations:** Early stage; only tested at a few meters.

Commercial Information

This work was conducted by Jose Ilton de O. Filho, Abderrahmen Trichil, Boon S. Ooi, Senior, Mohamed-Slim Alouini, Fellow, and Khaled Nabil Salama. It was supported by funding from King Abdullah University of Science and Technology. Testing was conducted in partnership with the Red Sea Research Center and Coastal & Marine Resources Core Lab (CMOR).

TRL: 3/4 – Demonstrated prototypes/proof of concept.

Partnering & Deal Potential: TBD, early stage research in Saudi Arabia.

NOAA Use Case: Optical communication and energy harvesting.

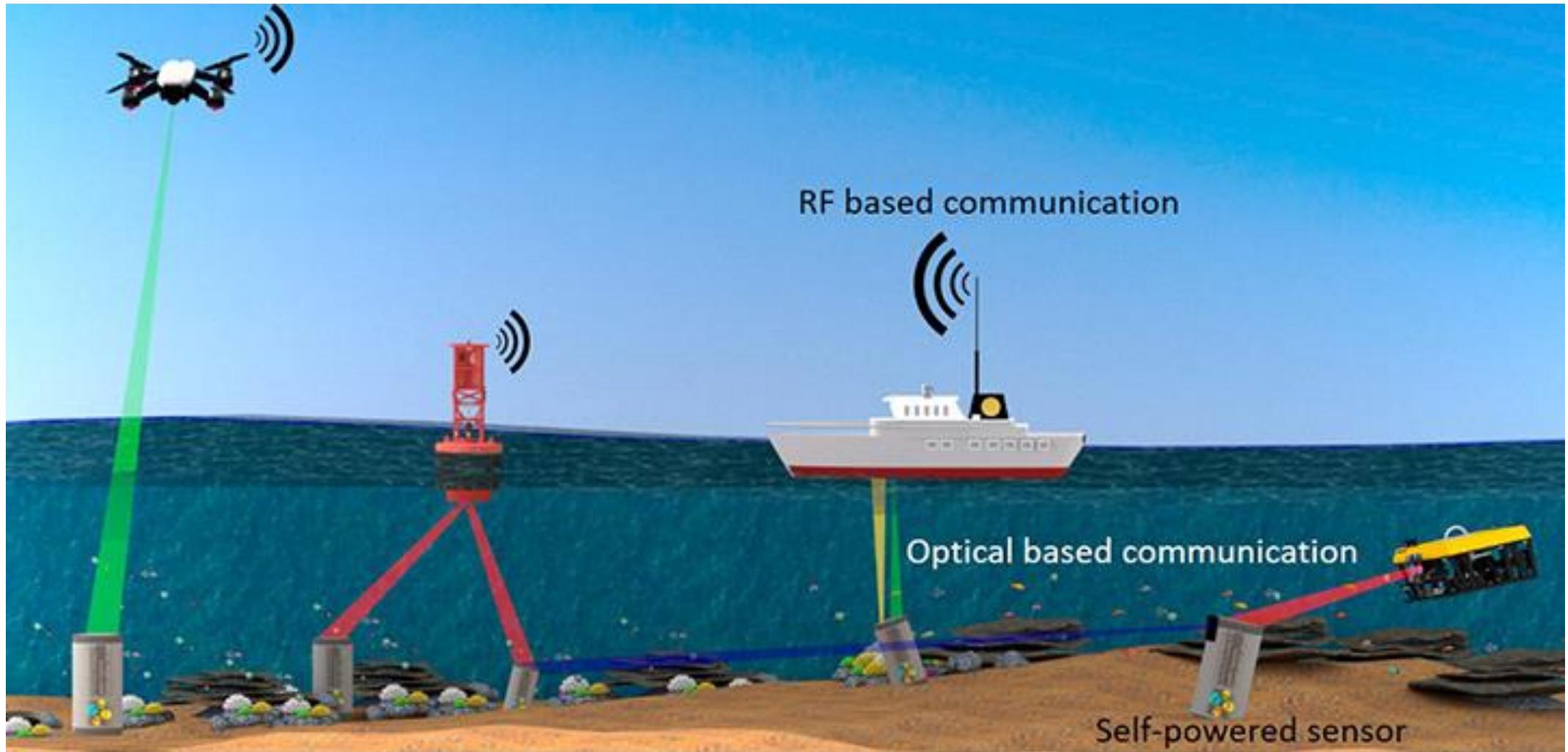
(a) Self-powered underwater camera. Photograph of the module (b) being charged by an LED source, (c) transmitting information (video streaming) with a red laser, and (d) deployed in a coral reef in the Red Sea.

KAUST (SLIPT)

Thuwal, Saudi Arabia.

Published in 2020.

<https://ieeexplore.ieee.org/document/8970169>



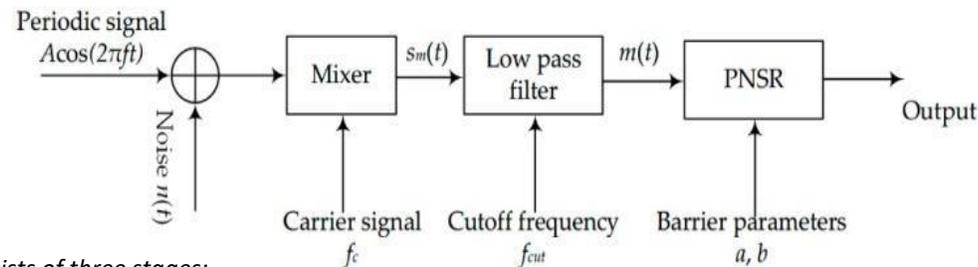


Technology Description

[A Novel Underwater Location Beacon Signal Detection Method Based on Mixing and Normalizing Stochastic Resonance](#) (2020)

By combing white noise with a weak signal, stochastic resonance (SR) can transfer the energy from noise to the signal, which will **amplify the weak signal** and improve the output signal-to-noise ratio (SNR). The classical SR limits state that the input must be small-parameter and the sampling frequency must be 50-200 times higher than the signal frequency.

To improve on traditional SR, researchers at Harbin Engineering University published a novel approach by mixing and normalizing stochastic resonance (MNSR). By mixing an underwater location beacon (ULB) signals and normalizing SR system parameters, MNSR provides a new way to detect weak ULB signal. Through mixing the ULB signal with a carrier signal, the ULB signal detection can be replaced by the “low” frequency difference signal detection.



MNSR consists of three stages:

1. Periodic signal immersed in noise is mixed with a carrier signal (frequency of the carrier signal is f_c). The output of the mixer is $s_m(t)$, which consists of the difference frequency signal component, the sum frequency periodic signal component, and the modulated noise.
2. Low-pass filter is used to filter $s_m(t)$. The pass-band cutoff frequency of the filter is f_{cut} . The filtered output, $m(t)$, only contains the difference frequency component and the noise.
3. Parameters normalized stochastic resonance (PNSR) is used to detect the difference frequency component in $m(t)$.

Comparative Value Proposition

- MNSR is a method of large-parameter stochastic resonance (LPSR) which can **overcome the small-parameter limitation of classical SR**. As shown in simulations, re-scaling frequency stochastic resonance (RFSR) requires higher sampling frequency and MSR requires longer signal duration time.
- By adjusting the carrier frequency f_c and the barrier parameters a and b , **MNSR is more exercisable**, even if the **signal sampling frequency is less than 50 times the signal frequency and the signal duration time is short**.
- **Limitations:** Very early stage, unclear if this has been tested in an underwater environment yet.

Commercial Information

This work is supported by the National Key Research and Development Plan, the National Natural Science Foundation of China, Qingdao National Laboratory for Marine Science and Technology Open Found, and the Acoustic Science and Technology Laboratory Foundation.

TRL: 2/3 – Early stage research.

Partnering & Deal Potential: TBD, based in China.

NOAA Use Case: Novel communication system for weak underwater signal beacons.



Technology Description

W Sense is an **Internet of Underwater Things (IoUT) R&D company** with experiences in underwater IoT network components. Their work includes acoustic/optical modems, sensors, underwater vehicles, and networking software for complete cableless networking interoperability among various vendors of underwater sensors and autonomous vehicles (UAV, ASV, AUV). The kind of technology used for localization is **long baseline (LBL) acoustic underwater positioning** (with some additional features). Examples of some shallow water projects:

- **Localization of assets in aquaculture cages in Norway** (installing in September 2020)
- **Localized underwater robots** in multiple projects supporting relatively short-term missions (weeks) in the last few years including in the US with SPAWAR
- Divers localization as part of a more complex system provided by WSense for monitoring
- They are also supporting the [MUSAS project](#) for monitoring and enhancing underwater archaeological heritage by developing a network of underwater sensor nodes in the submerged sites of Baia and Egnazia
- The company has been editor of networked scenarios, NATO NIAG 190 on JANUS evolution, and is currently coordinating the EC EASME ArcheoSub project after gaining experience by supporting the EC FP7 GENESI and SUNRISE projects



Comparative Value Proposition

- They offer support to **interoperability by JANUS and multi-modem support**. The architecture is designed to run on a large number of embedded platforms, supporting integration of heterogeneous, multivendor commercial acoustic devices.
- They are **seeking to develop partnerships for applications with high impact goals**. They have multi-annual contracts with key stakeholders in different Blue Economy sectors (Aquaculture, Defence, Energy, Environment). W Sense (UK) joined the National Oceanography Centre's (NOC) Marine Robotics Innovation Centre as a Strategic Partner. They also participate in scientific collaboration with top international R&D centers, including MIT, UCLA, ETHZ and others.

Commercial Information

W Sense is a spinoff of Sapienza University of Rome run by Prof. Chiara Petrioli. W Sense currently has 30+ employees and offices in Italy, the UK, and Norway. W Sense helps small and large organizations bridge technology gaps in the monitoring & control of marine environments involving such areas as: Offshore Oil & Gas, Mineral Mining, Energy Production & Efficiency, Defense, Aquaculture, Archeology & Cultural Heritage, Underwater Environmental Monitor, and Diving. W SENSE IoUT solutions are on the market since 2017. Pricing depends on modules and a number of factors (depth/features supported/volumes). W Sense is intensively R&D but has an ecosystem used for production of its technologies.

TRL: 6-9 – running pilot studies with customized equipment; some solutions on market.

Partnering & Deal Potential: Seeking partnerships.

NOAA Use Case: Partner for development of low-cost sensors and modems.

Smart Ocean Technology

Shenzhen, Guangdong Province, China.
 Founded 2016.
<http://www.smartocean.com/>



深圳市智慧海洋科技有限公司
 SMART OCEAN TECHNOLOGY CO., LTD

Technology Description

Smart Ocean Technology has developed devices for underwater communication that use **Orthogonal Frequency Division Multiplexing (OFDM) modulation technology**.

OFDM enables reliable high-speed wireless underwater digital communication technology by combining several signals operating at different frequencies simultaneously. Additionally, the devices use an omnidirectional transducer, which has omnidirectional and non-directional transmitting and receiving functions.

- **Deepwater version of underwater acoustic network modem** - OFDM modulation with reliable underwater acoustic data transmission in a water depth of up to 2 kilometers.
- **Integrated underwater acoustic communication network system** – OFDM modulation technology, integrated network development framework, and supports multi-layer network interfaces. Users can customize network protocol stacks.
- **Shallow version of underwater acoustic network modem** – OFDM modulation technology with configurable hydroacoustic network development platform.



Comparative Value Proposition

- OFDM technology adopts multi-channel communication, which **effectively utilizes bandwidth and improves the communication speed**.
- The hydrophone array is used as the signal receiver, which **improves the signal recognition rate, improves the decoding efficiency, and makes full use of the bandwidth**, so as to achieve the performance that other underwater acoustic modems cannot achieve.
- Claims to have excellent performance in depth transmission, while still achieving **good performance in horizontal transmission due to omnidirectional transducer**.
- **Depth Operating Range:** Up to 5000 meters

Commercial Information

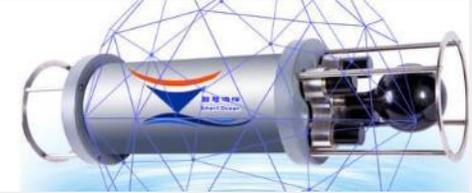
Shenzhen Smart Ocean Technology Co., Ltd. is a high-tech company engaged in the research and development and production of marine communications electronic information equipment. Their products are mainly used in marine meteorological monitoring, marine disaster monitoring, hydrological survey monitoring, marine environmental monitoring, marine salvage, hydroacoustic network research, offshore oil exploration and development, etc. They raised an undisclosed amount of venture funding in a deal led by Decent Capital in April 2018.

TRL: 9 – appear to be commercially available.

Partnering & Deal Potential: TBD, based in China.

NOAA Use Case: Underwater communication system.



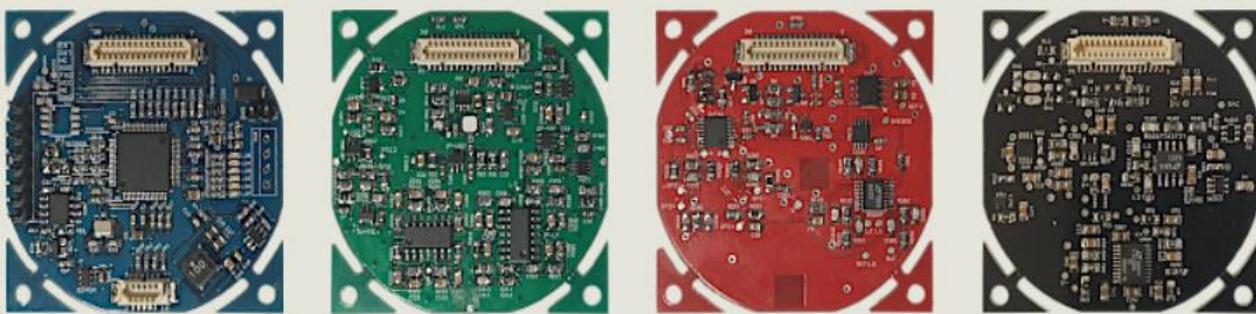
	Deepwater version of underwater acoustic network modem	Integrated underwater acoustic communication network system	Shallow version of underwater acoustic modem
<i>Data rate</i>	Up to 3kbps up to 9kbps	Up to 9 kbps (typical value 1~4 kbps)	Up to 3kbps up to 9kbps
<i>Bandwidth</i>	21-27kHz	21-27kHz	21-27kHz
<i>Communication distance</i>	Up to 5000 meters	Up to 5000 meters	Up to 5000 meters
<i>Depth</i>	2000m	Up to 5000 meters	200m
<i>Transducer pointing</i>	Horizontal omnidirectional	Horizontal omnidirectional	Horizontal omnidirectional
<i>Data interface</i>	RS-232	RS232, RJ45 (split type)	RS-232
<i>power supply</i>	12-16V DC	12-16V DC	12-16V DC
<i>Standby power consumption</i>	<3mW	<3mW	<3mW
<i>Monitor power consumption</i>	<200mW	<200mW	<200mW
<i>Receive power consumption</i>	<1W	<1W	<1W
<i>Transmission power consumption</i>	3W, 1000m range 8W, 2000m range 35W, 3500m range 80W, maximum usable	3W, 1000m range 8W, 2000m range 35W, 3500m range 80W, maximum usable	3W, 1000m range 8W, 2000m range 35W, 3500m range 80W, maximum usable
<i>Network features</i>	Optional	Built-in SeaLinx underwater acoustic network protocol stack	Optional
<i>Picture</i>			

Technology Description

Researchers at the Hamburg University of Technology have developed the ‘**ahoi**’ **acoustic modem for micro AUVs**.

The ahoi modem is small enough to be carried by micro AUVs and reliably communicates at distances of **150+ m (supports ranging with additional hardware)**. The current cost point comes in at under \$600. Due to its modular build, the modem can be customized and is suitable as research platform to analyze, e.g., MAC and routing protocols. The hardware comprises a stack of three boards: a mainboard with a microcontroller, a receiver with analog filtering and amplification, and a transmitter. All boards follow a trade-off between high integration to achieve a small overall footprint and easy assembly by hand. The ahoi modem is **compatible with various hydrophones and frequency bands**.

Depth Operating Range: 150 m



Individual boards of the ahoi modem: mainboard (blue), receiver (green), transmitters (red: long-range, and black: low-power).

Comparative Value Proposition

- All sources of the modem hardware, firmware, and tools are released under a **permissive opensource license**. A brief overview and links to the public repositories are found at <https://collaborating.tuhh.de/smartport/public/ahoi>.
- **Costs below \$600** due to design optimization and COTS components that were easily sourceable at the time of development.
- Researchers conducted extensive **real-world studies** and present results of communication range, packet reception rate, ranging accuracy, and efficient and reliable self-localization in their recent publications.

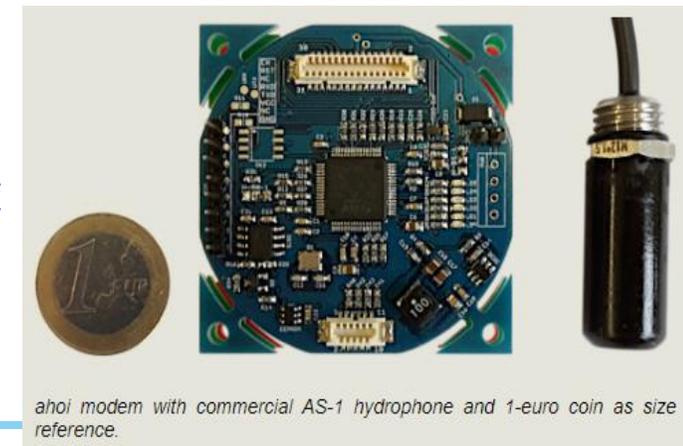
Commercial Information

This research was conducted by Bernd-Bhristian Renner, Jan Heitmann, and Fabian Steinmetz. More on the topic can be viewed at Renner’s [website](#). This technology is part of the [smartPORT](#) project at Hamburg University of Technology.

TRL: 5/6 – open source and tested underwater.

Partnering & Deal Potential: Open source. Currently used by:

- [Universität zu Lübeck, Institute of Computer Engineering](#)
- [University of Padua, SIGNET Research Group](#)
- [ALU Freiburg, Department of Microsystems Engineering](#)



ahoi modem with commercial AS-1 hydrophone and 1-euro coin as size reference.

	name	reference	price (€)	availability / distribution	firmware	processing	network size	dimension (mm)	weight (g)	housing
A	ahoi		ca. 600	open source / can be ordered	open source	μ C	255	50 × 50 × 25	150	yes (100 m) ^d
research devices										
R1	WHOI Micromodem 2.0	[27, 28]	ca. 8,000	open source / commercial	open source	DSP	n.a.	79 × 127 × 44	n.a.	-
R2	UWModem	[10]	250	open source	open source	FPGA	n.a.	n.a.	n.a.	-
R3	n.a.	[50]	n.a.	software based	n.a.	FPGA	n.a.	n.a.	n.a.	-
R4	Itaca modem	[70]	n.a.	n.a.	n.a.	μ C	n.a.	n.a.	n.a.	-
R5	n.a.	[35]	n.a.	n.a.	n.a.	Arduino + μ C	n.a.	n.a.	n.a.	-
R6	n.a.	[90]	n.a.	breadboard design	n.a.	RaspPi + μ C	n.a.	>85 × 56 × 20	n.a.	-
R7	Nanomodem	[49]	60	n.a.	n.a.	n.a.	n.a.	Ø 42 × 60	n.a.	-
R8	n.a.	[71]	n.a.	n.a.	n.a.	μ C	n.a.	Ø 80 × 100	n.a.	-
R9	n.a.	[18]	>3,000	software based	n.a.	PC + FPGA	n.a.	n.a.	n.a.	-
commercial devices										
C1	Evologics S2C 18/34	[24]	ca. 8,000	commercial	proprietary	FPGA	n.a.	Ø 110 × 265 (170 ^e)	2,445	yes (200 m) ^b
C2	Evologics S2C M HS	[24]	n.a.	commercial	proprietary	FPGA	n.a.	Ø 63 × 310 (235 ^e)	1,120	yes (200 m) ^b
C3	Teledyne ATM-903	[72]	n.a.	commercial	proprietary	n.a.	n.a.	n.a.	n.a.	yes (500 m) ^b
C4	Sonardyne Modem 6 Sub-Mini	[65]	ca. 15,000	commercial	proprietary	n.a.	n.a.	Ø 75 × 420	3,200	yes (1,000 m) ^b
C5	Applicon SeaModem	[16]	n.a.	commercial	proprietary	DSP	15	130 × 60 × 25	530	-
C6	TriTech Micron Data Modem	[86]	n.a.	commercial	proprietary	n.a.	n.a.	Ø 56 × 79	235	yes (750 m)
C7	blueprint subsea X110	[11]	n.a.	commercial	proprietary	n.a.	15	Ø 55 × 106	676	yes (2,000 m)
C8	develogic HAM.BASE	[19]	n.a.	commercial	proprietary	DSP	15	Ø 85 × 600	n.a.	yes (6,000 m) ^b
C9	DSPComm Aquacom Gen2	[22]	n.a.	commercial	proprietary	DSP	64	100 × 80 × 20	n.a.	-

Technology Description

Bridget Benson’s PhD thesis project at UCSD, [Design of a Low-Cost Underwater Acoustic Modem for Short-Range Networks](#), designed an underwater acoustic modem with a specific focus on **reducing the cost of the transducer**. The design substitutes a commercial transducer with a home-made transducer using inexpensive piezo-ceramic material and builds the rest of the modem’s components around the properties of the transducer. The **total cost of the transducer is approximately \$50** (including the ceramic, leads, potting and labor), and the **total parts cost for the modem is estimated at \$250-600**.

TABLE IV. UNDERWATER ACOUSTIC MODEM COMPARISON

	Data rate	Transmission distance	Transmit & Receive power	Cost	Firmware and software design
Teledyne Benthos	2400 bps	2-6 km	12 W 0.4 W	\$10,000	Proprietary
LinkQuest	9600 bps	1500 m	4 W 0.8 W	\$8,000	Proprietary
WHOI Micro-Modem	80 bps (FH-FSK) 300-5400 (PSK)	1-10 km	10-100 W 200 mW – 2W	\$8,000	All design information is available online.
UCSD Modem	200 bps	2 km	1 – 40 W 1W	\$600	All design information will be available online.

Other notable work at UCSD for underwater sensors:

- 2019 Master’s thesis -[Towards a Modular, Low-Power, Low-Cost, and High-Speed Underwater Optical Wireless Communication Transmitter](#)- Transmitting at speeds up to 8.88; transmitter consumes 1.75 W; materials cost \$41.95.
- [Scripps Institution of Oceanography](#) & [Ocean Instrumentation and Technology](#)

Comparative Value Proposition

- Benson’s modem was estimated to cost **\$250-600 with the transducer costing \$50**.
- Benson’s final modem prototype, which uses a frequency shift keying modulation scheme, was field tested in a lake proving it could communicate over distances up to **400 meters for rates up to 200 bits per second with less than 5% error**.



From left to right: The raw piezoelectric ring ceramic, the potted ceramic, the transducer in the potting compound mounted to a prototype plate to be attached to a modem housing.

Commercial Information

Bridget Benson is currently an Assistant Professor in the Electrical Engineering Department at **California Polytechnic State University San Luis Obispo**. Her research interests span computer engineering and aquatic sciences, focusing technology to advance marine science research. She received a PhD degree in Computer Science and Engineering at the University of California San Diego in 2010.

TRL: 7/8 – parts commercially available, but sensors themselves not sold assembled.

Partnering & Deal Potential: TBD, Benson now at CalPoly

NOAA Use Case: Design for low cost underwater sensors.

COST AND POWER ESTIMATES FOR THE UNDERWATER MODEM

	Cost (\$)	Power (W)
Transducer	50	N/A
Transceiver	125	1- 40
Digital Components	75	0.2
Power Supply	100	TBD
Interfaces	TBD	TBD
Total	~\$250	

Desert Star System

Marina, CA, USA.
 Founded 1992.
<https://www.desertstar.com/>



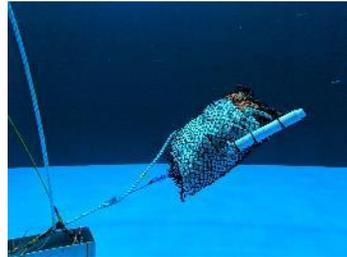
Technology Description

Desert Star Systems (DSS) offers a ropeless fishing system comprised of three components based off a fusible link release mechanism.

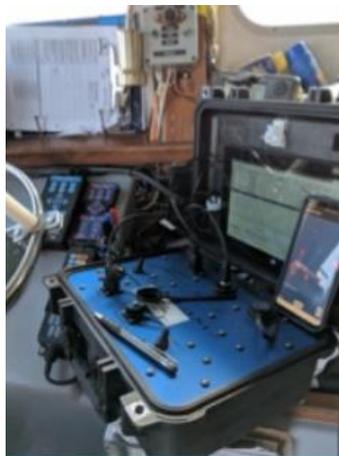
Operating at depths up-to 300m, Ropeless Fisher offers a fully functional virtual/acoustic gear marking package, custom release bag options/kits, and a ranging acoustic release with a lifetime of 15-20 years. DSS's free Ropeless Fisher app logs trap deployment locations. Each deployed trap has a marked GPS location which is stored and updated to a cloud database when in cell-phone/wifi reach. The app then lists each trap deployment through a list or map view which indicates if a trap is near and whether a fisherman should lay traps in that location given the presence of nearby traps. Regulators may see submerged gear from any location at any time.

As of 2020, DSS also offers **Acoustic Gear Marking** used in conjunction with virtual gear marking to help find lost gear, or for an inspector to cross reference virtual gear markings and actual locations. Releases can be interrogated and ranged in case they may have moved. Company also added an efficient fisher public identifier (PID). Company claims that gear logging, mapping, and sharing functions are in progress.

Depth Operating Range: 300m



Virtual Gear Marking



App used with the surface station

Comparative Value Proposition

- The Ropeless Fisher **app is and will always be free** of charge for anyone who wishes to download it.
- Gear owner can specify a range, a **“visibility radius” within which the gear can be visible to others.**
- **Regulators with the Ropeless Fisher app can see all trap locations** from any distance.
- **Limitations:** acoustic gear marking is still under development.

Commercial Information

With over 25 years of experience manufacturing marine technology, Desert Star System offers satellite tags, underwater passive acoustic monitoring recorders, acoustic release systems used for ropeless fishing or large instrument arrays deployed on the seafloor, underwater precision positioning/surveying, acoustic communication, underwater navigation and more.

TRL: 9 - commercially available since 2012; [Broadcast release starter system](#) retails for \$5,250 and the [ranging release starter system](#) retails for \$10,295.

Partnering & Deal Potential: System was funded by the Canadian Department of Fisheries and Oceans (DFO), the Atlantic Fisheries Fund (AFF), Internal Fund for Animal Welfare, Government of New Zealand, and the Government of New South Wales.

NOAA Use Case: ropeless fishing system working in underwater acoustic gear marking.

Technology Description

Ashored Innovations developed the ‘rope on-command’ (ROC) fishing system to minimize the risk of whale entanglements and trap loss/damage.

Ashored’s ROC fishing systems include a rope containment and release module (MOBI) that also uses sensors to collect and transmit data to an **onboard gear tracking system (ATLAS)**. ATLAS is a suite of software and hardware that tracks the location, inventory, connection, and ownership of a user’s fishing gear. Super Tags, Smart Tags, and sensor arrays collect data and ATLAS+ software automates and displays this information.

[According to Ross Arsenault](#), co-founder and COO, “Each trap is tagged with a wireless tag that is scanned as the trap shoots off the boat. At that moment the **GPS location is recorded and uploaded to a cloud server** so is constantly live. The system will only be accessible when out fishing and it only pings gear in a radius of what can normally be seen on the horizon.”

[As of October 2018](#), the team is working on a **talkback feature via acoustics to tell a nearby vessel where a lost trawl is** if in a listening range if the buoy and trap were to be pushed off its original location.

Depth Operating Range: TBD.



Comparative Value Proposition

- **Automated system:** ropeless gear tags attached to traps are scanned as they are shot off the boat, unlike other systems where fisherman need to manually input location.
- Company claims to be working on a **feature to locate a trap if pushed off its original location.**

Commercial Information

Ashored develops sustainability-enabling technologies for the commercial fishing industry. Currently, Ashored is addressing issues of marine animal entanglements, derelict fishing gear, ghost fishing and the related challenges to the industry and governance. Ashored retrofits existing lobster and crab traps/trawls with underwater buoys that can be triggered to the surface using an acoustic release (with time-activated backup release) — this permits the buoy and connecting rope to rise to the surface where fishermen can use existing onboard equipment and processes to retrieve the trap and prepare it for redeployment.

TRL: TBD.

Partnering & Deal Potential: TBD.

NOAA Use Case: ropeless gear location marking system.

Technology Description

Recent Advances and Future Directions on Underwater Wireless Communications. A summary of the topics reviewed is as follows:

- Due to the wide range of applications of **underwater sensor networking (UWSN)**, the **most typical challenge is to supply power in an underwater medium**. Paper reviews energy harvesting systems to UWSNs architecture through Wireless power transmission (WPT), Simultaneous Wireless Information and Power Transfer (SWIPT), Microbial Fuel-Cell process, and acoustic piezo-electric method.
- Researchers anticipate the high **data rate and bandwidth range in the future with the implementation of 5G wireless network candidate**. Frequency bank multi-carrier technology (FBMC) and Generalized frequency division multiplexing (GFDM) promising techniques towards 5G networks are also overviewed. **Future work and recommendations of 5G wireless network is also included in underwater** based on most recent literature on particular emerging technology.
- Paper reviews **underwater communication emerging technologies and their applications for both academic and industrial perspectives** that have a great impact on UWC system. Massive multi-Input-multi-Output (MIMO), Non-Orthogonal Multiple Access (NOMA), mm-Waves wireless carriers and Internet of underwater things (IoUTs) enable in underwater wireless communication play a significant role to the development and encourage the communication vitality. Recommendation and future work of each particular section is also included.

Comparative Value Proposition

- Comprehensive overview of existing Underwater wireless communication (UWC) techniques including Acoustic, Electromagnetic (RF) and Optical Technologies, with possible future directions and recommendations to enable the next generation wireless networking systems in the underwater environment.

Commercial Information

Research performed by Mohammad Furqan Ali, Dushantha Nalin K. Jayakody, Yury Alexandrovich Chursin, and Sonkin Dmitry from the School of Computer Science and Robotics at the National Research Tomsk Polytechnic University

TRL: 5/6 – overview of existing technologies.

Partnering & Deal Potential: Work was funded, in part, by the Ministry of Education and Science of the Russian Federation.

NOAA Use Case: overview and comparison of Recent Advances and Future Directions on Underwater Wireless Communications.

**Description and summary of
proposed underwater
wireless techniques**

Main features during signal propagation	RF waves	Acoustic waves	Optical waves
Types of water for signal propagation	Fresh water Seawater	Shallow water Deep water	Clearlest water, Intermediate water and Murkiest water Pure ocean water, Coastal ocean water, Clear ocean water, Turbid harbor and estuary water
Requirements	High attenuation over short distances	Doppler estimation and compensation Latency in communication, Existence of shadow zones	Line of sight link Receiver direction tracking Subject to marine fouling
Benefits	Relatively smooth progression in air-water channel over a shor distance (Up to 100 m) Unaffected by pressure gradient RF waves can propagate in dirty and high turbid water. High propagation speed High data rate(Up to 100 mbps) Low Dpppler shift and propagation delay	Widely used in UWC Low bandwidth (Up to 20 kbps) Long range propagation (Up to 20 km)	High data rate (In Gbps) Ultra high bandwidth Low cost and small volume transceiver Moderate distance propagation (Up to 30 m)
Limitation	Shows tolerance with natural properties of water (salinity, pressure and turbidity), Does not need line of sight, Does not affected by sediments and aeration, High bandwidth over a short distance, Moderate latency RF waves can tolerate tidal waves, ambient noise, man-made noise and human activities Costly, bulky and High energy consuming transceiver Limited propagation range (short link range)	High communication latency Low data transmission rate(In kbps) Costly, Bulky and high energy consuming transceiver Harmful for marine life, Strong reflection and attenuation through air-water boundary, Poor performance in shallow water, Affected by pressure, turbidity and salinity of water channel	Require line of sight Propagation for short distance, Suffers from severe absorption and scattering Moderate link range, Low latency Can not cross air-water boundary
Main characteristics	Cross water-air surface boundary	Propagates over long distances	Achieve higher data rates
Reliable communication on targeting range	Few meters (Up to 10 m)	Kilometers (Up to 20 km)	Several meters (Up to 100 m)
Frequency range (Hz)	30–300	10–1000	10^{12} – 10^{15}
Achievable data rates	1–10 Mbps for 1–2 m 50–100 bps for 200 m	1.5–50 kbps for 0.5 km 0.6–3.0 kbps for 28–120 km	1 Gbps for 2m 1 Mbps for 25 m
Dependence of the speed propagation	Frequency Water conductivity Salinity and temperature	Temperature Salinity Water depth	Frequency water turbidity Chlorophyll concentration salt ions
Propagation Speed (m/s)	2.255×10^8	1500	2.255×10^8
Attenuation	Frequency and conductivity dependent (3.5–5 dB/m)	Distance and frequency dependent (0.1–4 dB/m)	0.39 dB/m (Ocean) and 11 dB/m (turbid water)
Efficiency	Medium at short ranges	Medium (Non-multipath)	Highest (Non-trubid)

Tomsk, Russia.

Paper published on July 2019.

<https://link.springer.com/article/10.1007/s11831-019-09354-8>

Applications of current project schemes and main contributions in underwater wireless communication system network

Current underwater communication project schemes	Contributions and key visions	Current underwater communication project schemes	Contributions and key visions
UnderWorld [41]	Increasing interest of industries vitality, military, environmental operations and seaport management infrastructures Encourage and Recommend to Electro-magnetic communication framework for shallow water instead of acoustic communication due to worse performances Aim to setup new paradigm and alternative paths (1) DSP (digital signal development) (2) Antenna design (3) Design of communication system in low power regime (4) UUVs development for new paradigm underwater communication	CORODIS [42]	Aim to conceiving, developing and testing submerged and aerial sensors network Minimizing response delay and optimization of acoustic communication vitality Point-point connection Macro network configuration by adapting node geometric configuration
SWARMS [43]	Development of AUVs, ROVs and USVs to opening new applications and ensuring usability Increasing autonomy of AUVs and improving usability of ROVs Aiming Seabed mapping Berm building Observing of chemical pollution Corrosion prevention in offshore installations	BWNL [44]	Ultra-massive MIMO Dynamic massive MIMO Design and development of physically reconfigurable and electronically tunable multi-frequency antennas Design of piezoelectric underwater harvesting system
SUNRISE [45]	Development and implement of Underwater internet things (IoUTs) Underwater Robotics technologies Novel paradigm of software defined open architecture modem (SDOAM) and software defined communication stack (SDCS) Novel underwater communication technologies and paradigms	DEUS [47]	Viable cyber interconnection scheme Advance magnetic-induction (MI) antenna design AUV design and development of IoUTs
ARCHEOSub [46]	Development of low cost AUVs Real time communication multimedia data	SHOAL [49]	Underwater mobile Ad-hoc network (UMANet) Reduce time delay due to acoustic propagation

Technology Description

Marecomms has developed **ROAM (Robust Acoustic Modem)**, a robust and broadband underwater acoustic communication system with advanced algorithms.

Marecomms uses efficient **signal processing algorithms to correct for distortions and corruptions**, and the original message content is reconstructed quickly. In experiments, they reached a user-experienced data rate of 26.66 Kilobits per second in a challenging horizontal shallow water environment with random surface movement, where they used nearly 30 dB less sound level than typical values. Their current focus is on further increasing these data rates without a significant incline in the transmit sound levels. This will make it possible to transmit images and videos to a lateral reference distance of 1 Km with an acceptable latency.

ROAM has been tested in the Northern Atlantic in different temperature, salinity, and water depth conditions and has been proven to deliver several tens of kilobits per second throughputs in a vast variety of circumstances where typical modem design approaches are shown not to work.

Depth Operating Range: TBD



Comparative Value Proposition

- ROAM **does not depend on pristine conditions** to work properly and effectively utilizes limited bandwidth.
- In sea trials performed in January 2020 at Bedford Basin, Nova Scotia, Canada, the received data were significantly distorted and corrupted by the underwater propagation environment as anticipated. Applying Marecomms' algorithms to the raw received data, however, **restored a perfect replica of the original transmitted image (i.e., zero Bit Error Rate (BER))**.
- ROAM can transmit at **greater distances** than can be achieved with current methods.
- **Limitations:** Focused on transmitting images and videos

Commercial Information

Marecomms was founded by Dr. Ulaş Güntürkün for the R&D, design, and implementation of maritime wireless communication and remote sensing systems. Marecomms has been working with **Geospectrum Technologies** for the past two years in testing. They are now ready to build a prototype and hope to have a product on market by the summer of 2021. Marecomms is currently a two-person operation and this year they hoping to raise investment capital or finance the growth in the short term through revenue and grants. In September 2020, Marecomm was shortlisted as one of 31 companies to compete for prizes in the [Ocean Startup Challenge](#).

TRL: 5/6 – prototype testing completed.

Partnering & Deal Potential: "Although we do not currently have a readily available product to perform underwater positioning, our communication system can be a facilitator for the buoyless positioning system you mentioned."

NOAA Use Case: Modem and algorithms for signal processing.

Update IR5

“As you may know, shallow water – soft bottom environments pose arguably the most challenging environments for underwater acoustic communications.

Since we wanted to test our algorithms against the highest grade of difficulty, the water depths we considered so far varied between 8 and 40 meters.

The test areas included Halifax harbor and Bedford basin, which, in addition to the soft bottom and shallow water, also offer a very noisy environment due to shipping and wind activity as well as a rail network surrounding the harbor.

That said, deep water environments in the open ocean are typically more straightforward for communication, and our gear has a depth rating of up to several kilometers.

Thus after proving our background science and the algorithms embedded in ROAM, we believe our product is in a favorable status for deep water conditions too.

As for the range, we have tested up to 600 meters thus far, but we used only 165 dB Source Levels (averaged over the whole spectrum). Hence considering that typical source levels can be as high as 195 dB, we have another 30 dB of power budget at our disposal, which is considered to be enough to increase the range up to 1 Km or more.

I hope this answers your questions, and please let me know if you require further clarification.”

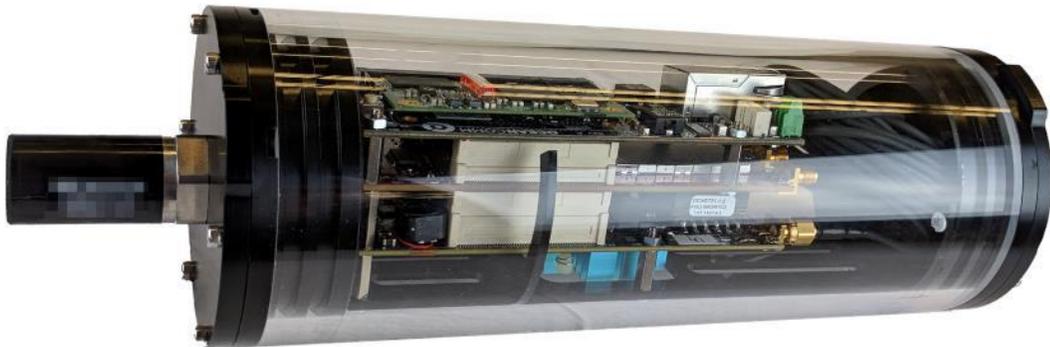


Technology Description

OceanComm have developed wireless acoustic modem that they claim acts like **underwater Wi-Fi**.

The team is developing a new technology that uses ultrasound to wirelessly transmit data at broadband speeds. They developed a **signal processing algorithm** to significantly improve transmission rate from a picture per minute to greater than 15 pictures per second, making **live-streaming possible**. Their advanced signal processing algorithms are capable of including 5 bits of information in every hertz of acoustic bandwidth available (5 bits/s/Hz).

The modem is 2.82" x 5" and can be readily mounted within or on buoys, AUVs, ROVs and other subsea platforms. Reliable, high-speed connections can be maintained using as little as 2.2 Watts of power. The transmission of 1 Gbit over 100 meters takes just about 1 Wh of energy. They currently sell a 10-kbps version of the modem for \$6,000 (\$2,000 more for a depth rating of > 400 meters). They claim their acoustic modem is a flexible platform that can be easily customized with trade offs between data rate, range and cost.



Comparative Value Proposition

- Payload data rates are between **10 to 100 times higher** than in competing systems, e.g. 1 Mbps over a distance of 100 meters or 500 kbps over 400 meters.
- Ultra-wideband piezo transducers achieve **excellent SNR at fractional bandwidths well above 100%**.
- Signal processing algorithms **validated in field tests with the US Navy**.
- Claim that their technology “will drive down cost of deep-sea access by a **factor of ten**”.
- **Limitations:** Cost; targeting high-end applications that require video and image streaming.

Commercial Information

OceanComm was founded by Thomas Riedl, PhD, and Andrew Singer (Professor of Electrical and Computer Engineering) at the University of Illinois.

TRL: 5/6 – claim to have tested the prototype with the US Navy.

Partnering & Deal Potential: TBD, They are currently partnered with DARPA, ONR, NSF, Mbari, University of Illinois and University of Wisconsin – Milwaukee.

NOAA Use Case: Underwater modem, signal processing algorithms.



Updates IR5

“Our acoustic modem is a flexible platform with a couple knobs to trade off between data rate, range and cost. It can easily be customized. A basic acoustic modem could probably be built for \$1k or less, if the volume was in the thousands. Do you know how many of these devices would ultimately be needed?”

“The product of communication distance and payload data rate is about 100 Mbits * meters for our modems. So over a distance of 100 meters, you get about 1 Mbits per second. Over a distance of 1 km, you get about 100 kbps. And over a distance of 10 km, you should get about 10 kbps. The size of the data packets can be adjusted as needed.

We have not looked at distances greater than 10 km yet, but expect a data rate of about 1 kbps over a distance of 100 km. It would just require a very low frequency transducer. What range do you need?

We can provide some test units for NOAA to experiment with.”

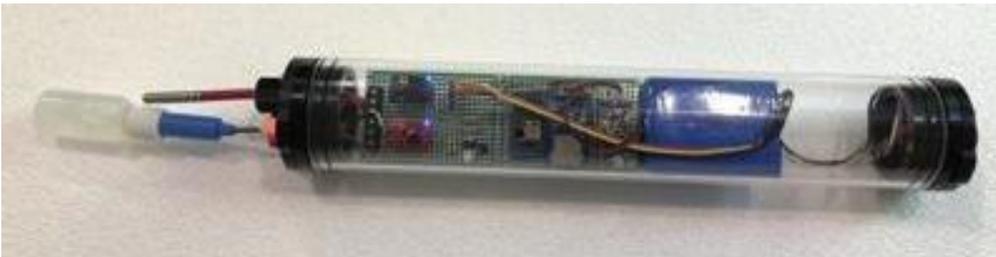
Technology Description

Gloucester Innovation is working with the Lobster Foundation of Massachusetts to develop a **smart IoT lobster trap called LobsterNet**.

The devices, or ePods, will be nested within lobster pots and monitor and collect **pH and temperature data at the depth and location of the lobster pot**. When the trap is hauled, the information will be communicated wirelessly via a SigFox IoT network to a “marine data cloud” where the data will be stored and further analyzed. By incorporating Sigfox’s IoT technology into devices that will simply attach to lobster traps with zero intrusion to the lobstering process, Gloucester Innovation is able to gather oceanic floor information in days, rather than months.

The sensors used in the project already have been **developed and the pilot project occurred in the summer of 2019** along the Massachusetts coast. They have also said that the project partners are looking at the possibility of **tethering additional sensors** in specific static locations to provide other real-time data, as well as possibly adding small cameras or hydrophones to assemble even more data streams.

Depth Operating Range: They have tested off the coast of MA, but exact depth unknown.



Comparative Value Proposition

- Potential partner who has already **developed a ruggedized device for lobster traps** and is working with the **same target stakeholders as NOAA**.
- Aiming to make a smart trap with sensor to collect high resolution data about ocean conditions at scale and over time, and generate information for commercial and recreational fishermen, researchers, and the larger blue economy.
- Unlike other connectivity options, such as Wi-Fi, Bluetooth or cellular, Sigfox U.S.A.’s LPWAN (Low Power Wide Area IoT Network) technology offers reliable, long-range coverage across oceanic waters **upwards of 20 miles off the shoreline**.
- **Limitations:** Not collecting location data; only able to collect data when the traps are hauled (i.e. communication through air, not water).

Commercial Information

Gloucester Innovation is focused on building platforms, solutions, and businesses at the intersection of marine applications, robotics, and biotech. They have received grant funding from the Massachusetts Seaport Economic Council for the LobsterNet project.

TRL: 5/6 – testing pilot projects.

Partnering & Deal Potential: Other partners on the LobsterNet project include: UMass Gloucester Marine Station, the Angle Center for Entrepreneurship at Endicott College, the SigFox network provider and the Scituate-based Lobster Foundation of MA.

NOAA Use Case: Potential partner for developing device that can survive conditions for a similar use-case.

Microfine Materials Technologies

Singapore.
Founded 1995.

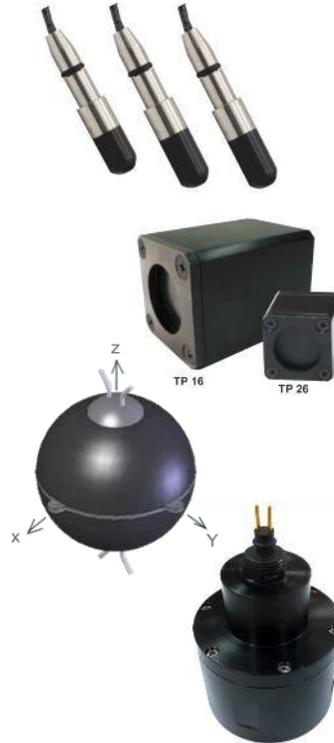
<http://www.microfine-piezo.com/index.php>

MICROFINE
MATERIALS TECHNOLOGIES PTE LTD

Technology Description

Microfine Materials Technologies has developed a range of high-performance piezoelectric actuators based on novel lead zinc niobate-lead titanate or $\text{Pb}(\text{Zn}_{1/3}\text{Nb}_{2/3})\text{O}_3\text{-PbTiO}_3$ (PZN-PT) single crystal technology for underwater applications.

- [PZN-PT Single Crystal Miniature Hydrophone](#) – High sensitivity and reduced noise from the large piezoelectric coefficients (2000-2800 pC/N) and low dielectric loss (of <0.003) of PZN-PT single Crystal.
- [Projector TP16 and Arrays](#) - Compact underwater projectors of broad to Ultra-Broad (CUB) bandwidth, driven by transverse-mode PZN-PT single crystal. 24 mm thick in bare, unpackaged form. Wide-band communication (12-52 kHz operating frequency range) and power efficient (180 dB source level per element at 20W).
- [Accelerometer-based Acoustic Vector Sensor](#) - Single crystal acoustic vector sensors with 3D (or 2D) highly sensitive accelerometers and phase-reference hydrophone.
- [Ultra Broadband Chirp Ready Transducer Technology](#) – Ideal for underwater (UW) broadband communications, UW imaging, and UW detection, location, classification and tracking of low signature objects, etc. Frequency range from 15 kHz to 300 kHz.
- [Large Stroke Single Crystal "Hi-Fi STAKE" Actuator](#)
- [High Authority Piezoelectric Actuators \(HAPA\)](#)
- [Flextensional Actuators \(FTA\)](#)



Comparative Value Proposition

- PZN-PT single crystal materials offer **higher electromechanical coupling coefficients than PZT ceramics for improved bandwidth and sensitivity.**
- Technology is based on novel university research. See publications [here](#).
- **Limitations:** Cost is TBD.



Commercial Information

Microfine Materials Technologies Pte Ltd, a spin-off of National University of Singapore. After years of focused R&D, their first product, PZN-PT piezo single crystals, was launched in 2002. Since then, Microfine has evolved from a crystal supplier to a developer and manufacturer of advanced piezoelectric devices, They have customers worldwide, including in Japan, France, United Kingdom, Germany, Australia and USA. Microfine Materials Technologies Private Limited have an ISO 9001:2015 Quality Management Accreditation.

TRL: 9 – commercially available.

Partnering & Deal Potential: Works with Singapore Defense.

NOAA Use Case: Materials for underwater hydrophones, transducers and projectors with high sensitivity and extended bandwidth.

Technology Description

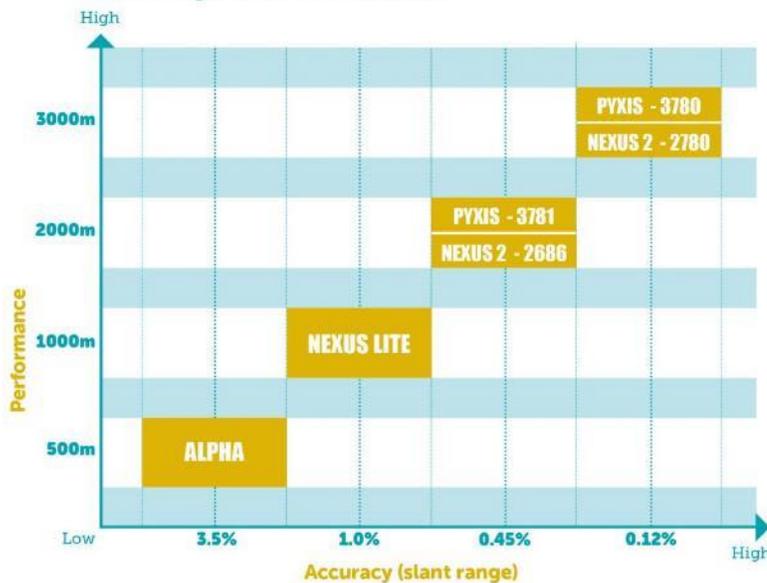
Applied Acoustics offers the [Easytrak](#), an Ultra Short Baseline (USBL) underwater positioning and tracking system.

Easytrak is centered on a multi-element, single transducer that transmits and receives acoustic signals to dynamic subsea targets from which range, bearing and depth information can be determined. The family of systems manufactured cover applications from professional high accuracy positioning to low cost quick deployments. They can be supplied with a range of target beacons from small lightweight units that can be charged from a mobile phone, to long-term deployable transponders incorporating acoustic release functionality.

Depth Operating Range: TBD.



USBL System Selection



Comparative Value Proposition

- Rapid deployment and ease of operation.
- Can track multiple targets simultaneously.
- Claims to have the **most extensive available range of acoustic [positioning beacons](#)** including very small models for use in shallow water or where space is limited, up to the Seabed Beacons operating in deep, noisy or difficult environments.
- Beacons have been designed to be **compatible with almost all industry standard tracking systems** operating worldwide.

Commercial Information

Applied Acoustics specializes in the design, development and manufacture of a wide range of products using hydro-acoustics to the offshore oil and gas industries, oceanography and research institutes, defense and law enforcement agencies. Company is part of AAE Technologies Limited, an independent cluster of engineering companies that designs, manufactures and maintains technical products and equipment that is used in the subsea environment and the wider marine industries. [Modulus Technology](#), another AAE Technologies company, is a custom engineering supplier that designs and develops innovative products for the marine industry.

TRL: 9 – commercially available.

Partnering & Deal Potential: TBD.

NOAA Use Case: underwater positioning and tracking system.

Technology Description

LinkQuest offers the [TrackLink systems](#), a family of USBL acoustic tracking systems with integrated high-speed acoustic communication capability.

TrackLink systems use LinkQuest's Broadband Acoustic Spread Spectrum (BASS) technologies and claim to provide end users with solutions for underwater tracking and communication with increased robustness. An extensive line of models are available to suit the users' specification and budget constraint.

LinkQuest's lowest priced system is the [TrackLink 1500 Series](#). Its price starts at \$15,000 for a complete system. It has a range of up to 1000 meters and an accuracy of up to 0.25 degrees. Other TrackLink models can be [found here](#).

Comparative Value Proposition

- **No need for a heavy proprietary deck unit:** PC Windows tracking software to display range, bearing, depth, GPS position and other information from the sensors.
- The USBL transponder and acoustic modem share the same electronics and transducer significantly reducing the total size, weight and power consumption.
- **Limitations:** high price points.

Commercial Information

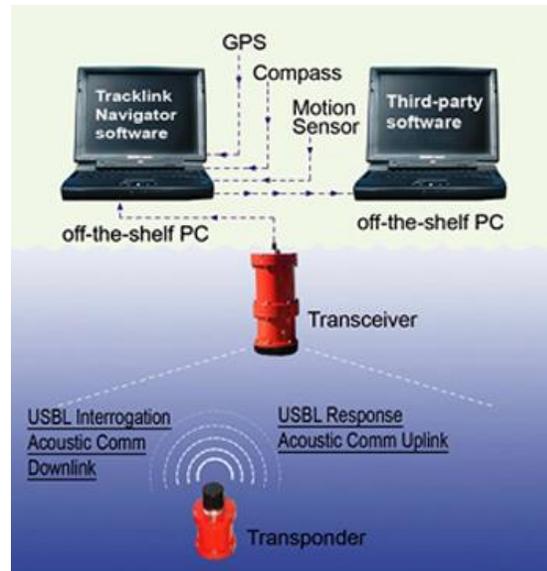
LinkQuest is specialized in developing and manufacturing sophisticated electronic systems using advanced acoustics, Doppler, array signal processing, digital signal and imaging processing technologies for underwater and medical applications. LinkQuest's products have been deployed in more than 75 countries around the world for offshore oil exploration, construction, drilling, survey, environmental study and other oceanographic applications.

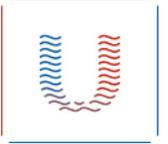
TRL: 9 – commercially available.

Partnering & Deal Potential: TBD.

NOAA Use Case: underwater positioning and communication systems.

Depth Operating Range: up to 11,000m.





Technology Description

UN & CL (Underwater Communication & Navigation Laboratory) offers products for underwater navigation, underwater data transmission, and underwater telephones.

The RedWAVE system is a line of devices that solve underwater positioning problems for a wide range of users: divers, industrial or rescue divers, as well as subsea remotely operated vehicles (ROV) and autonomous unmanned underwater vehicles (AUVs). It includes the underwater acoustic navigation system [Zima](#), which is intended to determine in real time the horizontal angle and distance to underwater objects equipped with hydroacoustic responders [Zima-R](#) (dimensions: Ø64 x 62 mm). The Zima navigation system is an ultrashort baseline navigation system (USBL) that allows the transmission of telecontrol signals to beacons and receive telemetry data from beacons.

Depth Operating Range: up to 8000m.



Comparative Value Proposition

- **Acoustic modem costs \$480** which is between 5x-6x times cheaper than most other acoustic devices and are made in Russia.
- **Flexible production:** company works from ideas or concepts all the way to commercialization.
- **Open source software and hardware interfaces:** RedWAVE devices can be easily integrated into their own systems through open interfaces and detailed documentation.
- **Lightweight, durable and compact body** for modems and navigation systems.

Commercial Information

Underwater communication & navigation laboratory is a Russian developer and manufacturer of commercially available devices and complexes for underwater wireless navigation and communication, used by divers and ROV/AUV in a wide range of underwater works.

TRL: 6/7 – customizable products.

Partnering & Deal Potential: Russian-based company UC & NL claims that California-based company Beringia ([DiveNET](#)) is their partner.

NOAA Use Case: underwater positioning systems.

Technology Description

AppliCon has developed and is commercializing the SeaModem, an acoustic modem that allows underwater digital communication and networking.

The SeaModem was designed to offer a suitable open hardware/software platform for developing underwater cost-effective control, communication and localization applications, especially in the first concepts validation phases. In order to expand as much as possible its flexibility, the SeaModem consists of two main boards in its basic configuration the Power board and the DSP board. All parameters are fully reconfigurable and can be adapted to any need with easiness, also remotely. The SeaModem supports the JANUS protocol and has a unique ID.

AppliCon claims to be looking to improve the SeaModem, specifically to increase the distance covered by the modem and the bit-rate, in order to support in the future voice and video streaming. As far as the development of a complete underwater localization system is concerned, AppliCon is actively working on developing such a system for the need of the [VISAS project](#) (Project's goal is to provide an integrated system able to improve the ability to generate value from a responsible and sustainable exploitation of underwater archaeological sites). Company claims that expertise will be made available to all customers that will need to develop any sort of communication and localization proprietary system.

Depth Operating Range: 400m.



Comparative Value Proposition

- **Fully reconfigurable modem** for different applications.
- Claims to be a **cost-effective solution** for open hardware/software platforms.
- Company offers **device design and development** for underwater communication and localization.

Commercial Information

AppliCon is an engineering company, spin-off of the University of Calabria, focusing on the hardware/software design and development of microprocessor-based embedded systems for all needs of communication, networking, localization, navigation, monitoring and remote control of vehicles, sensors, plants and divers in underwater environments. Since its establishment, AppliCon is engaged in research and development of underwater technologies, mainly for digital underwater acoustic communication and localization and active safety systems for divers.

TRL: 6/7 – company claims to be currently improving the SeaModem.

Partnering & Deal Potential: TBD.

NOAA Use Case: acoustic modem for underwater communication; company claims to be working on a complete underwater localization system.

Technology Description

TriTech provides underwater positioning technologies including:

MicronNav - USBL Tracking System designed for small ROV / AUV. It has been primarily designed to be used in conjunction with the Tritech Micron sonar and other Tritech Micron products. The system comprises of a subsea MicronNav unit, a surface USBL transducer unit with integral Magnetic Compass and Pitch / Roll sensors, a surface Micron Nav 100 interface module and operating software. The USBL transducer is designed to provide 180 degree hemispherical coverage below the transducer.



Micron Modem - With a range of up to 500m (500m horizontal & 150m vertical), the Micron Modem has been designed to transmit a maximum data rate of 40 bits per second, making it suitable for a range of through-water, low data rate transfer requirements.



Tritech also offers standard software or customized software solutions for their technologies.

Depth Operating Range: 30m depth rating; 500m range

Comparative Value Proposition

- MicronNav uses **Spread Spectrum acoustic technology**, which provides a robust method for communications between the dunking transducers and the vehicle responder/ transponder.
- Tritech has a team of engineers dedicated to working with clients to produce **variations of standard products**, as well as producing integrated solutions to help define, design and qualify new products to meet requirements.
- Claims to be a **simpler device** with an average cost point of **18,000 euros**.

Commercial Information

Tritech International Limited [Tritech], a Moog Inc. Company (NYSE: MOG.A and MOG.B), is a high-technology business making imaging and ancillary equipment for use in underwater applications. The company has 3 UK sites; in Ulverston, Cumbria, Westhill, Aberdeenshire and Edinburgh, Scotland, and an office in Blacksburg, Virginia, USA.

TRL: 9 – commercially available.

Partnering & Deal Potential: TBD

NOAA Use Case: USBL tracker and modem

Technology Description

MicronNav100 Surface Hub	
AC power supply	90V to 264V, 47Hz to 63Hz
DC power supply	12V to 36V, 2.1mm pin (positive core)
Power consumption	4.8W from either source with no additional load
DC power output	50W or 2A maximum current draw +33V with AC input 1.5V less than supply on DC input Defaults to highest voltage if both AC and DC are connected
Additional ports	USB 2.0, RS232, RS422, RS485, ARCNET LAN
Dimensions	232 x 185 x 52mm (width, depth, height)
Weight	1.3kg
Materials	Painted aluminium with matte anthracite textured finish
IP rating	IP21 (no protection against water ingress)
Temperature rating	5 to 35°C operating, -20 to 50°C storage

System	
Positioning technology	Ultra Short Baseline (USBL)
Frequency band	20 – 28kHz
Tracking range	500m horizontal, 150m vertical
Range accuracy	±0.2m
Bearing accuracy	±3° (determined by USBL integrated heading sensor)
Position update rate	0.5 – 10s
Targets tracked	1 responder, 15 transponders
Data display	Polar and Cartesian display with optional bitmap chart, marker overlay and tracking features
Data recording	Data recorded in Seanet Pro format
Surface navigation	Most GPS, Heading or Altitude sensors supported by Seanet Pro

Micron Modem		USBL Transducer	
Beamwidth	Omni-directional	Operating beamwidth	180°
Power consumption	12 – 48V DC (3.5W transmitting, 0.28W standby)	Maximum diameter	110mm
Transmitter source level	169dB re 1µPa at 1m	Body tube diameter	75mm
Communication protocols	RS232 or RS485 (in Responder mode)	Height	270mm
Depth rating	750m	Weight in air	2kg
Diameter	56mm	Weight in water	0.8kg
Height	76mm	Depth rating	30m
Weight in air	225g	Deck cable length	10m standard 20, 30, 50m available
Weight in water	70g		

Technology Description

Submarine Open Technologies (Subteq.io) claims to have created the “first GPS localization system for divers” permitting to see their position on a small map.

The technology uses GPS signals relayed from a floating antenna. An underwater transducer then sends an acoustic signal to the diver’s unit, which calculates the exact position of the buoy and the diver’s relative location. Each diver can visualize his own position and the positions of the others divers on a small screen. One buoy is sufficient to cover a 500-meter radius and 150 meter depth, and the buoy dimension is approximately 20cm x 20cm x 20cm with a weight of 2 kg. The system works for 8 hours on a single charge.

Depth Operating Range: 150 m



Comparative Value Proposition

- Creating a **low-cost solution based on USBL** (Ultra Short BaseLine) technology for individual and technical divers. Their **research in signal processing has been focused on replacing expensive components by low cost ones.**
- Allows positioning up to **30 underwater sensors** for each buoy with a **position accuracy on the order of one meter.**
- They claim to be open to sharing knowledge through scientific publications.
- **Limitations:** Recent updates TBD

Commercial Information

Jean -Marie Codol is the founder of the Submarine Open Technologies (Subteq.io) project. He has a PhD in signal processing from LAAS-CNRS, Toulouse, France and has several years experience in novel technologies for land localization. Recently, he has focused on how to obtain accurate localization for submerged divers or vehicles. He is collaborating with researchers and engineers from other fields such as robotics, signal processing and electronics. This work was funded in part by the award winning of CNACETI (Concours National d’Aide à la Création d’Entreprises de Technologies Innovantes) in 2013.

Moïra Chanzy, president of Subteq.io, reported that their prototype using this system will be available at the end of 2017, but recent information has been sparse.

TRL: TBD

Partnering & Deal Potential: TBD, have [patents](#) on the localization technology and method

NOAA Use Case: Potential partner working on research in signal processing has been focused on replacing expensive components by low cost ones.

Subnero

Heng Mui Keng Terrace, Singapore.
 Founded 2011.
<https://subnero.com/>



Technology Description

Subnero offers a wide range of [acoustic modems](#) that can reach depths of **2000m**.

The modems are available in three editions.

- **Silver edition modems** are robust communication devices, typically suited for most standard commercial deployments.
- **Platinum edition modems** use components that are designed for extended range of operating conditions, and undergo extensive environmental testing. They are best suited for applications in harsh environmental conditions or increased level of robustness.
- **Research edition modems** provide a flexible, lower-cost tool that allows students, researchers and hobbyists to develop and test underwater networks.

Subnero's products provide underwater navigation along underwater communication with [three different variations](#) (surface, node, and embedded) which communicate via surface buoys or surface nodes to an on-surface electronic. The underwater modems can be used for acoustic ranging for localization as well as communication.



Comparative Value Proposition

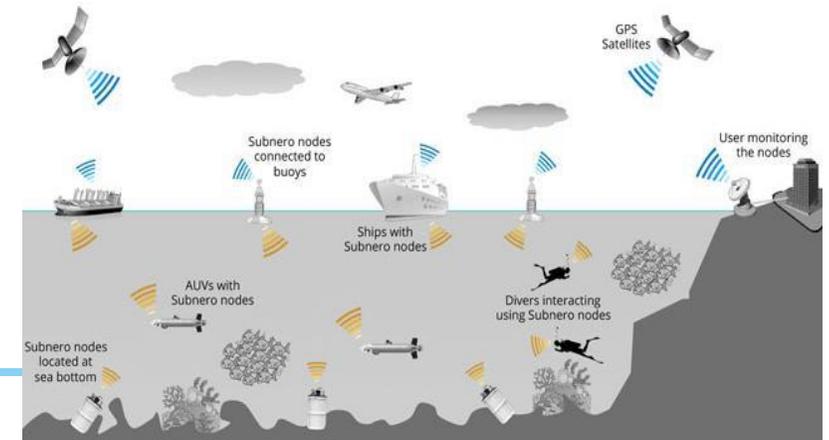
- Can transmit up to **5km (5000m)** offshore with operational depth of up to **2000m**.
- Up to 15 kbps of data rate and 1TB of data storage.
- Subnero offers **customizable and extension of products** to fit certain environments and individual company needs.
- Powered by [UnetStack](#), a flexible agent-based **underwater network stack**, the modems provide options for customization and extension at many levels, allowing network protocols as well as physical layer algorithms to be implemented and tested easily.

Commercial Information

Subnero products facilitate underwater wireless networked communications and in-water sensing & monitoring. These solutions include software-defined underwater modems, a customizable network stack that adapts to a variety of environments and applications, and a **Subnero Water Assessment Network (SWAN)** that uses autonomous robots to monitor the quality of water in reservoirs and lakes.

TRL: 9 - commercially available with customizable options

Partnering & Deal Potential: Customizations available for products
NOAA Use Case: Systems for communication



Subnero

Heng Mui Keng Terrace, Singapore.
 Founded 2011.
<https://subnero.com/>



Edition	Platinum Edition		Silver Edition			Research Edition
Configuration	Surface	Embedded	Surface	Node	Embedded	Surface
Model number	WNC-M25MPS3	WNC-M25MPE3	WNC-M25MSS3	WNC-M25MSN3	WNC-M25MSE3	WNC-M25MRS3
						
Data rate	Up to 15 kbps (depending on channel conditions and reliability requirements)					Up to 300 bps (depending on channel conditions and reliability requirements)
Operating range	3-5 km (nominal, depending on channel conditions)					1 km (nominal, depending on channel conditions)
Ranging precision	0.1 m					
Doppler resilience	±4 knots or better					
Modulation (software defined)	PSK-OFDM, FH-BFSK					FH-BFSK
FEC (Forward Error Correction)	LDPC, up to 1/6 rate code; JANUS 1/2 rate convolution code					
Software framework	UnetStack3 (www.unetstack.net)					
Software interface	UnetStack3 (Java, Groovy, Python, C, Matlab, Javascript, Julia), interactive web UI, JSON/TCP					
Hardware interface	Ethernet, power, RS232					Ethernet, power
Transducer beam pattern	Omnidirectional					
Carrier frequency	24 kHz					
Bandwidth	12 kHz (20 - 32 kHz)					
Source level	185 dB re 1 μPa @ 1 m rms (nominal)					175 dB re 1 μPa @ 1 m rms (nominal)
Power consumption	< 4 W (receive mode, nominal) < 60 W (transmit mode, avg.) < 80 W (transmit mode, max.) < 1.5 W (sleep mode)		< 4 W (receive mode, nominal) < 60 W (transmit mode, avg.) < 80 W (transmit mode, max.)			< 4 W (receive mode, nominal) < 25 W (transmit mode, avg.)
Power source	External power: 22 – 28 V DC (24 V DC recommended)		1.5 V D size battery × 16*		External power: 22 – 28VDC (24VDC recommended)	
Operating depth	300 m (Aluminium hull)	2000 m (Transducer depth rating)	100 m (Aluminium hull)		2000 m (Transducer depth rating)	100 m (Acrylic hull)
Dimensions	ø 127 × 400 mm	90 × 90 × 180 mm	ø 127 × 280 mm	ø 127 × 700 mm	ø 104 × 147 mm	ø 135 × 400 mm
Weight (in air / water)	6.0 / 2.5 kg	1.0 / n/a kg	4.0 / 1.0 kg	6.0 / 0.5 kg (without batteries)	1.0 / n/a kg	3.0 / TBC kg
JANUS compatibility	Yes, subject to operating frequency band					
Wake up module	Included (acoustic, Ethernet, RS232)					Included (Ethernet)
Onboard storage	Not available		32 GB			32 GB
Arbitrary waveform transmission & reception	Included					
Qualification testing	MIL-STD-810G, MIL-STD-810E, MIL-STD-461E					Not available

DARPA & US Navy

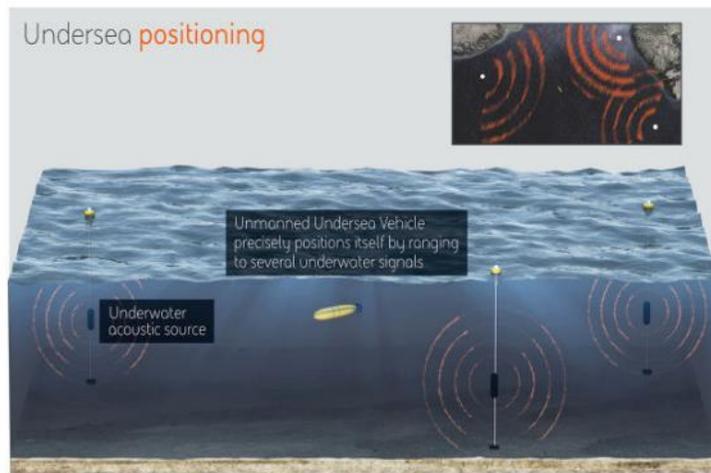


Technology Description

The US Navy and DARPA have developed the **Positioning System for Deep Ocean Navigation (POSYDON)** program to develop an undersea system that provides **omnipresent, robust positioning across ocean basins**.

Using underwater acoustic signals, a surface buoy, beacon or “node,” and GPS signals in a coordinated fashion, the Positioning System for Deep Ocean Navigation (POSYDON) is able to quickly relay location coordinates from undersea drones on patrol to command and control systems on board a ship or submarine.

Phase I (2017) of the program focuses on accurately modeling the signal propagation channel, and Phase II focuses on developing the signal waveform. A complete positioning system is scheduled to be demonstrated in Phase III. Once operational, POSYDON technology could work with existing platforms for military applications, as well as oceanographic and hydrographic information.



Comparative Value Proposition

- By ranging to a small number of long-range acoustic sources, an undersea platform would be able to obtain **continuous, accurate positioning without surfacing for a GPS signal**.
- They have developed **models and algorithms that account for underwater acoustic signals** that handle interference from factors such as temperature and salinity.
- **Limitations:** Limited details; status TBD

Commercial Information

John Waterston is the program manager in the Strategic Technology Office (STO) at DARPA. He is focused on the topics of maritime autonomy, undersea warfare, distributed sensing, and non-traditional communications. He oversees the POSYDON project, as well as the [Ocean of Things](#) program that “seeks to enable persistent maritime situational awareness over large ocean areas by deploying thousands of **small, low-cost floats that form a distributed sensor network**”.

DARPA officials say **BAE Systems, Raytheon BBN and Draper Laboratory** are all working on the POSYDON program. **BAE Systems' FAST Labs** appears to be leading the effort. BAE Systems' FAST Labs™ team is the advanced technology R&D group inside the Electronic Systems sector who invents, innovates, adapts, and produces advanced science, electronics, and engineering technologies. FAST Labs also collaborates with business areas throughout BAE Systems and external partners.

TRL: TBD

Partnering & Deal Potential: US military, as well as BAE Systems expertise

NOAA Use Case: Network of underwater sensors and technologies to be used

Appendix

Tech Surveillance

Tech Surveillance is a new service aimed at re-engaging with your technology challenge on a regular basis after the initial active scouting phase has been completed.

Innovation fatigue is a common cause of high interest targets not being engaged appropriately within the organization.

Re-engaging with your technology challenge on a regular basis has proved to increase success with **deals**.

Our experience of asking the right questions enables you to relax in the knowledge that your challenge is in **safe hands**.



PROTECTION

- Protect your initial investment
- Stay up to date on trends
- Refresh knowledge in your interest areas
- Increase your possibilities on getting to a deal



COMMITMENT

- 3 x 6 months between rounds recommended

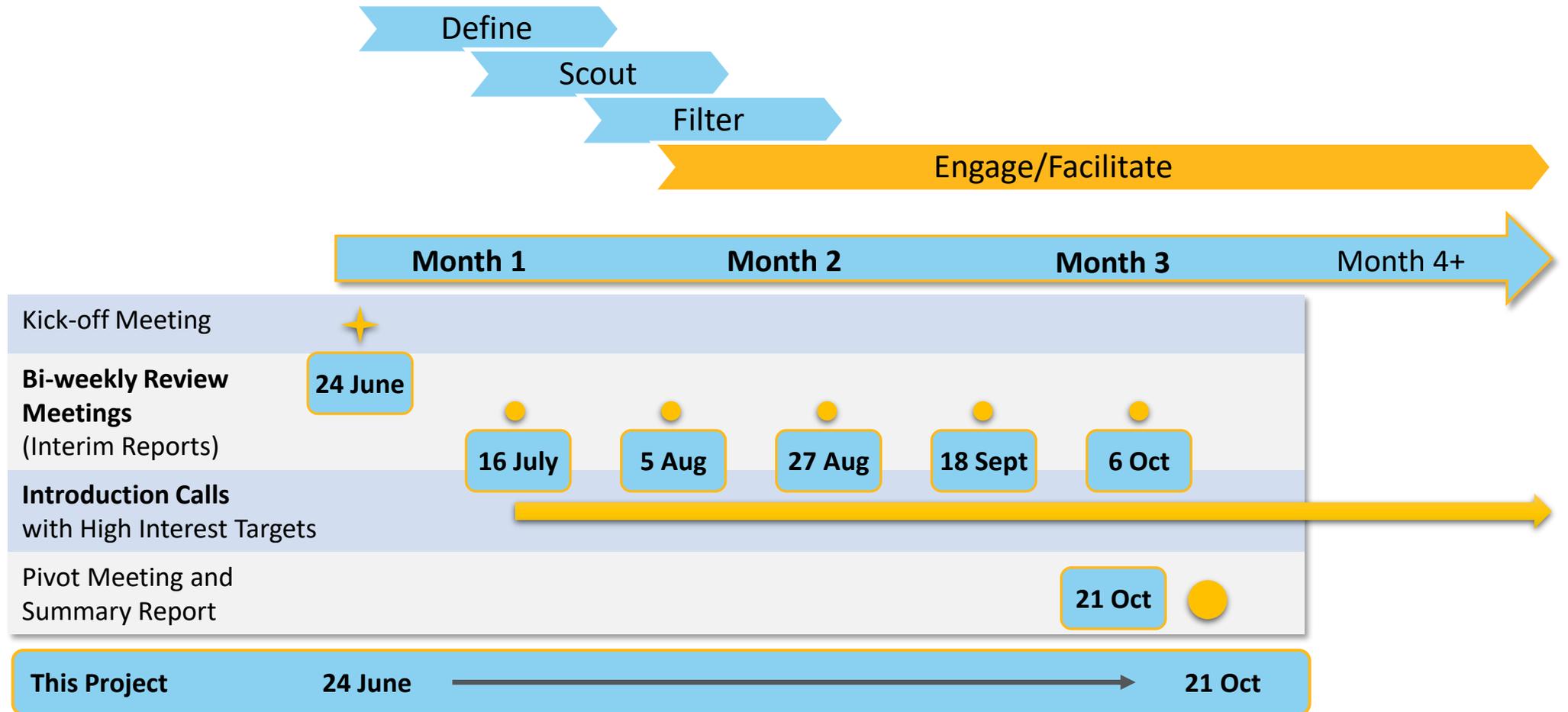


DELIVERABLES

- Re-engage every 6 months
 - Updates on 5-8 previous targets
 - 2-3 new players
 - Overview and trend observations

yet2 Project Timeline

1 week – 3 months +



Turning Open Innovation Into Impact

Global Reach

An International Technology & Venture Network that's over twenty years in the making

Fulltime offices in Boston, Liverpool, and Tokyo

Expert Team

Astute, Tactical Consultants: commercial, technical, IP & ventures expertise

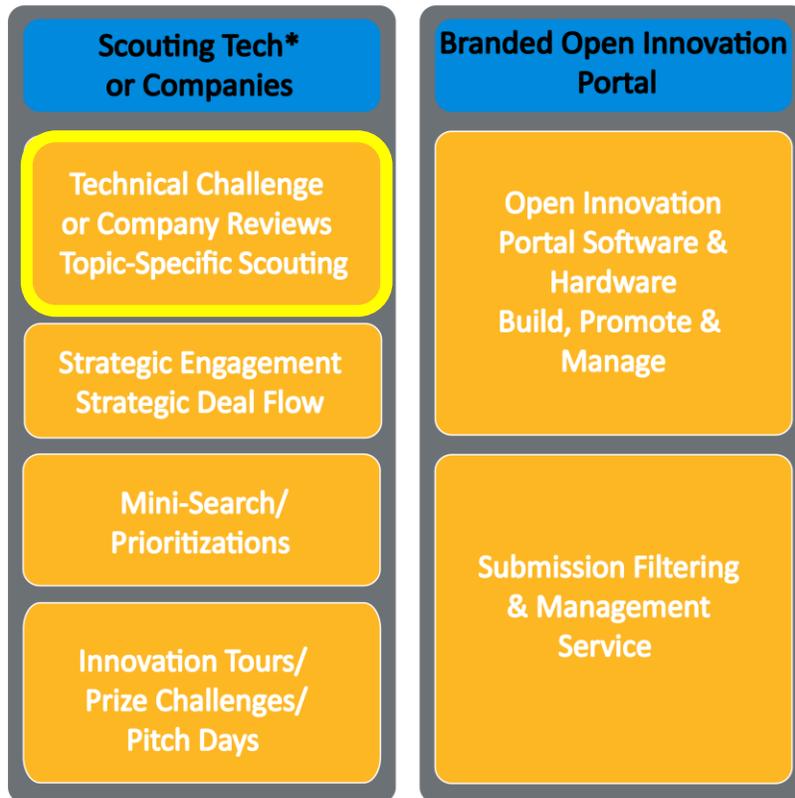
Clients love working with our project leads

Trusted Partner

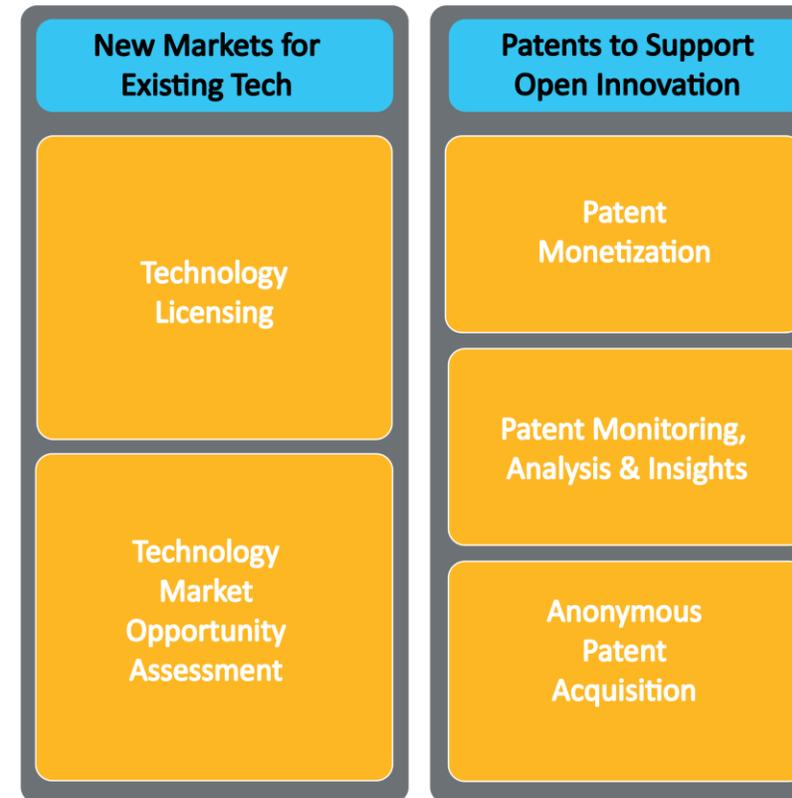
Effective Methodologies: integrated, iterative, flexible, actionable work product

Finesse: rich understanding of how to overcome standard hurdles at the corporate boundary

Technology Acquisition



Technology Monetization



yet2 Process



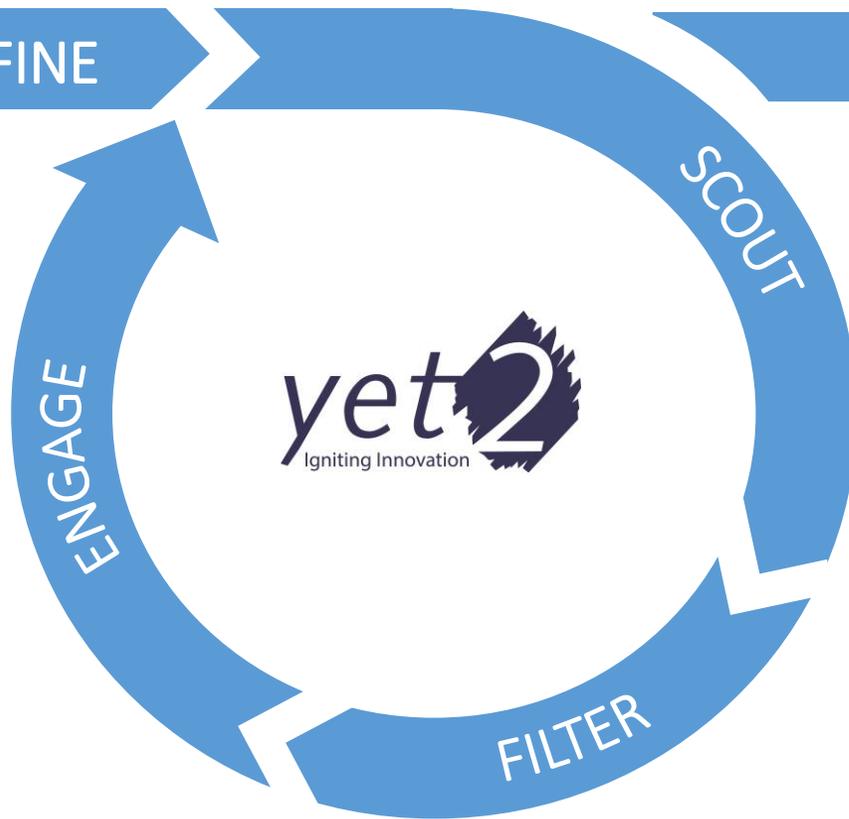
- TechNeed
- Situational Summary

Kickoff Report

DEFINE



- Intro Calls
- Samples
- Anonymous Inquiries



Pivot Report



- Recommendations
- Rankings
- Key Learnings

Interim Reports



- Detailed Technology Write-Ups
- Updates
- Next Step Summaries

yet2 Project Methodology

Define

We work with client to optimize:

- Client's objectives and needs
- Project strategy and deliverables
- Partnering requirements
- Anonymous TechNeed document

- Provide strategic objectives
- Identify initial key partnership criteria

Scout

yet2's Technology Scouts will:

- Proactively scour global markets
- Reactively receive submissions in response to anonymous TechNeed
- Pull information from established yet2 database

- Respond as questions arise
- Evaluate preliminary info
- Prioritize

Filter

Based on key criteria, we will:

- Evaluate and interview companies
- Gather additional information
- Refine target criteria and continue scouting
- Evaluate each partner's Comparative Value Proposition

- Review Interim Report information
- Refine criteria
- Confirm next steps

Engage

When top companies are identified, we can:

- Coordinate intro calls, samples, NDAs, in-person meetings, etc.
- Provide initial due diligence and deal making support

- Prioritize most interesting partners
- Participate in intro calls



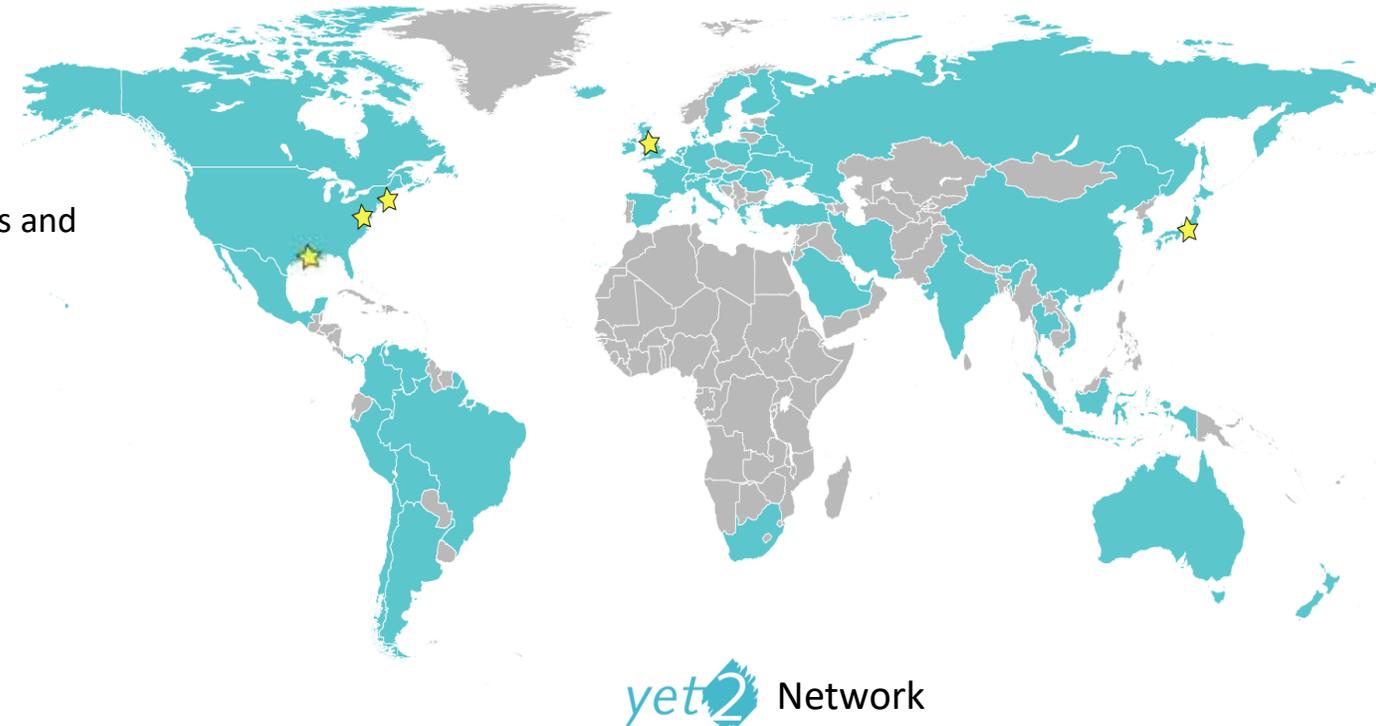
yet2 Global Reach

Direct Targeted Scouting & 'Rolodex' Relationship based channels

- **yet2 competencies technology database** – 20 years of OI & technology scouting.
- Established ventures network & 30,000 Small-Medium-sized companies.
- **Relationships** borne of over 10,000 introductions between buyers and sellers (including Fortune 500, SME, University, Research, VC).
- Proactive experts reach out to new opportunities identified by experienced *yet2* scouts.

Broadcast Channels

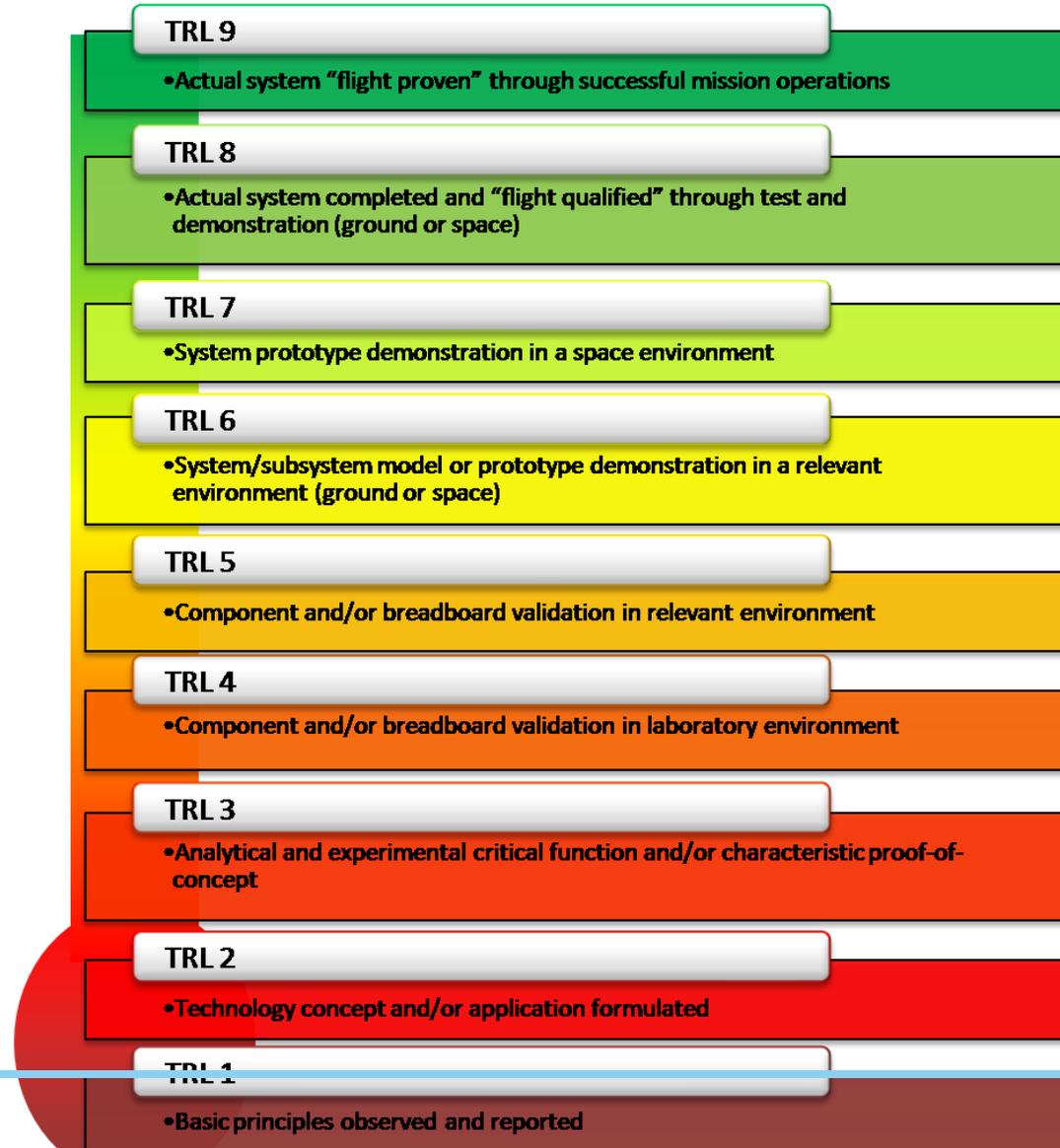
- *yet2* Active Projects Pages (formerly *yet2* Marketplace)
- Syndication partners – e.g. Innoget, NASA Tech Briefs
- 800+ Global Broker Partners
- Online Technical networks/Social Media (20,000+ reach)



Highlighted Areas: Location of *yet2*'s 800+ Global Broker Partners

★ *yet2* Global Offices

TRL Guide





Thank you

www.yet2.com