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The Lead

Communication/Navigation Systems

The Development of WaveRadar for Ocean Wave Measurement

By Katy Pozerskis (Research Manager, RS Aqua)

Offshore oil and gas platforms are typically located in harsh environments. Think of the North Sea between the UK and Norway, the South China Sea and the Gulf of Mexico. Severe winter storms, typhoons, and hurricanes are commonplace. The offshore industry is well practiced at dealing with such extremes of nature but relies upon the provision of precise meteorological and oceanographic data to do so. Understanding the magnitude and complexities of ocean waves around offshore structures is crucial for the safe berthing of support vessels, landing of helicopters, for safe working of men and machines on deck, and for confirmation that operational platform response parameters are within design limits. Furthermore, these data are essential for the validation of numerical models used in the structural design of offshore platforms, informing the design and management of offshore structures now and into the future.

During the 1990s a series of trials in the southern North Sea by RS Aqua, Shell and Saab (now Emerson), led to the introduction of WaveRadar REX to provide the much needed stable and accurate measurement of the sea surface profile and ocean wave parameters. More than 20 years on and the WaveRadar REX is still the leading wave radar specified for offshore installations, and latterly has successfully migrated into a variety of other markets such as offshore windfarms in the European coastal zones. The UK's Channel Coastal Observatory has installed a network of WaveRadar REX on structures along the southern coast of England as part of its government-funded, long-term coastal monitoring programme, with similar coastal installations in Vietnam, China and elsewhere. Today the WaveRadar REX is firmly established as the world's

Photo Credit: DONG Energy

leading wave radar sensor with over 700 installations across the globe.

The WaveRadar REX has historically been perceived as a simple yet reliable stand-alone sensor, but in recent years it has grown into an advanced wave measuring system for many different installation scenarios. As outlined below, this year RS Aqua have developed the **CODE** system which provides sophisticated back-up power, data processing and cellular or Iridium telemetry. Other additions such as local wave data processing and advanced local or cloud-based software systems are now readily available and in use throughout the world.

Following the 2017 release of the new ***WaveView Connect*** software, featuring real-time wave processing, configurable displays and advanced data networking capabilities, WaveRadar REX systems can now be deployed on vessels and moving platforms whilst underway. This new capability is thanks to a motion compensation module within *WaveView Connect*, which accepts heave, pitch and roll inputs from all leading motion reference unit (MRU) sensors commonly found on vessels. The quality and reliability of wave data, where the sensor is mounted on a moving vessel, are drastically improved. This allows the WaveRadar REX to provide meaningful wave data during jack up operations, to aid vessel performance monitoring and, as described below, to enable safety and comfort monitoring on the world's largest cruise liners.

WaveRadar REX on-board Harmony of the Seas

With nearly 25 million passengers travelling by cruise ship each year, ensuring their comfort and safety is of utmost importance to the operators within the global cruise industry. Built by STX France, the Royal Caribbean vessel Harmony of the Seas is the largest cruise ship ever constructed, at 362 m long and 66 m wide. RS Aqua were approached by Wärtsilä to provide a measurement solution that would allow wave conditions on both sides of the Harmony of the Seas to be monitored in real time, whilst transporting more than 6000 passengers and over 2000 crew from one port to the next.

Three WaveRadar REX are now installed on the ship; one on the bow, one on the port bow and one on the starboard bow. These WaveRadar REX measure with great precision the distance to the surface of the water, 10 times per second. Pitch and roll data from the ship's MRU feed into a new motion compensation software module and are used to offset the WaveRadar REX inclination. The vessel's motion effects are subtracted from the air gap measurements in real-time prior to the usual wave statistic processing.

The world's largest cruise ship, Harmony of the Seas, fitted with three WaveRadar REX.

Photo credit: STX France / Bernard Biger

The system has now been running successfully since Harmony of the Seas departed on her maiden voyage from Saint-Nazaire, France to Southampton, UK on 15th May 2016.

Motion compensated draft data for Fugro Satellite Positioning

Shortly after the Harmony of the Seas deployment RS Aqua were approached by Fugro Satellite Positioning (FSP) to supply accurate motion compensated draft data to supplement their on-board decision support system, Oceanstar™. The Oceanstar system enhances berthing operations and vessel navigation in confined waters by using satellite positioning technology to provide essential information such as approach speeds, rate of turn and distances to the berth. It allows ship owners and operators to better manage the performance of their vessels by reducing operating costs and improving navigational safety.

A potential benefit of including motion compensated draft measurement is the possibility of observing ship squat effects. These effects are important in shallow waters as they reduce the under keel clearance available to a ship. As a vessel travels through shallow water the restricted water depth means that the speed of the water flow under the ship's hull increases. This in turn causes the pressure under the hull to decrease and the vessel experiences sink. Squat is believed to have been one of the causes of the grounding of the QE2 in 1992.

During February and March 2017 an initial sea trial using WaveRadar REX to help calculate squat took place in the Skagerrak. A WaveRadar REX was installed on the port side bridge wing of the Stena Saga, a Superferry operated by Stena Line that provides a regular link between Frederikshavn, Denmark and Oslo, Norway, taking approximately 9 hours during the day and 12 hours at night. The purpose of the trial was to take heave, pitch and roll data measured from an on-board Kongsberg MRU and use it to apply motion correction to the WaveRadar REX measurements. The motion compensation module was embedded into RS Aqua's then developing *WaveView Connect* software to process and report in real time dynamic draft and other non-typical parameters for this application.

Vessel draft data were of particular interest during periods approaching and manoeuvring in port, it was found that the WaveRadar REX data compared extremely well with ellipsoid height measurements from an on-board GNSS antenna mounted within 5 m of the WaveRadar. Following the success of this initial sea trial a second is planned that will replace the MRU input with the position data from the GNSS feed which only contains pitch and roll information. A successful outcome in the second trial will lead to a fully integrated WaveRadar Oceanstar system.

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Screen shot of the new WaveView Connect customisable user interface

WaveView Connect – the next generation of wave processing software

RS Aqua's legacy WaveView software has supported WaveRadar REX since 2000. In 2017 we are surrounded by smart phones, tablets and even voice assistant speakers and have come to expect that our devices and software will be intuitive to use and easy to connect with other systems. Following the WaveRadar REX deployments on Harmony of the Seas and the Stena Saga, RS Aqua not only wanted to support motion compensated measurements but also to offer users a better connected experience; to access their data from anywhere in the world, to allow them to change their instrument setup up remotely, and to process wave data in real time. This was much more than a routine software update, this described a whole new software product: ***WaveView Connect***.

Developed in exclusive collaboration with Icon Software, *WaveView Connect* delivers all of the standard features that existing WaveView users are familiar with plus additional functionality such as:

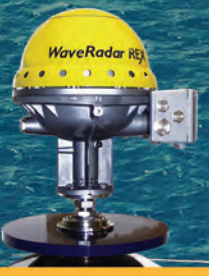
- local or remote access via a real time web view
- sensor status monitoring and remote reconfiguration
- compatibility with multiple directional and non-directional wave sensors as well as generic pressure sensors
- configurable data outputs
- easily customisable data display
- alarm thresholds
- motion compensation capabilities

RS AQUA

WaveRadar REX

Wave, Sea Level, and Air Gap Sensor

STABLE. PROVEN. RELIABLE.



The perfect medium for the extreme demands of harsh offshore, maritime, and coastal environments.

Applications

- Safety status monitoring
- Structural monitoring
- Weather forecasting
- Water level observations
- Air gap studies
- Motion-compensated wave & draft measurement from ships

EMERSON

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Live real time data from a WaveRadar REX that have been processed and presented in *WaveView Connect* are available to view by **clicking here**.

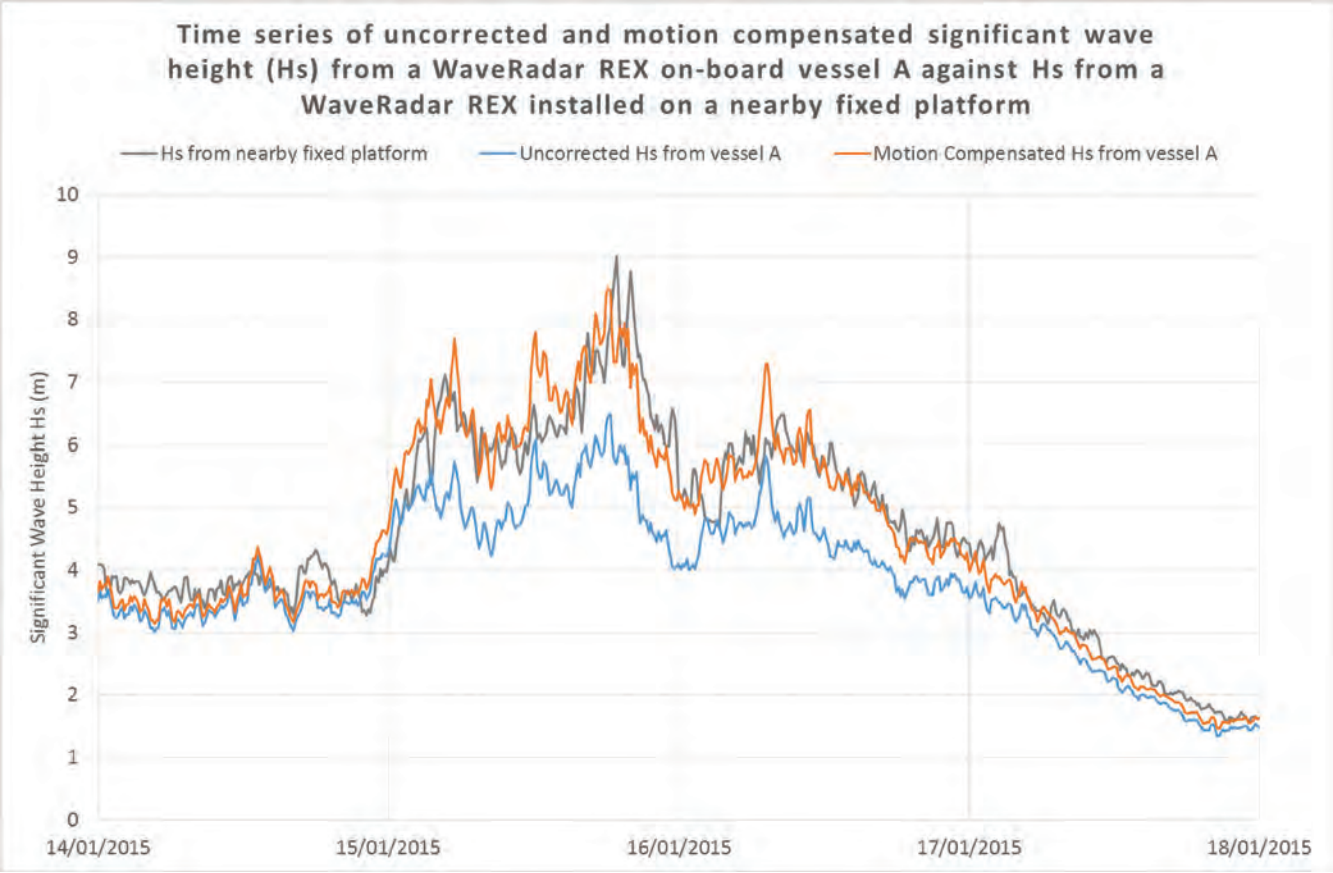
Combining a WaveRadar REX with an on-board MRU *WaveView Connect* can deliver accurate data collected from a vessel whilst underway. The time series comparison shows significant wave height measured by a WaveRadar REX on-board a moving vessel and at a nearby fixed platform. The motion corrected data are produced within the *WaveView Connect* motion compensation module.

Importantly *WaveView Connect* is not limited for use only with the WaveRadar REX, but it also supports serial port, TCP/IP (connect or listen modes) and UDP/IP inputs. This makes it compatible with other wave sensors such as the Datawell MkIII or DWR4 Waverider buoys and generic air gap/pressure sensors. A full trial version of *WaveView Connect* is available to request now from **rsaqua.co.uk**.

Uninterrupted ocean wave data access in real time

Increasingly WaveRadar REX users require access to their data in real time and for several years these data have been available online via a customised version of OceanWise's cloud-based Port-Log system. Typically data are sent to Port-Log via an Ethernet connection but, in remote locations or construction areas, this is not always available. In these areas power supplies are also subject to intermittent interruptions and outages, which increases the possibility of gaps in recorded data caused by a temporary loss of power. To address these issues RS Aqua, in partnership with OceanWise, have developed the **CODE** system: a **C**ontinuous **O**peration and **D**ata **E**nclosure providing remote back-up power, data processing and telemetry for WaveRadar REX.

Commonly consisting of a WaveRadar REX Field Bus Modem, data controller, heavy duty battery, battery charger, GSM or Iridium modem, and antenna with SIM card, all mounted within a sealed IP66 enclosure, the CODE provides back-up power to the WaveRadar REX in the event of a standard power supply interruption. This is typically provided by a lead acid battery which is trickle charged by either AC power, solar panel and/or wind turbine. The single battery will allow the system to run for up to 24 hours in the event of a power fail-



Comparison of Significant Wave Height (Hs) from two WaveRadar REX sensors. One on-board vessel A and the other on a fixed platform approximately 30 nm SE of vessel A in the North Sea. Corrections applied using Icon Software's motion compensation algorithm which is embedded in WaveView Connect.

ure. Longer durations are supported by increasing the number of batteries. With the addition of a single board computer, running *WaveView Connect*, the CODE can also process raw wave data locally prior to sending processed wave statistics anywhere in the world via Ethernet, cellular or Iridium networks. This is of particular benefit to installations where broadband telemetry is either not available or not cost effective. The CODE can also support data input from third party equipment such as weather stations and temperature loggers.

The CODE has now been installed at sites in East Africa with WaveRadar REX sensors to facilitate remote wave monitoring. These systems have provided continual data return.

The future of ocean wave measurement

The WaveRadar REX has been supporting offshore and coastal operations for over 20 years. With recent advances, such as RS Aqua's CODE system, today it forms part of a sophisticated measuring system capable of delivering high quality processed wave data from even the most remote locations or moving platforms. Every WaveRadar REX is still manufactured to order by RS Aqua in collaboration with Emerson, with new units supplied every month to coastal and offshore systems integrators and end users around the world. RS Aqua's active development of the sensor and its accessories continues with further exciting advances to be announced soon.

The new *WaveView Connect* software allows operational users to create a suite of wave statistics that can be accessed from anywhere in the world in real time. Scheduled for future development is the ability to derive directional wave data from WaveRadar REX units installed on a single structure. Already achieved by some metocean system integrators using WaveRadar REX sensors RS Aqua are working to include this feature on a future release of *WaveView Connect*.

The WaveRadar REX has maintained its role as the world's most robust, reliable and accurate wave sensor for offshore applications, and it has enhanced that reputation with the addition of notable features such as local data processing, real time telemetry and software. These developments have kept the WaveRadar REX at the forefront of coastal, offshore and underway wave measurement, and will do so for many years to come.

To find out more about WaveRadar REX, *WaveView Connect* or CODE please contact us at **rsaqua.co.uk**

Screen shot of OceanWise's Port-Log system for the WaveRadar REX

EvoLogics GmbH - Bionic solutions for maritime industries

EvoLogics GmbH from Berlin, Germany, designs and manufactures underwater communication and positioning systems as well as smart robotic solutions. The company's core technologies stem from bionic concepts that fuse state-of-the-art engineering with the best ideas found in nature.

EvoLogics launched in 2000 with a small group of scientists and R&D experts, aimed to develop innovative technologies for maritime and offshore industries. To overcome the common problems of transmitting data underwater, the team turned to dolphins, known to use a wide variety of acoustic signals to efficiently communicate in most challenging underwater conditions. The resulting EvoLogics S2C spread-spectrum communication technology over the years grew into a whole ecosystem of products that now includes several series of underwater acoustic modems, underwater positioning systems (USBL, LBL, SBL), advanced framework for developers, as well as novel robotic solutions and advanced R&D projects.

S2C Technology - solutions for underwater communication and positioning

The company's key offer are solutions for underwater communication, positioning, navigation and monitoring applications. EvoLogics S2C R and S2C M lines of underwater acoustic modems and positioning systems cater to various scenarios and provide the highest degree of customization.

EvoLogics bestsellers provide a highly reliable bidirectional data link along with acoustic positioning, broadcasting and networking functionalities. Modern applications range from retrieving data from subsea sensors and navigating unmanned underwater vehicles to deploying complex underwater sensor networks for monitoring and exploration. USBL and LBL positioning systems, coupled with EvoLogics positioning software (SiNAPS), deliver accurate results and allow for simultaneous positioning of underwater assets and bidirectional data transmissions.

To meet the growing demands of the maritime and offshore

Figure 1. EvoLogics underwater acoustic modems in action

industries, the product lines are constantly revised and expanded. Advanced networking and seamless system integration, minimizing the footprint and lowering energy consumption are the ongoing trends for new product launches.

Sonobot unmanned surface vehicle

EvoLogics actively develops its robotic USV platform: the **Sonobot** unmanned surface vehicle was conceived as an easy-to-deploy bathymetric survey vehicle for inland and harbour waters. The vehicle is a small, simple and usable platform for planning and executing a hydrographic survey that can deliver accurate geo-referenced bathymetry and high-quality imagery with minimum transport, launch and recovery efforts. The Sonobot is equipped with a GNSS receiver for precise positioning and a WLAN link to the control station on shore. The vehicle's payload measurement system is available in several configurations to best-fit the scope of its planned deployment. The options include an EvoLogics single-beam echo-sounder or a third-party multi-beam sonar, side-scan sonar, DGPS with RTK, as well as a front-view camera for monitoring and navigation in hard-to-access areas.

The Sonobot platform proved itself successful in commercial surveying applications around the globe. In addition, EvoLogics engineers found the USV to be a benefit for time-sensitive tasks like testing and demonstration. It has been incorporated into the company's demo-setup as a mobile node for LBL calibration and a target for LBL positioning. The opportunities of using a USV for various tasks beyond bathymetry are under further investigation, and the Sonobot is being tested as a deployment platform for a mini-ROV for monitoring operations, as well as a support surface vehicle for experiments with AUV networking and coordination.

Advanced R&D projects - EvoLogics BOSS Manta Ray

Constant innovation is the backbone of EvoLogics technology and the company is an active collaborator of several national and EU-funded R&D projects. Current development is focused in intelligent integrated solutions extending the capabilities beyond communication and positioning into telecommunication centers and robotics.

The BOSS Manta Ray is an autonomous underwater bionic vehicle the company has been developing since 2013 within the framework of the Bionic Observation and Survey System project.

BOSS is a joint research effort, supported by the German

Figure 2. EvoLogics Sonobot USV

Caption: EvoLogics Sonobot in action, courtesy of Schällibaum AG https://www.schaellibaum.ch/

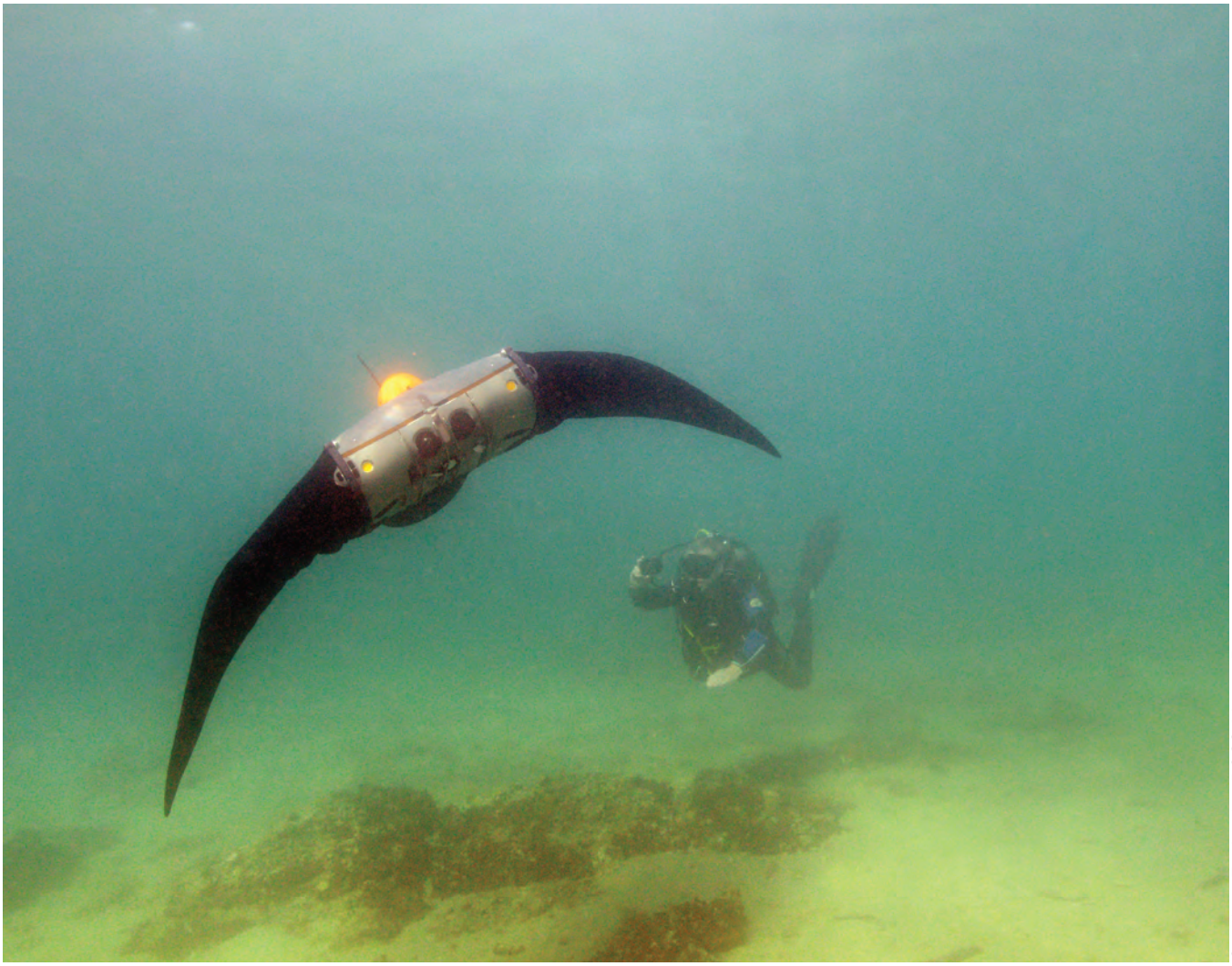
Federal Ministry for Economic Affairs and Energy (BMWi). BOSS Project partners are Sea & Sun Technologies and Lübeck University of Applied Sciences.

The goal is to create a powerful and flexible underwater exploration and monitoring system, particularly suitable to access hard-to-reach or yet unexplored areas with its unique functional properties. Deployed in the target area for observation and survey, the BOSS system is a self-coordinating swarm of autonomous underwater vehicles (AUVs), all linked into a multimedia sensor network with latest communication and navigation technologies. The AUV is the project's core innovation - engineered and built at EvoLogics, the experimental bionic vehicle is modeled after a Manta ray and can move through the water by wing-like movements of its "pectoral fins".

The AUV construction mimics the manta's flexible body, giving the robot unique mobility characteristics: the large wing surface provides the vehicle with excellent dynamic depth control capabilities. The moving AUV can hold depth with highest precision, as well as perform highly dynamic dives and climbs. Inspired by nature, propulsion in "flapping wing" mode is very energy-efficient and offers long range and endurance.

During its missions, the robotic Manta can demonstrate the wildlife counterpart's gliding and maneuvering abilities in open ocean, as well as precisely navigate over rugged seafloor terrain or in a closed-off environment, overcoming the limitations of traditional torpedo-style AUVs that lack agility near unstructured objects (coral reefs etc). In addition, the bionic Manta vehicle is fitted with jet thrusters and can move in high-speed mode, similar to standard AUVs widely in use today.

Figure 3. EvoLogics BOSS Manta Ray



Caption: EvoLogics BOSS Manta Ray

UNDERWATER COMMUNICATION AND POSITIONING SOLUTIONS

S2C TECHNOLOGY: COMMUNICATION AND TRACKING COMBINED

- time, space and cost-saving solutions
- low power consumption for autonomous operations
- advanced data delivery algorithms, addressing and networking, remotely configurable settings
- extendable platform with multiple configuration options: power-saving Wake Up module, acoustic releaser, additional sensors, custom solutions, OEM versions availableh

USBL POSITIONING SYSTEMS

simultaneous positioning and communication - no need to switch between positioning mode and modem mode

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: up to 0.04 degrees

LBL POSITIONING SYSTEMS

highly accurate, precise and stable performance, simultaneous positioning and data transmissions

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: better than 0.01 m

UNDERWATER ACOUSTIC MODEMS

reliable data transmissions even in adverse conditions, customizable R-series modems, light and compact M-series "mini" modems, **new S2CM-HS high-speed modem**, special editions for developers, S2C communication and positioning emulator - remote access or standalone device

- range: up to 8000 m
- depth: up to 6000 m
- data rate: up to 62.5 kbps

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BOSS Manta Ray Propulsion Modes are

- Active life-like wing propulsion and leveled gliding - quiet, fast and efficient with extraordinary maneuverability
- Hydro-jet propulsion - precise control of the trajectory maintaining accurate depth levels without body oscillations - suitable for precise sonar measurements, sea-floor mapping and add-on speed requirements

The BOSS fleet of AUVs offers smart functional design with life-like swimming capabilities for future hydrographic profiling, seafloor mapping, inspection of subsea installations, as well as search and monitoring.

Conclusions

The challenges of modern offshore and maritime industries are more and more demanding, whereas most systems currently in use are large, heavy and extremely expensive to deploy. There is a strong need for smaller and smarter platforms, as operation of bulky equipment is very risky and requires significant support.

New technologies and smarter constructions enable cost-efficient solutions by getting rid of cables, “unchaining” underwater equipment and replacing traditional instruments with intelligent autonomous underwater vehicles. Underwater “internet of things” that enables intelligent cooperation between various vehicles and sensors is one of the the main vectors of EvoLogics development strategy.

Acknowledgements

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Figure 4. EvoLogics S2C R Underwater Acoustic Modems

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