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FURTHER DEVELOPMENTS OF MULTI-PURPOSE UNDERWATER DATA COLLECTION DEVICES DEPLOYED WITH REMOTELY OPERATED VEHICLES

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Abstract: *This paper is following further development of the common framework model for multi-purpose underwater data collection devices focusing on second generation of simulation techniques VMAX2.0 on Perry-Slingsby ROV simulator. It is addressing physics-based simulation differences and their impact on the previous research for deployment challenges of underwater sensor networks called "Safe-Nets" by using Remotely Operated Vehicles (ROV) in the Black Sea area.*

***Keywords**. Remotely Operated Vehicles, ROV, simulation, testing, object modelling, underwater component, oceanographic data collection, pollution, Black Sea.*

I. INTRODUCTION

In early 1969, within a 10-day period, an estimated 80K-100K barrels of oil spilled into the Santa Barbara channel, southern California, when Union Oil Platform A blew out. At the time, it was the largest oil spill in US waters. Now it ranks only 3rdin history. On the 6th of July 1988 an explosion and resulting fire destroyed the Piper Alpha production platform in the North Sea and 167 men lost their lives. In March 1989 Exxon Valdez tanker spilled 500K-750K barrels of oil into waters of Alaska after running a ground. The Montara blowout, located on the north coast of Australia, started on 21st of August 2009 and continued leaking for 74 days - it was finally plugged on the 5th attempt to seal the well.

The Macondo blowout (BP Deepwater Horizon) in 2010, is considered the largest accidental oil spill in history. It claimed 11 lives and during 87 days the sea floor oil gusher flowed leaking 5 million (!) barrels of crude oil into the Gulf of Mexico. Most catastrophic offshore oilfield exploration or production incidents cause loss of life and damage to the environment and their frequency and effects appear to have dramatically increased during the last century [1]. This drew considerable attention from decision makers in communities and governments, up to a global interest in the area of underwater technologies development, therefore research efforts in the exploration of offshore resources are continuously increasing in the last years.

As every technology developed on land eventually ended up being used in offshore as well, while it's the natural tendency of human behavior out at sea to take commonly used home technologies to the "home out at sea", we are confident that Industry 4.0 revolution will embrace the offshore world as well. Underwater sensor networks are going to become in the nearby future the background infrastructure for applications which will enable geological prospection, pollution monitoring, and oceanographic data collection at the touch of a smartphone. Furthermore, these "offshore IoT" data collection devices could in fact improve offshore exploration and production tools by steadily replacing on-site instrumentation used today in the energy industry,as well as in maritime operations.

This theoryissued the idea of deploying multi-purpose underwater sensor networks along-side with oil companies' offshore operations and previous studies [2] tried to emphasize the collateral benefitsof deploying underwater sensor networks. We addressed state-of-the-art ideas and possible implementations of different applications such as military surveillance of coastal areas, assisting navigation [3]or disaster prevention systems – including earthquakes and tsunami detection warning alarms in advance.

The number of offshore constructions is constantly growing and we should be able to implement underwater sensor networks as auxiliary systems that allow us to better understand and protect the offshore environment. We are using Remotely Operated Vehicles (ROVs) and a VMAX-Perry Slings by ROV Simulator with scenario development capabilities to determine the most efficient way of deploying our "Safe-Nets" around offshore oil drilling operations, including all types of jackets, jack-ups, platforms, spars or any other offshore metallic or concrete structure.

The future offshore world may include "underwater railways" as a variation of Hyper-loop conceptual high-speed transportation system. We

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can imagine a version of this reduced-pressure tubes in which pressurized capsules ride on an air cushion driven by linear induction motors and air compressors in The Black Sea, moving goods and connecting the harbors of Constanta and Istanbul for instance. In close relation to this concept we can introduce our common framework model for Multi-purpose UnderwaterData Collection Devices, which can be attached along-side the underwater tubes, offering constant monitoring system and in the same time expanding the “Water Net” networks (Internet over the seas)concepts we previously presented [2]. The ability to have small devices physically distributed near existing or future offshore operations brings new opportunities to observe and monitor micro-habitats[4], structural monitoring or wide-area environmental systems[5]. The main advantages of our “Safe-Nets” are also in favor of disaster preventions systems, for seismic activity and tsunami warning systems in advance, which are quite limited today compared to their counterparts on land and which themselves alone can represent one of the possible justifications for overcoming the financial hindrance for underwater networks deployment. Furthermore, we have proposed a model of interoperability in case of a marine pollution disaster for a management system based upon Enterprise Architecture Principles [6].

II. TESTBED

We are creating simulation scenarios on the VMAX-Perry Slings by ROV Simulator (Fig. 1) [7]for the offshore industry, used to develop various simulation applications in conjunction with real-life Perry Slings by Triton XLS and XLR models of ROVs, which are currently available in the Black Sea area. Before deploying such Safe-Net underwater sensor networks on a large scale, a thorough investigation and simulation must be performed beforehand any actual physical implementation. Simulation helps preventing any damages to the ROV itself or any of the subsea structures we may use as point of insert.

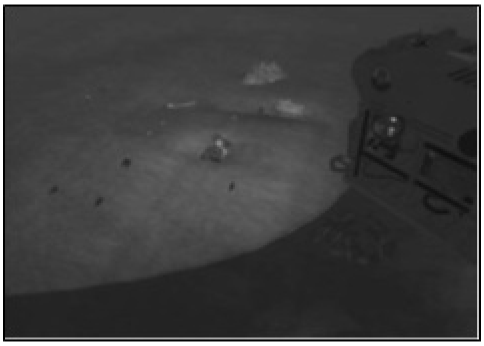

Fig. 1 Simulation scenario in ROV Simulator

The ROV Simulator is software and hardware package intended to be used by engineers to help in the design process of procedures, equipment and methodologies, offering a physics-based simulation environment. The ROVs have two robotic-arms: a Schilling Robotics Titan 4 manipulator with 7 degrees of freedom (Fig. 2) and a Schilling Robotics Rig Master 5 function heavy-lift grabber (Fig. 3).

Fig. 2 SR Titan 4 Master Arm and control console

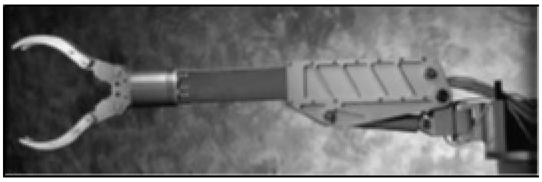

Fig. 3 SR Rig Master 5-function

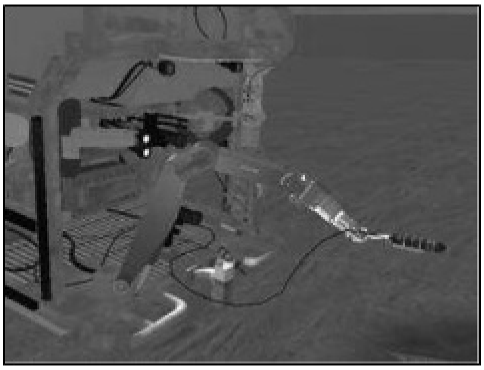

Fig. 4 SR 7- Function Arm in simulation scenario

With these two manipulator systems we are going to develop modelling and simulation scenarios concerning the deployment of underwater sensors Safe-Net surrounding areas of offshore operations trying to foresee and overcome any design flaw.
Our previous studies [2][8][9] included CAD-based modelling and “.lua” script programming skills. The simulator is capable of creating scenarios that are highly detailed and focused on one area of operation or broad in scope to allow an inspection of an entire subsea field. In version 1.0 this is two-step process meant the creation of any object's model in third-party software and afterwards programmatically insertion into the simulation

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scenario. The simulator which is open-source regarding the scenario developmentmodule was the starting base for a scenario where we translated the needs of the ROV in terms of sensor handling, tether positioning and pilot techniques combined with the specifications of the sea-floor where the Safe-Nets will be deployed. In version 2.0 we are going to use the VMAX Vm Editor Scenario Creator which will provide us the ability to take control over the scenarioand asset creating process. One of the main advantages of this improvement is that it provides a development environment that allows users to easily importassets into the simulation environment forphysics setup. This refers to the process of addingcollision geometry, physical attributes (mass,center of mass, center of buoyancy) andother physics based criteria used to defineobjects within the simulation environment.Users can also define logic and connectphysical objects through behaviors and interactions to create highly complex scenarios.

Moreover, during development of the scenario the programmer can run the simulation within the Vm Editor to test the scenario prior to release. The endresult of the editor is a self-installing package file containing the scenario which can easily be imported into VMAX Project Simulatorsoftware for immediate use. This provides rapid engineering analysis in simulated offshore environment.

We are looking forward to a future plan where the ROV simulator will also be included in an integrated immersive simulation center developed by Kongsberg A.S.

III. CHALLANGES

Current terrestrial sensor network practices are quite different than underwater approaches: terrestrial networks emphasize low cost nodes, densely deployed and use multi-hop short-range communication. By comparison, typical underwater wireless communication today are very expensive (US$10.000 per node or even more), sparsely deployed (a few nodes, placed kilometers apart), typically communicating directly to a “base-station” over long distance ranges rather than with each other. We seek to reverse these design points which make land networks so practical and easy to expand and develop and apply the same concepts to underwater sensor nodes by firstly perfecting a common framework model which can provide backwards compatibility, as well as a starting platform for various developments of process-specific modules.

We keep in mind that the sea is a very harsh environment, where reliability, redundancy and maintenance-free equipment are a “must”, therefore we seek the methods and procedures for keeping the future development in a framework that should ensure backwards compatibility with any other sensor nodes already deployed out at sea. We have designed our common framework model with multiple layers and drawers for components which can be used for different purposes (Fig. 5).

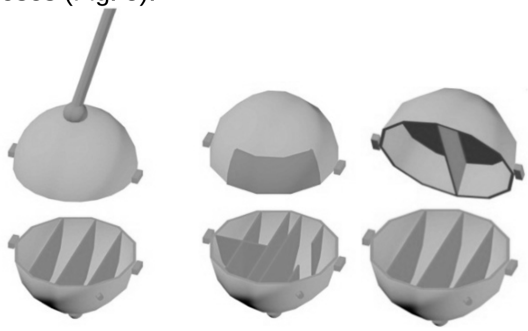

Fig. 5 Common Framework Model for Multi-Purpose Underwater Devices

The modular approach and the ability to accommodate a variety of sensors, positioned inside the “drawers”, led to a spherical-shaped model which we now consider to be best suited for future use, as it is providing us the much needed versatility and satisfies the buoyancy capabilities for a stand-alone device.

Our 3D models for underwater multi-purpose sensors have proven tobe a good idea, at least in simulation scenarios for our Safe-Nets, but this remains to be further investigated in real-life development and implementation stages. Tethered or untethered, the upper hemisphere can include a power adapter which can be used also as batteries compartment.We have chosen a very simple closing mechanism for starters, using clamps on both sides, which can ensure the sealing of the device. The upper and lower hemispheres close on top of an O-ring seal which can be lubricated additionally with water repellent grease. Also, we have designed a unidirectional valve which can be used for a vacuum pump to clear out the air inside. The vacuum strengthens the seal against water pressure.

Based upon repeated fails in trial scenarios with an ROV Schilling Robotics 7-function Titan-4 manipulator (Fig. 2) trying to grab and hold a Spherical shaped Safe-Net node,within the same common modular framework we have designed a simultaneous deployment method for 3 or more sensors in the same time.

Because of the real difficulties encountered, especially when inserting higher waves into the scenario we have come up with the grouping method presented in Fig. 6.

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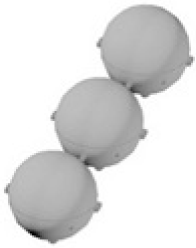

Fig. 6 Grouping method for 3 or more Safe-Net nodes

Moreover, we have designed a "cup-holder" shape for grabbing more easily the sphere and in case the sensor is cabled and not wireless, we made sure that the cable connection will not be tampered by the grabber, as it can be seen in Fig. 7, assuming the node has to be deployed in a special position around the offshore structure.

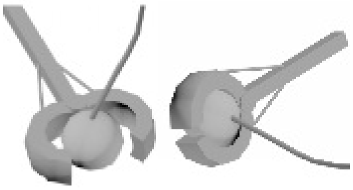

Fig. 7 Tool for Safe-Net device easier deployment

Offshore constructions represent the installation of structures and facilities in a marine environment, usually for the production and transmission of electricity, oil, gas or other resources. We have taken into consideration most usual encountered offshore types of structures and facilities.

Power supply is an important chapter in our study, because until now, only batteries were considered to be a viable solution for underwater-based sensor deployments. The sensors have been deployed and based upon the degree of how refined the power-saving algorithm was, after a certain amount of time, these sensors were afterwards always recovered. In our case, the close proximity to offshore structures means pre-existing external power sources: diesel or gas generators, wind turbines, gas pressure turbines, so on and so forth. We can overcome the power issue by linking the Safe-Nets to jackets or to autonomous buoys with solar panels [10]which are currently undergoing researches for various purposes [11].

The first project for an offshore wind farm was developed in Denmark in 1991. The wind speed offshore is usually greater than inland, however, wind turbines (Fig. 8) are harder to install at sea and need more technical and financial efforts. The distance to land, water depth and sea floor structure are also factors that need to be taken into consideration. Wind power produced the equivalent of 42.1% of Denmark's total electricity consumption in 2015. This constantly increased during the last years from 33% in 2013, and 39% in 2014 with plans of reaching 50% by 2020[12].

We have also looked into future systems types of producing electricity from waves [13]:

• Attenuator-type (Fig. 9);
•Multi-point absorber (Fig. 10);
•Overtopping devices principle (Fig. 11)
•Submersible differential pressure (Fig. 12)

All of the above may prove to be points of insertion for our Safe-Net nodes.

Fig. 8 Wind Farms in North Sea

Fig. 9Pelam is Wave Energy Converter Orkney, U.K

Fig. 10 Wave Star Machine [14]

Fig. 11Wave Dragon

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Fig. 12Archimedes Waveswing(AWS)

Another design hard stone is the **communication** issue. Two possible implementations are buoys with high-speed RF-based communications, or wired connections to some sensor nodes. Once the information gets to the surface, radio communications are considered to be already provided as standard.
We do not intend to mix different communication protocols [15] considering the different physical layers, but we analyze the compatibility of each with existing underwater acoustic communications state-of-the-art protocols and our approach will be a hybrid system, similar to the schematics presented inFig. 13.

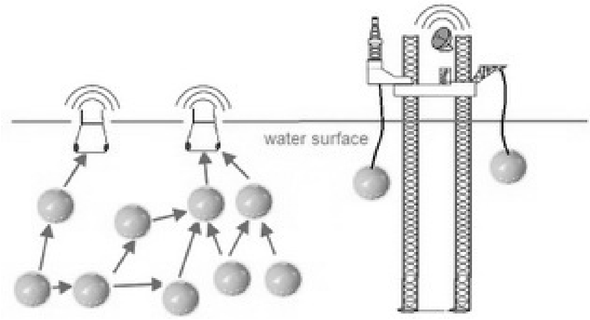

Fig. 13 Safe-Net development near offshore pre-existing structure

FURTHER DEVELOPMENTS AND CONCLUSIONS

The VMAX project simulator software has been successfully used by ROV 'pilotechs' and the engineering designs and procedures have been validated with instant feedback, prior to systems integration testing. VMAX distinguishes itself from the rest of the industry and version 2.0 sets the standard with extremely realistic visuals and highly accurate physics simulation that can have a dramatic impact on design as well as mission execution. This robust application solution provides the option to develop in-house scenarios as part of the engineering efforts, thus reducing change orders and improving operating margins.
As an improvement from initial version based in part on traditional high end 3Dmodeling programsthe asset creationprocess allows easy transition into creatingsimulation scenariosby dragging-and-dropping aswell as through scripting. This new developmenttool provides a classic 3D-view of the scenarioscene as well as a free camera view that allowsthe developer to "fly" around the scene.
We are looking to develop different option modules for the Safe-Nets nodes in order to facilitate their use for all types of underwater operations, which can include instrumentation sensors nearby offshore drilling and production facilities or any type of data collection. Our goal is to provide cost-effective solutions for the offshore operations. This could provide the financial means of deploying underwater Safe-Nets, especially by tethering to all offshore structures for exploration or production, which need different instrumentation systems by their default nature.
Possible applications include:
• Seismic monitoring
• Environmental monitoring
• Disaster prevention
• Weather forecast improvement
• Assisted navigation
• Military surveillance used for coast-line or border-lines, detecting the presence of boats and ships. Fixed underwater sensors can monitor areas for surveillance and reconnaissance (e.g.: immigrants' intrusion detection systems).
We suggest various extension possibilities for applications of these Safe-Nets in support of passing the biggest challenge of the whole project: the cost of implementation of such underwater networks.

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