DEXROV
SPACE ROBOTIC SOLUTIONS APPLIED TO SUBSEA ROBOTICS

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ABSTRACT

There are significant cross-links and synergies between subsea robotics and space robotics. Today, it is possible to control a rover on planet Mars, but similar control techniques have so far not been applied to subsea robotics: A remotely operated vehicle (ROV) working offshore Africa is still operated by ROV pilots sitting in the support vessel just above. The DEXROV project (financed by the European Commission under H2020) is aiming to apply solutions known from space robotics to subsea robotics. The aim of the project is to control a COMEX subsea robot offshore Marseilles through a control centre located in Brussels. The project will be finalized with several campaigns at sea, with a ROV operated down to -1300m water depth from a distance control centre.
This paper will give an overview on the project, its aims and planned sea trials. It will conclude with a vision for future projects, such as what could be called a "subsea-METERON" where an underwater robot could be controlled from space - from one extreme environment to another.

1. FROM SPACE TO SEA

The Mars Exploration Rover OPPORTUNITY reached on May 15th, 2017 its main target of its two-year extended mission, *Perseverance Valley* on planet Mars. OPPORTUNITY is operating on the Martian surface since January 2004 and explored over 44 km (as of May 2017) without any human intervention or maintenance and a time delay of communication in average of 20 minutes (one direction). [NASA, 2017]

In the same moment multiple Remotely Operated Vehicles (ROV) are working on subsea Oil&Gas structures in the deep ocean offshore Africa or other locations. These robots perform tele-manipulations in order to construct underwater facilities or to perform inspection and maintenance on those. The difference between both application scenarios is the fact that while we are able to operate a robot on Mars, with a tremendous time delay, subsea robots that are tethered to the surface, still require the local presence of pilots.

Figure 1: (left) Artist's view of the Mars Exploration Rover OPPORTUNITY and (right) COMEX' subsea robot APACHE.

The DEXROV project has as objective to develop technologies and techniques (from the space sector) to make tele-manipulation of a ROV possible through a distant control centre. The expected outcome of the project is to operate an ROV in -1300m water depth offshore Marseilles, France from a control centre located Brussels, Belgium. The project furthermore will test novel control methods for dexterous tele-manipulation allowing such subsea robot to perform tasks on structures that are not designed for robots: Installations from the Oil&Gas sector are designed in a manner that facilitate robotic interventions (e.g. interfaces specifically designed to be performed with a manipulator arm). These conditions do not apply to older facilities that were designed for human divers; nor to other fields such as subsea archaeology or marine science (e.g. biology) in general. DEXROV shall handle all such application cases in the end.
Figure 2 shows the overall architecture of the system.

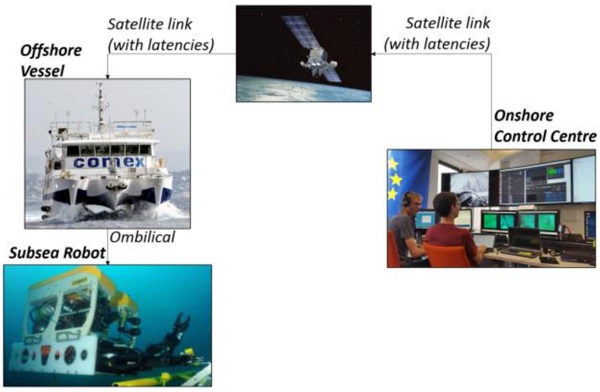

Figure 2: Architecture of the DEXROV system

The DEXROV project is financed by the European Commission under the Horizon 2020 programme. It features seven partners: Space Applications which is the Coordinator of the project, COMEX which provides the subsea robot and all logistics for the sea trials, the Interuniversity Center of Integrated Systems for the Marine Environment (ISME) that develops the robot control, Jacobs University that develops an underwater 3D perception system, IDIAP Research Institute that works on the tele-manipulation, Graaltech that develops the manipulator arms and EJR Quartz which manages the communication and outreach.

2. ARCHITECTURE OF THE SYSTEM

The DEXROV system consists of four major elements:

- An **Onshore Control Centre** including haptic and visual user interfaces, a simulation framework and a cognitive engine. The simulation framework receives via the satellite link telemetry data from the ROV, video signals and the 3D environment model. Those are displayed on the visual user interfaces (screens) and the simulation framework receives back the user’s arm and hand position (for the manipulator) and the force sensing.

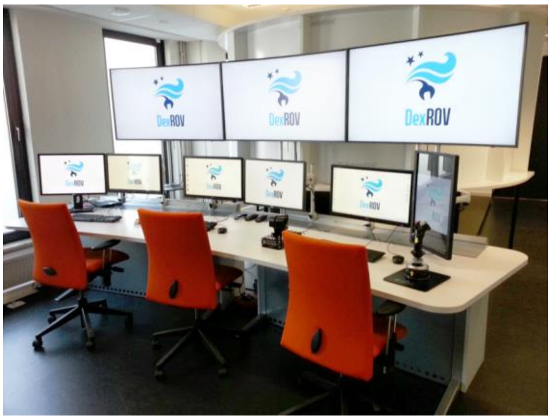

Figure 3: Offshore Control Centre located at SPACE APPLICATIONS in Brussels, Belgium.

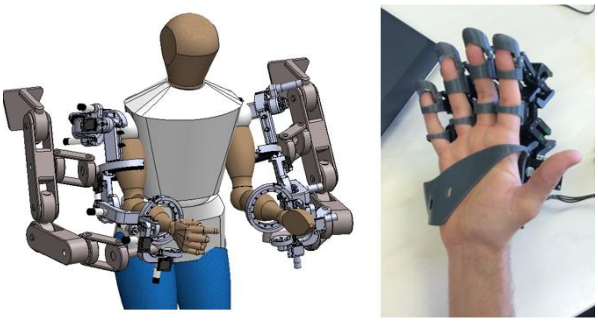

Figure 4: Haptic interface for the manipulator operations

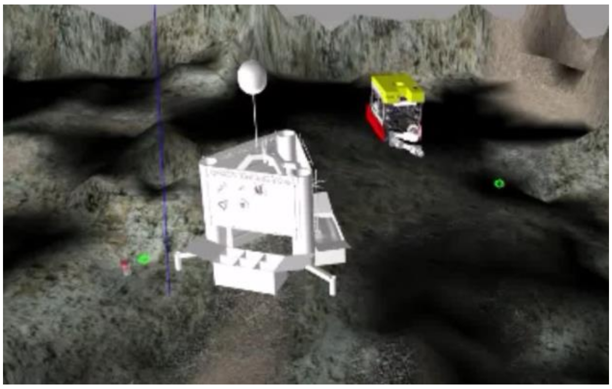

Figure 5: Screenshot of the 3D model created in the simulation environment.

- The **Offshore Vessel** with a local control centre includes the online data processing (SLAM and 3D model) and a control engine for the semi-autonomous ROV navigation and manipulation. The ROV is linked to the vessel via an umbilical.

Figure 6: The COMEX JANUS Research Vessel that will host the offshore control centre and ROV.

Figure 6: Offshore control centre on-board the COMEX JANUS research vessel.

- The **satellite communication** with traffic shaping and Quality of Service (QoS) on the data and command flows. In the context of DexROV, a maritime VSAT solution is deployed on the vessel - Ku band Cobham Sailor 800 tracking antenna, its controller and modems. The uplink bandwidth from the vessel is 768Kbps and the downlink to the vessel is 256kbps with the nominal round trip delay of 620ms. Multiple data and command flows for effectively monitoring remote ROV operations, such as ROV commands, video streams, pose updates, 2.5/3D environmental maps, status updates etc. Hence, it is important to optimize usage of the bandwidth by prioritizing data flows with specific QoS, avoid overloading the network by shaping the traffic and ensure data reliability with the minimal overheads. To address the described challenges, a custom data flow control software has been developed using OpenSplice Data Distribution Service (DDS) middleware to exchange data between the onshore and offshore nodes over the bandwidth constrained satellite network[1].

- The **Subsea Robot** of DEXROV is a standard medium size ROV (APACHE 2500m) to which the DEXROV SKID is attached including a 3D vision system and dexterous manipulators.

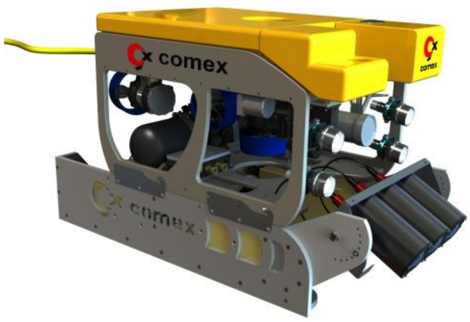

Figure 7: The APACHE ROV which can operate down to -2500m. The DEXROV system will be included in a SKID similar to the one shown on the image below the ROV.

3. SEA TRIALS

The DEXROV project is in its third year and will perform in June 2017 first complete sea trials of the system. Main objective of these trials will be the test of the 3D perception system developed by Jacobs University. Also a first version of the tele-manipulator arms by Graaltech will be operated during this mission. In order to simulate various operations on subsea Oil&Gas facilities (e.g. wellhead) a specific ROV Test Panel was developed that will be deployed in -100m and then -1300m water depth. The panel is entirely passive and also includes elements to demonstrate the ROV's arm dexterity for applications such as subsea archaeology or marine science (sampling of biological items). During these trials the ROV will be operated from the control centre in Brussels.

Figure 8: The ROV Test panel which will be used for the trials with the ROV. It features three sides (Oil&Gas ROV interfaces –shown-, human diver interfaces and biology/archaeology tests).

4. BACK TO SPACE: TOWARDS A SUBSEA-METERON?

The architecture and system developed in DEXROV could be used in the future to enhance experiments such as those performed in the METERON project. METERON, which stands for Multi-Purpose End-To-End Robotic Operation Network, is an ESA led technology demonstration to validate advanced telerobotics operations from space with a robotic platform in ground. The concept is to control a robot on Earth (which could late be a robot on a planetary surface such as Moon or Mars) from a space-based platform (ISS or later a space station in the orbit of the Moon or Mars). Both projects, METERON and DEXROV, have a number of similarities and a combination of both concepts could lead to an experiment where a subsea robot is controlled from an orbital station (ISS) [ESA, 2017].

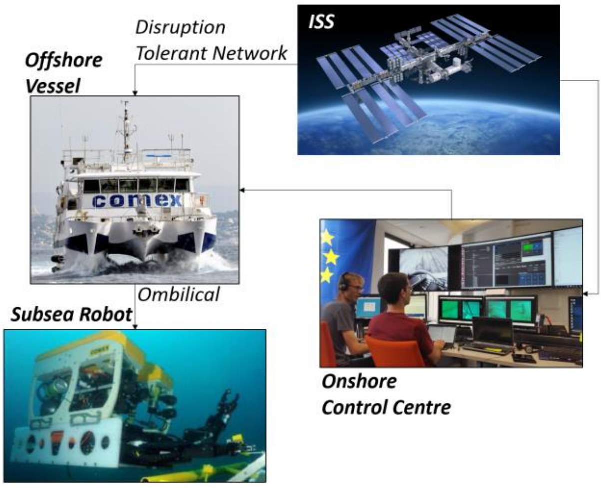

Figure 9: Possible "SUBSEA METERON" architecture for the control of an underwater robot through ISS – from one extreme to another!

[1] *RTI Whitepaper, "Limited-Bandwidth Plug-ins for DDS - Integrating Applications over Low Bandwidth, Unreliable and Constrained Networks using RTI Data Distribution Service"*

Figure 9 shows two possible ways to achieve such an experiment, either with a direct link between the offshore vessel to ISS or through a communication loop via the onshore control centre at Space Applications.

Such “SUBSEA METERON” would be a technology demonstration for telerobotics from one extreme environment (space) to another (subsea).

5. REFERENCES

NASA (2017), Mars Exploration, Mars Rover Opportunity begins study of Valley’s origin, webpage accessed on 03/06/2017 on https://mars.nasa.gov/news/2017/mars-rover-opportunity-begins-study-of-valleys-origin

ESA (2017), Meteron project webpage accessed on 04/06/2017 on http://esa-telerobotics.net/meteron