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Rov Based Survey: A New, More Effective Approach

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Abstract

Objectives/Scope: The paper presents results from developing a specialized Survey-ROV (Remotely Operated Vehicle) aimed at higher speed and unsurpassed resolution. Multi beam, laser and photogrammetry data will be presented.

Methods, Procedures, Process: The Surveyor Interceptor is a newly developed specialized Survey ROV. It has a hydro dynamically favorable hull, thin tether, and powerful propulsion to allow high resolution surveys, close to the seafloor, at speeds up to 10 knots.

The ROV was built during 2014 and has been tested during Quarter 1 2015. This paper presents results from tests and the first commercial tasks for the new SROV. The ROV has been used for pipelines, route surveys and environmental surveys in the North Atlantic at water depths between 50 -1200m. Acquired data will be presented. Performance as well as resolution and accuracies obtained are above the initial specifications and new technologies are developed.

The combination of high resolution equipment in a stable hull, renders accurate data for enhanced risk mitigation of offshore installations

Results, Observations, Conclusions: The SROV has surveyed with average speed of above 4 knots at several hundred meters water depth while collecting data from Multibeam echo sunders, laser bathymetry, still photos, photogrammetry, Side Scan Sonar's and Sub Bottom Profilers. The Underwater Navigation results are greatly improved by the use of inverted USBL, DVLs and INS systems. The vehicle is very stable at speed, thus rendering clean data with very little outliers. All in all the total concept can reduce the cost of pipeline and route surveys with improved data quality.

Integrity Management decisions based on data from the SROV will greatly reduce risk of offshore pipelines and installations.

Novel/Additive Information: Specialized Survey ROV's will lower the cost for Pipeline Inspection and Environmental Impact Surveys while rendering 3D models and resolution of hitherto unseen density and accuracy.

Introduction

This paper describes a Specialized Survey ROV capable of saving costs by being faster while also delivering data with a resolution and accuracy never before achieved.

The need for detailed knowledge of the subsea installations, the subsea environment and eventual hazards is crucial. To accurately map, inspect and intervene is a high priority for the industry. Remotely Operated Vehicles (ROV) are used to perform most tasks previously performed by divers and to bring instruments close to the seafloor to enhance resolution and precision. The standard Work class ROV(WROV) is the workhorse of the industry and used to carry many tools and instrument. During 2014-15 we built a more specialized vehicle; a Survey ROV (SROV). The problem with using ROVs for inspection and seafloor survey is that they are primarily constructed for replacing divers and carry tools. Their swimming ability is poor, often leading to average speed in production being as low as 0.4 m/s. A typical daily production is seldom above 50 km. Since competent surface vessels are necessary for energy, data flow and positioning, a cost per km is typically 1 200 - 2 000 USD. An Autonomous Vehicle (AUV) is faster and can achieve speeds up to 2-2.5 m/s, they are however dependent on battery power, limiting the number of instruments and requiring daily recoveries to charge batteries and unload data, making them sensitive to weather and limiting production to typically 120 -140 km per day.

Based on our experience in running both WROVs and AUVs for pipeline inspection and detailed survey we wanted a vehicle with higher speed and relevant instrumentation to ensure gapless data coverage at speed. It was evident that the vehicle would need an umbilical to power all instrumentation as well as fiber optics to transfer all data in real time back to the vehicle. These were the final design criteria:

Design Criteria SROV

Depth capacity	2 000 m
Payload	1 000 kg
Speed	4 m/s
Instrumentation	Standard geophysical equipment
	Scanning laser bathymetry
	Still cameras w high resolution
	Enhanced positioning

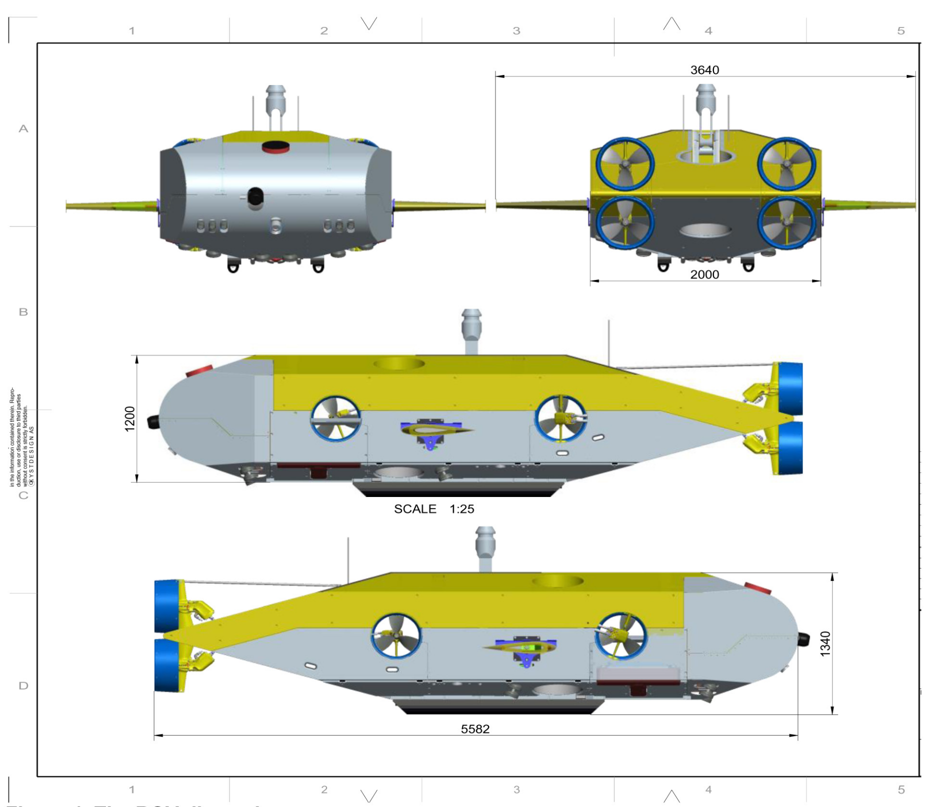

Figure 1—The ROV dimensions.

The final ROV specifications

Weight	4 200 kg
Current	4 000 V
Power	170 kW
Dimensions	5.6 m × 1.3m × 2 m (3.6 m with wings down)
Free payload	700 kg
Speed	5 m/s
Operative depth	10-2 000 m
Umbilical	25 mm 4 fibers steel coated
Multibeam	200-400 kHz 1600 beams Dual TX Dual RX Dual Ping 0.4° Beam width
Side Scan Sonar	600 / 1600 kHz multipulse
Sub bottom profiler	1-10 kHz
Underwater positioning	Dual transponders for USBL or LBL Inverted USBL mounted onboard SROV
Cameras 3 of	12.5 Mp w inbuilt processors
Led Flashes 6 of	56 000 lumen each
Led lights 6 of	28 000 lumen each
Lasers	520 Nm long range green laser.
Doppler Velocity Log	
Inertial Navigation 2 off	

This setup is designed to use standard geophysical equipment for surveying and acoustic inspection while still cameras and lasers are used for visual inspection and high resolution 3d modeling.

The systems first test was performed in December 2014 and tests were conducted until march 2015 when the first commercial job was carried out. The first days of testing was to synchronize the Dynamic Positioning system of the vessel in follow sub mode with the underwater positioning and measure the umbilical load at higher speeds. During the engineering the hydrodynamic forces and pull on the umbilical was simulated in mathematical models and a lot of concern was given to the models inability to correctly model semi flexible systems such as wires, hydraulics and winches. The calculations came up with high loads, in the region of the breaking strength of the umbilical of 25 tonnes. The surface vessels ability to accelerate and stop was also of high concern before tests.

The second phase of the test program was to ensure automatic steering functions and pipe following algorithms.

Third phase of the tests were to calibrate and collect data from the geophysical instruments.

Finally lasers and still cameras were tested and software integration was performed.

The testing was planned to be performed in the Norwegian sector of the North Sea west of Stavanger on the 40″ pipeline Europipe 2 but due to severe weather in December the initial tests were performed in less exposed waters in the Bömla fjord.

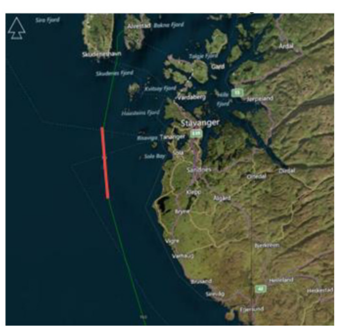

Figure 2—Europipe 2

Figure 3—Fjord sheltered test area.

Figure 4—Early days recovery in gale. No wings mounted.

Tests performed

Acoustic pipeline test

The test did comprise some 40 km of pipeline Acoustic Deep Water Inspection at Europipe 2 between KP 12 and 60 and different subsequent tests in the area.

The purpose of a pipeline acoustic survey is to:

- Detect third-party threats.
- Document the horizontal and vertical position of the pipeline in areas where the pipeline is exposed.
- Provide information on the pipeline-seabed interface.
- Provide information about the seabed in close proximity to the pipeline.
- Provide information on pipeline freespans

The Surveyor ROV performed surveys to estimate production quality and effectivity. Data was compared to previous AUV and WROV based surveys in the report.

DTM cell size was10cm.

Digital still images, Laser profiles, Side Scan Sonar and Sub bottom profiler data have been acquired simultaneously with the MBES data.

Pipeline visual inspection test

Multibeam and Laser data as well as still images and video was recorded at 1 m and 4 m altitude over the pipe to evaluate data and imagery quality and suitability for asset quality management.

Results

Speed test

The surface vessel and ROV did achieve 4 m/s while testing ultimate speed. The system was working on full hydraulic flow and close to the limit for hydraulic flow. The system can produce safely and stable at 6 knots.

The safety limit for the whole system (including hoists for USBL) is 5 m/s. It was decided to modify the SROVs propellers.

Speeds and height when Surveying Europipe 2

Section KP	Average speed m/s
58.043 – 53.447	2.1
53.102 - 52.529	1.8
52.475 – 42.535	2.0
41.994 – 33.139	1.7
33.026 – 29.528	1.8
Entire 28.5 km	1.9

Hydro acoustic tests

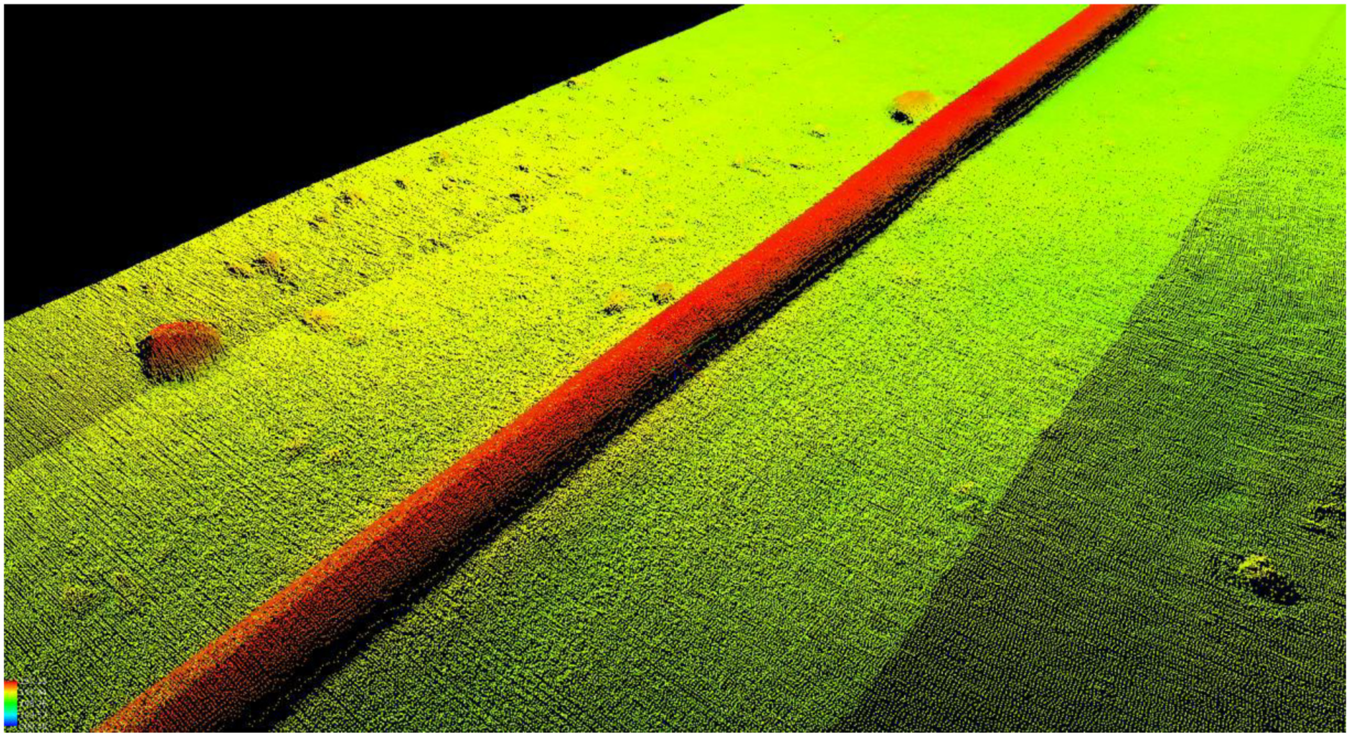

Figure 5—Multibeam data example from trials. Stable vehicle and little noise

Data from the test runs has less than 0.5% outliers. This is caused by a well calibrated systems and a stable vehicle with good positioning.

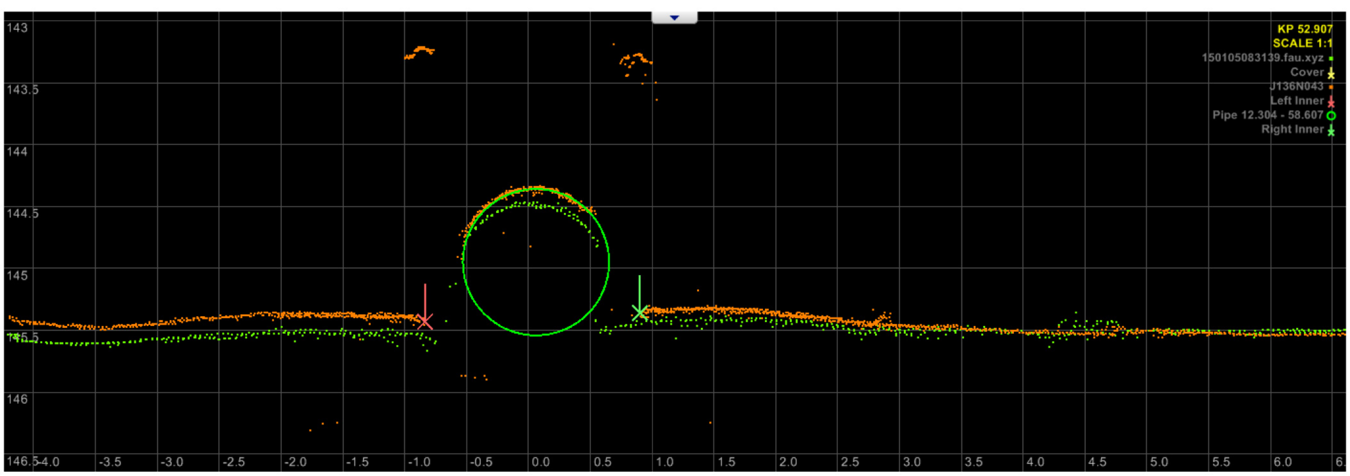

Figure 6—Comparison SROV data green with WROV data orange. Note frame interference causing noise in WROV data.

The multibeam data was lacking the typical side beam interface from standard WROV echo sounder setup.

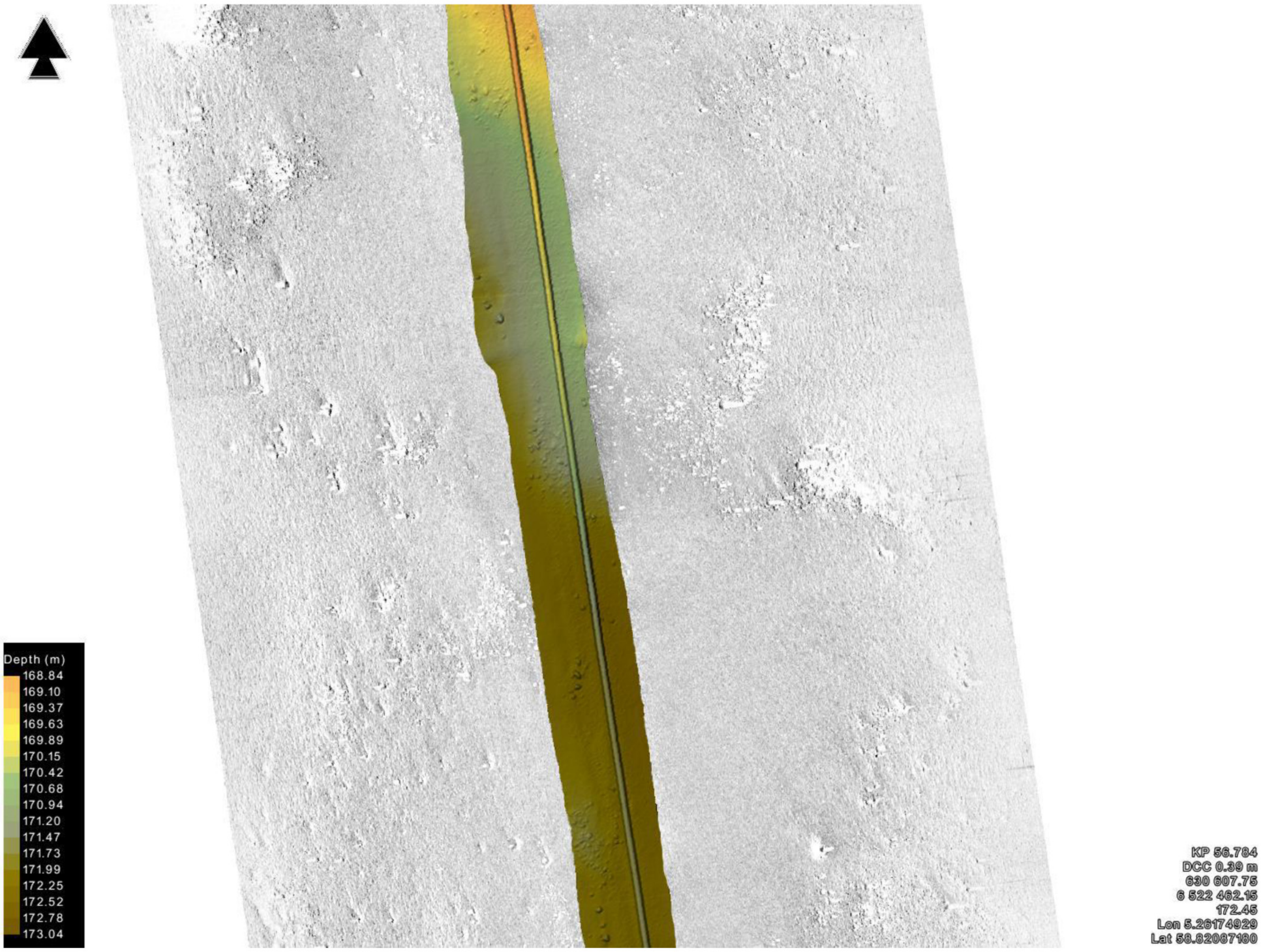

Figure 7—Side Scan Sonar and Multibeam data Europipe 2

Side Scan Sonar Data from Europipe 2 covers a larger area than multibeam data giving information of 3rd party threats or geological hazards.

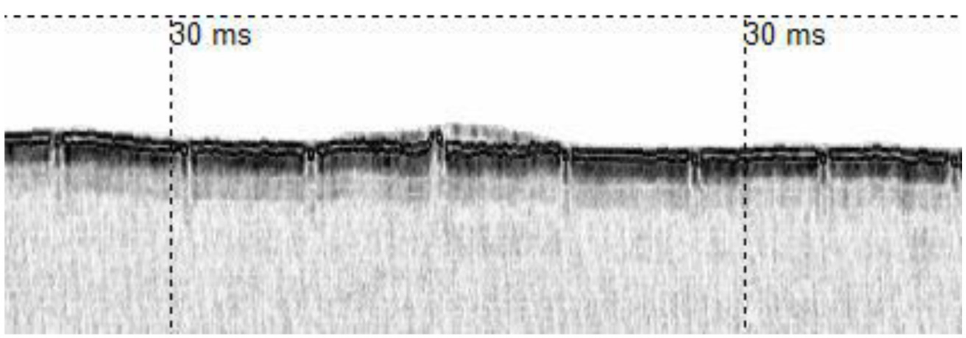

Figure 8—Sub Bottom Profiler Europipe 2 data field joints visible through rock berm.

When moving straight above the pipeline the Sub Bottom profiler could find the pipeline even when covered by rock berms. If the ROV is offset from the pipe, the pipe is not detected.

Camera and Laser tests

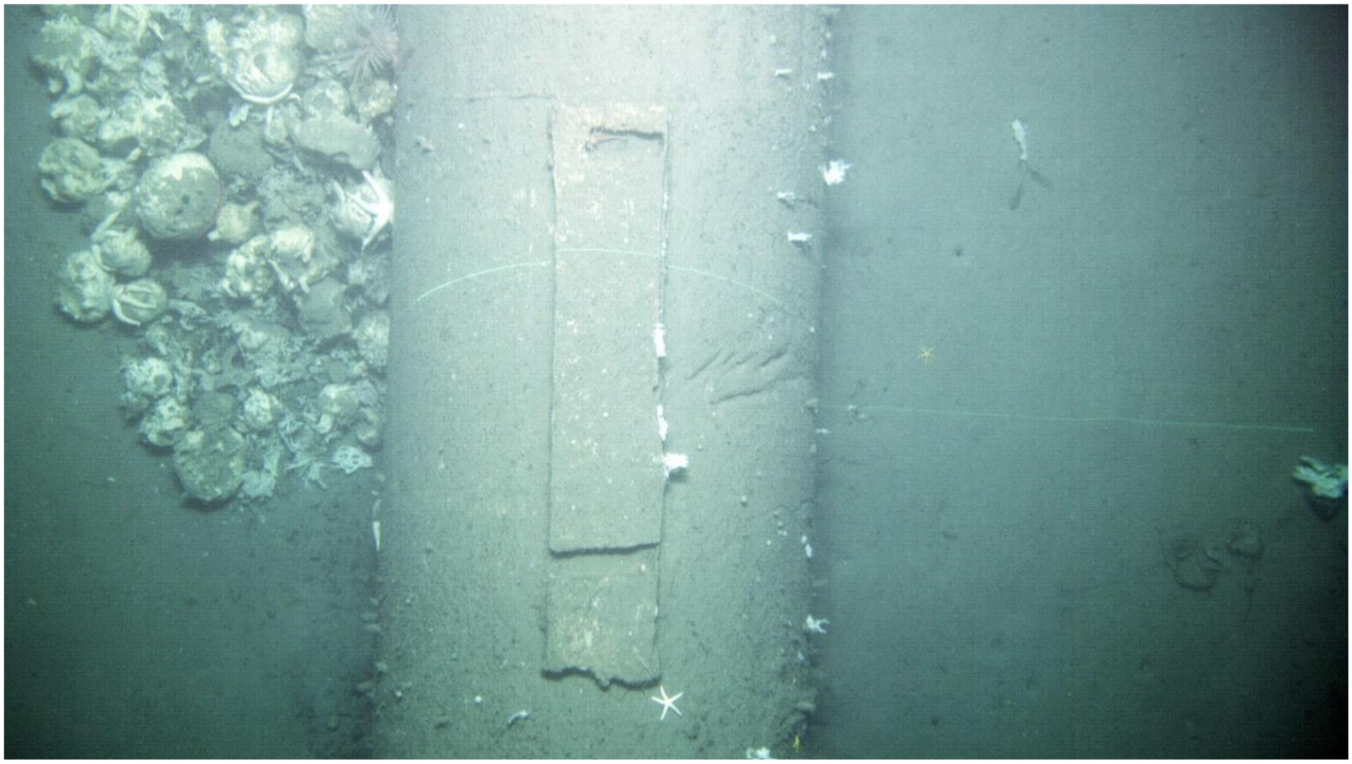

Figure 9—Centre camera 5.5 m above pipe speed 2.3 m/s. Laser line visible.

The 3 downward looking cameras were producing acceptable results but the exposure time of 3 ms was a fraction too long resulting in some motion blur. It was decided to increase the amount of light from the LED flashes.

The still camera system was intended to produce photo mosaics, geo corrected photography and possibility for stereo photography. The postprocessing team experimented with photogrammetry software and came up with very high resolution data making mm resolution models of pipe and seafloor possible. Please see below.

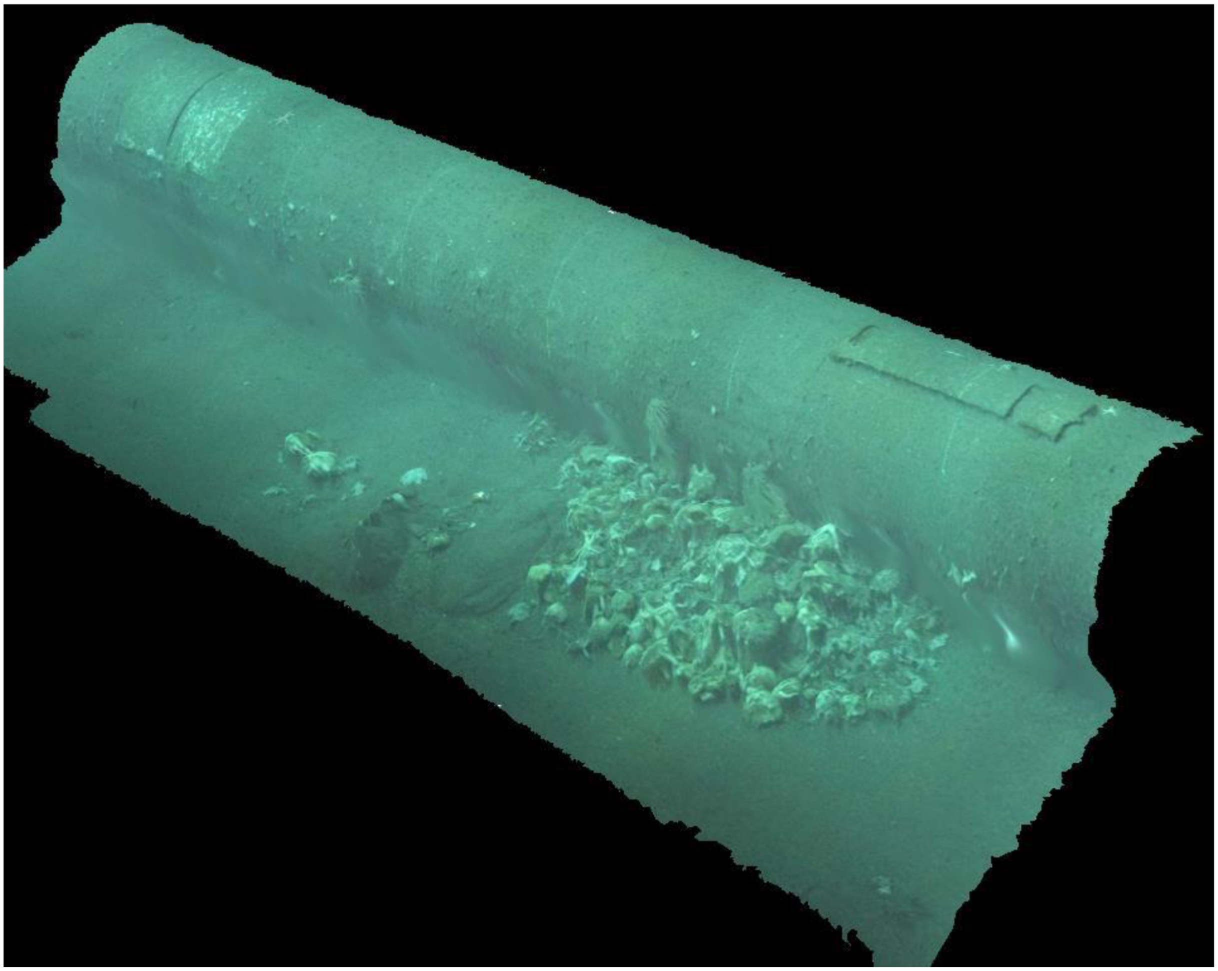

Figure 10—Photogrammetry from 21 images showing first High resolution 3D model examples

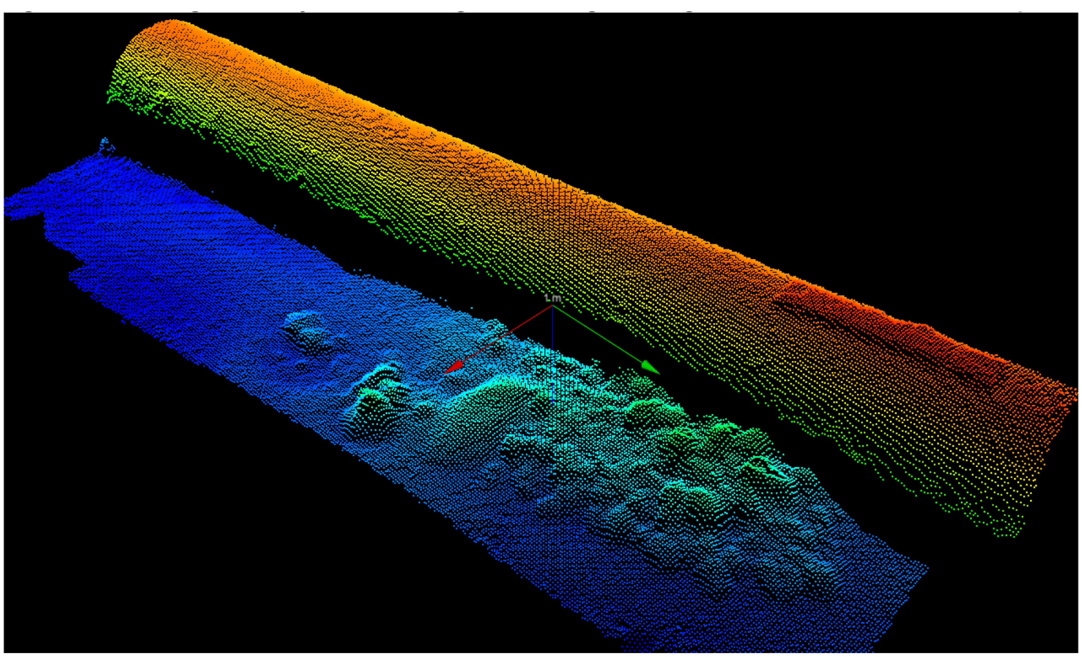

Figure 10—2 cm grid created by photogrammetry of above images with control points from laser scans.

Laser data example

The laser data has the potential to render up to 50 000 XYZ points per second at millimeter accuracy.

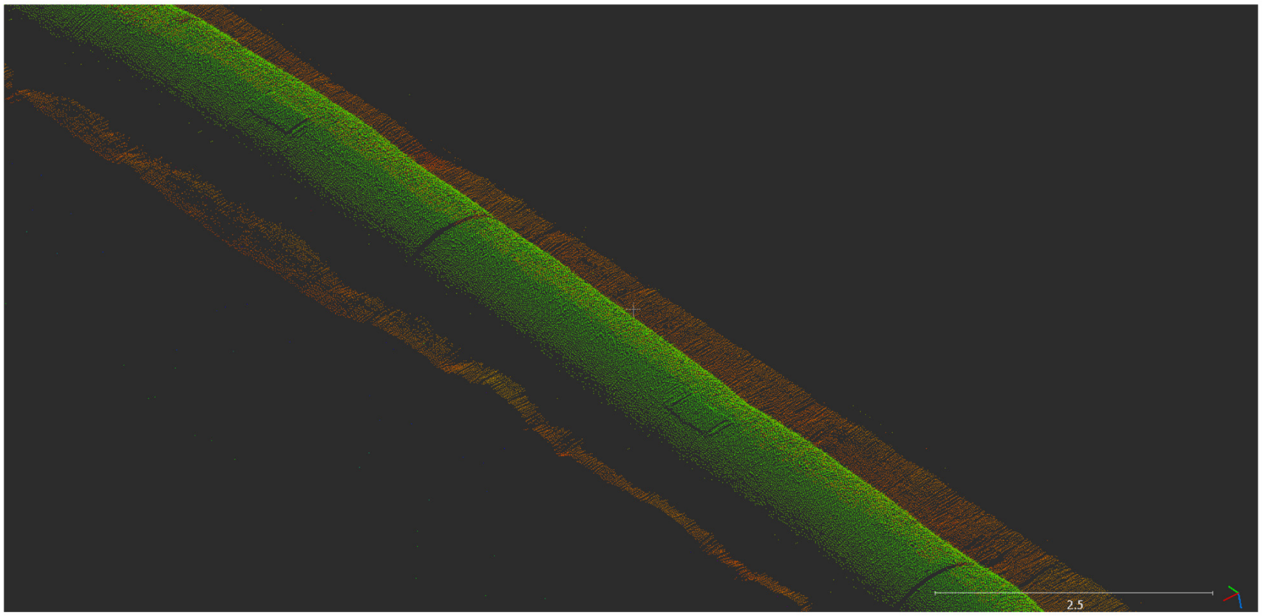

Figure 11—Laser data. Note resolution on anodes and field joints.

This creates a method to in real time measure the ovality and eventual damages of the pipe.

Summary of tests

The tests were successful and most of the goals were reached. However it was decided to replace the aft propellers with counter rotating propellers with higher pitch. The still camera flashes and lenses were also rebuilt to avoid motion blur at high speed.

Commercial tasks

The Surveyor ROV has been used for the Knarr Pipeline inspection in march 2015 and a reconnaissance project between Iceland and Shetland. It has been run for 2 months and 2750 km producing some 4 000 000 still images and high resolution charts of the seafloor. The typical survey average speed over weeks of operation is close to 4 knots while accuracy and point density is well above industry standard. The addition of Photogrammetry and laser brings the data resolution into a new era while maintaining higher speed.

Development projects

The promising results of the initial projects have inspired us to set up further development projects.

These are:

Photogrammetry - GIS interfacing

Machine Vision Automatic eventing

Pipe track, Depth of Burial and UXO detection by 8 gradiometers in the SROV.

Figure 12—Example of the high resolution data set in the 3D photogrammetry. Point cloud.

Conclusion

The results of the tests and the first jobs have convinced us that a specialized Survey ROV can be a very cost effective tool for pipe line inspection and high resolution seafloor surveys as well as environmental surveys and asset integrity management. For longer surveys cost can be reduced by 35-50% while maintaining very high accuracy and resolution.

The addition of still photography to replace video increases resolution and interfacing to Graphical Information Systems (GIS). When introducing photogrammetry and laser capacity to the inspection / survey capacity of the vehicle hitherto unexperienced accuracies and resolution are possible. This setup of tools will bring the knowledge of the subsea assets and their condition forward in a quantum leap.

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Abbreviations

AUV	Autonomous Underwater Vehicle
DVL	Doppler Velocity Log
GIS	Graphic Information System
INS	Inertial Navigation System (also a n attitude sensor)
LBL	Long Base Line (underwater navigation)
ROV	Remotely Operated Vehicle
SROV	Surveyor Remotely Operated Vehicle
USBL	Ultra Short Base Line (underwater navigation)