Seabed Mapping with HISAS Sonar For Decommissioning Projects

High-Resolution Surveying for Decom Planning

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The decommissioning phase of an oil field occurs at the end of the field's active life, and it is a critical phase, with potential for oil and chemical leakage that can damage the environment, which is why it is regulated by legislation.

The environmental impacts of decommissioning oil and gas production facilities were first highlighted in 1995 with the attempt to sink the Brent Spar structure in the British North Sea. At that time, the British policy for decom was to sink the platform at its location. Environmentalists feared an accumulation of polluting material in the sea, and after they protested, the platform was taken ashore and disassembled, and the steel structures were reused in the construction of a Norwegian wharf, confirming the possibility of reusing the material from old exploration platforms. This fact incited oil-producing countries, Brazil included, to create rules to regulate the decommissioning process of oil fields.

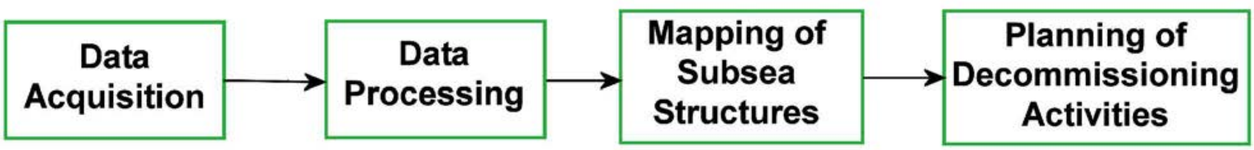
The complexities of the activity planning and decision making and the extremely high costs involved in the decommissioning, abandonment and removal of obsolete offshore installations led to the need to use new technologies and to develop consistent survey procedures to map the seafloor around the sites. One of the most critical steps in this process is to determine the exact location of the subsea structures to be removed, such as pipelines, wellheads, equipment, power cables, etc. This information is the base for decommissioning planning and management.

Pilot Project

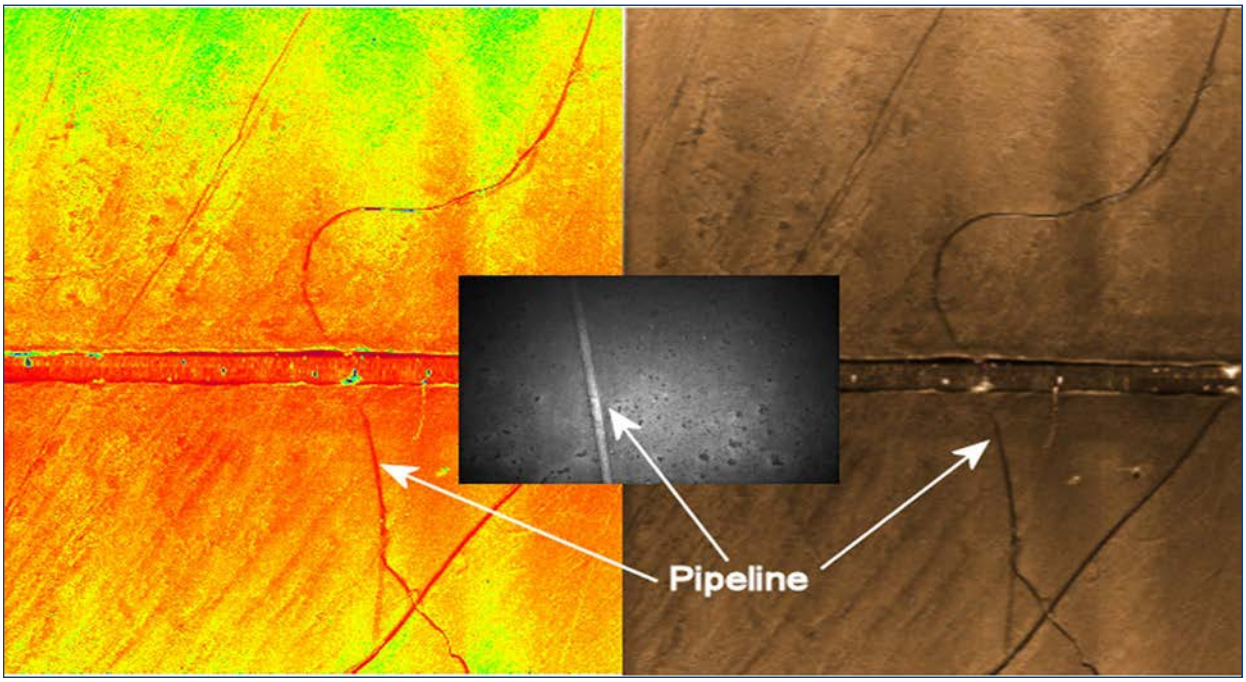
With the expected shutdown of 75 oil platforms in the Campos Basin in southeast Brazil in the next several years, a pilot project was conducted from summer 2016 to 2017 to test a new approach using sonar techniques to update the position of all subsea facilities in some priority areas for future decommissioning. Due to the limitations for navigation around oil rigs by conventional survey vessels with towed equipment and the need for high-resolution data (limited when using low-frequency, hull-mounted systems), the use of an AUV platform, instead of an ROV, was the natural choice.

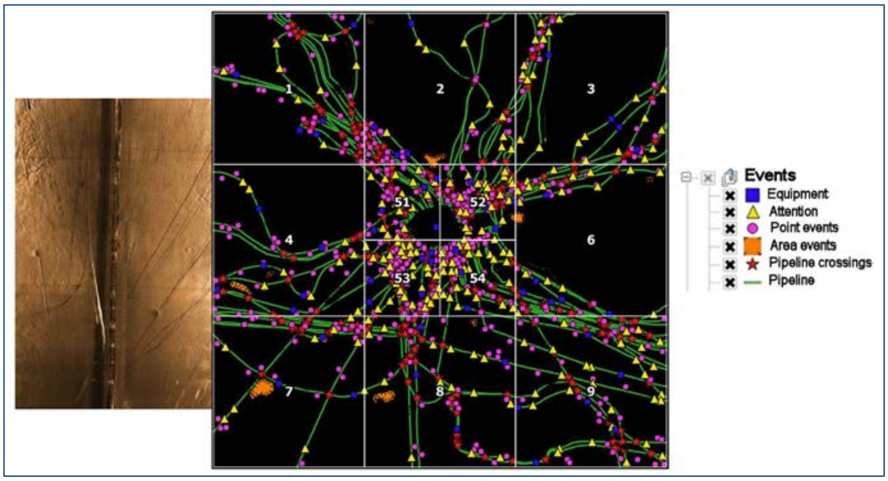
The Kongsberg HUGIN 3000 AUV was equipped with a state-of-the-art suite of imaging systems, including a Kongsberg HISAS 1030, an interferometric synthetic aperture sonar system capable of providing very high-resolution images and detailed bathymetry of the seabed at a speed of 4 kt., with resolution of approximately 3-by-3 cm out to a distance of more than 200 m from both sides of the AUV. Additionally, a Kongsberg EM 2040 multibeam echosounder and a black-and-white still camera with LED lighting were installed on the AUV. The EM 2040 system was used to cover the nadir area with bathymetric data with resolutions up to 4 cm, while the camera was used to take pictures of the subsea structures for inspection purposes.

This project represented a paradigm change in the inspection operations of subsea facilities, and some complications were expected. The first issue was choosing an AUV instead of an ROV as the survey platform. While an ROV operates at an average velocity of 0.5 kt., an AUV can run surveys in speeds up to 4 kt. This positively affects the information acquisition rate, increasing the efficiency and reducing the time to survey a specific area of interest. The second issue was that, using sonar techniques, the information would no longer be "visual" but based on a sonographic mosaic, the quality of which can be affected by environmental and operational factors.



Phases of the survey process.





(Top) Combined view of the interferometric bathymetry, SAS mosaic and photo survey products: interferometric bathymetry (left), synthetic aperture sonar image (right) and photograph (center). (Bottom) SAS mosaic and final product of the mapping.

Concerning data quality, questions emerged such as: How would the noise around the oil rig affect the data; would the resolution of the data be acceptable for the purposes of the project; by using two bathymetric systems simultaneously, what would be the differences in depth between measurements from each system; how would the effects of acoustic positioning impact the resolution of the final results; and what would be the time needed to process the data and generate reliable mosaics that could be effectively used for planning the decommissioning activities?

Survey Process

The survey process can be divided into four interdependent phases: data acquisition, data processing, mapping of subsea structures and planning of decommissioning activities.

Data acquisition comprised gathering bathymetric and sonographic data, as well as photographs of the installations in order to generate 3D high-resolution mosaics of the seafloor and all subsea facilities. This phase is one of the most critical concerning data amount and quality. HISAS and EM 2040 systems alone generate data of approximately 3.5 GB per hour and 2 GB per hour, respectively, resulting in a total of 132 GB every 24 hours of operation. Moreover, each photo (10 megapixels) generates files of 6 MB on average. The amount of photos depends on the number of pipelines within the area, but in general 2,000 photos (with 50 percent overlap) are needed per kilometer of pipeline (i.e., 12 GB/km). In order to achieve the required photo resolution, the acquisition of bathymetric and sonographic data is done separately from the acquisition of the photos. The former is conducted with the AUV 40 m above the seafloor, while the photos are taken with the AUV at an altitude of 6 m above the seafloor.

As in any other hydrographic survey, quality control during data acquisition is extremely important. Procedures regarding QC of bathymetric data, side scan data and subsea positioning should be well-defined and followed in order to assure data quality in accordance with the goals of the project, reducing rework and optimizing ship time. Good-quality data will also positively affect the data-processing time. Another important issue is data management. Because of the huge daily rate of data collection, the organization of the data packages (including security backups) allows a better planning of the processing activities, resulting in more precise delivery time for the final products.

The data-processing phase involves processing bathymetric and sonographic data to generate 3D mosaics, which will be the base for the mapping of the subsea structures in the area. It is important to have a well-defined processing routine. Parallel processing of bathymetric and sonographic data saves time, but integration between the two groups is important to solve ambiguities within the data. The mosaics were generated with 6-cm pixel resolution, allowing practically all kinds of structures to be recognized. As expected, there were differences between the two bathymetries from HISAS and EM 2040. These differences were at the order of 10 to 25 cm and basically observed on the outer-most part of the EM 2040 swath and created some undesirable artifacts on the seafloor. By analyzing the causes of these discrepancies, it was observed that most of them were the result of inappropriate QC procedures for calibration of the systems.

The quality delivered by synthetic aperture sonar is excellent, and using conventional interpretation techniques it is possible to identify pipelines with different diameters, subsea equipment, debris, free spans, overlaying and buried pipelines with good resolution. Small offsets between the pipelines' positions were expected. This is mainly caused by variations in the precision of the underwater acoustic positioning system, which is affected by different factors such as offset angles, timing errors, hydrophone alignment and INS integration. These differences, however, were smaller than 2 m and compatible with the precision of the underwater acoustic positioning system (Kongsberg HiPAP). There is no conclusive evidence that the noise around the platforms has affected the quality of the AUV positioning. However, the geometry between vessel and AUV when operating in shallow water (less than 200 m) can have huge impacts.

Mapping is the most time- and resource-consuming phase. It demands a relatively large team and powerful computers capable of processing large amounts of data. First, all pipelines (rigid and flexible) and cables (water, electrical, etc.) are digitized and individually identified. This is done based on the 3D mosaics generated in the processing phase. The next step is to select the photos located above each of the identified pipelines. In order to speed up the process, some in-house IT solutions based on categorical and numerical attributes were developed. For this specific task, a routine that automatically separates the photos exactly above each mapped pipeline and organizes them in a specific folder was developed. Considering that complex areas may need up to 240,000 photos (or 1.5 TB), this tool alone reduced the required time to validate the photographic coverage of the pipelines from months to hours. At this stage, all pipeline crossings (describing which pipeline is above/below the other), equipment, debris (area or point) and environmental factors (e.g., presence of corals) are mapped and classified. Events that are not clearly identifiable or that may indicate damages on the structure are separated in a different class. These locations are selected for later inspection with ROVs. These tasks are done manually by individual inspection of each photograph. Each event is plotted separately in specific layers on a GIS system that allows the visualization of the events individually or in any combination. The result is a complete inventory of all equipment and structures located on the seafloor. Finally, another computer routine defines the priority sequence for the removal of the pipelines and equipment. This list can be updated after every single pipeline is removed and the removal sequence is revalidated.

With all the products in hand (bathymetry, SAS mosaic and interpretation files), the last phase is the visualization of the data and the planning of the decommissioning operations. The main customers of this information are engineers, ROV operators and project managers. In order to facilitate the understanding of the real conditions on the seafloor, the data are presented in a virtual-reality setting. These environments, traditionally used for visualization of 3D seismic cubes, were adapted for visualization of environmental data based on a GIS platform (ArcScene). Tridimensional visualization is the most advanced and intuitive way to quickly and comprehensively interact with complex data. It assists in understanding problems that require a fuller consideration of facts and circumstances.

Indeed, this is one of the main advantages of using HISAS. It allows 100 percent of the area to be inspected—not only the pipelines—including environmental factors that may affect decommissioning activities, while inspections with ROVs are limited to the visual field of the cameras. Using a 3D visualization environment, it is possible to gather the various stakeholders of the project, favoring interdisciplinarity, helping to clarify the uncertainties and enabling a better definition of the problems.

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The combination of ultrahigh-resolution interferometric bathymetry with synthetic aperture sonar mosaics in a 3D visualization environment defines a change in paradigm for seabed inspections when complex problems are involved. The gain in productivity during acquisition (conservatively estimated at 40 percent) has relevant impacts on the overall project’s budget and deadline. The possibility of analyzing the problems in a more complete way facilitates the planning of future decisions with confidence, reducing the risks associated with decommissioning.

Lessons Learned

The use of an AUV and HISAS has proven to be the best-suited seabed inspection technology for decommissioning projects. The reduction in survey costs allied to a more complete visualization of subsea structures has clear advantages for planning and decision making. However, because of the very high resolution of the data acquired with HISAS, it is critical to have well-established acquisition protocols. As in any other hydrographic survey, the lack of quality control during data acquisition may have severe impact on the processing of the data, increasing time and costs for the project. Low-quality data will have huge impacts on the final results.

This is state-of-the-art technology being used in a new application with enormous business potential. There are some technological and methodological issues that still need to be worked out, and we have yet to master the different aspects of data processing, which, together with data acquisition, is the most critical step of the survey process for decommissioning projects, but the work is underway. **ST**

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