Stabilizing a Toxic WWII Submarine Wreck

Monitoring System Detects Possible Mercury Contamination

By Markus Motz • Thomas Radtke

Seventy-two years after the end of World War II, a large amount of ammunition from the war still dozes in the North and Baltic Seas. For example, toward the end of WWII, a German U-864 submarine was sunk by the British submarine *Venturer* at an outlet of the Bergen Fjord in Norway's waters. The wreck is broken in two major sections, resting at about 150-m depth on a subsea slope. The submarine has had a payload of 67 tons of mercury stored in steel containers. These containers are now failing due to corrosion, creating a high risk of severe mercury contamination into the environment.

After the wreck was rediscovered in 2003, there was an ongoing discussion on how to remedy the situation. Local citizens started an initiative for the removal of the submarine and its toxic load, concerned about the environmental consequences of mercury pollution. Once released into the ocean, the inorganic mercury could become converted to methylmercury by microbes. This form of mercury is even more dangerous than inorganic mercury because if this toxin makes its way into humans, it is transported freely throughout the body, as well as across the blood-brain barrier. It can also be biomagnified in the aquatic food chain and accumulate in fish. For this reason, fishing in the area of this wreck was stopped.

(Top) Deployment of the SB.600 spar buoy carried out by the vessel **Siddis Mariner**. *(Bottom) Deployment of the CSL.1000 seafloor lander.*

After extensive evaluation, the Norwegian Coastal Administration (NCA) in Ålesund, Norway, decided, as a first measure, to stabilize the wreckage by counterfilling the subsea valley upon whose slope the wreck is resting to prevent sliding of the submarine sections and to cover up and prevent further spreading of the potentially contaminated sediment. A corresponding tender was put out for installing the counterfill.

As the rock, gravel and sand dumping was likely to stir up potentially contaminated sediment in the area, extensive environmental monitoring accompanying the work was required. Van Oord of Rotterdam, Netherlands, was selected as the general contractor for the counterfill operation, subcontracting environmental monitoring activities to the Norwegian Institute for Water Research (NIVA) in Oslo, Norway. develogic of Hamburg, Germany, was selected as supplier for the real-time environmental monitoring system. Lead time from ordering the system to delivery of all components was less than four months.

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To meet these monitoring requirements, develogic delivered a turnkey monitoring system measuring sediment load and ocean current at several levels, as well as potential movement and vibration of the submarine hull due to the impact of the materials that make up the counterfill, together with deployment and operation support services.

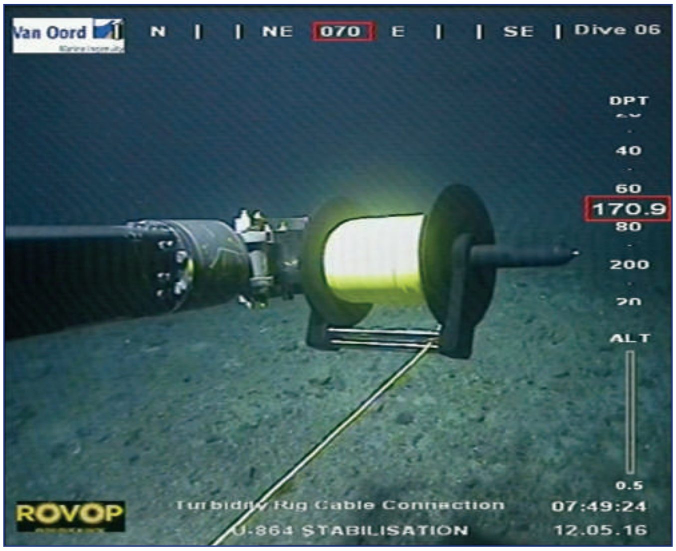
The extensive system included 10 CSL.1000 seafloor landers, one SB.600 telemetry gateway buoy, an MI.Sat II backup buoy, as well as the entire data storage, processing and visualization solution. Real-time data transmission from the seafloor landers was conducted via inductive and acoustic telemetry. Violation of predefined thresholds for sediment load in the ocean current outside of the operation area or detected wreck motion was to cause alert notifications and subsequently interrupt work activities.

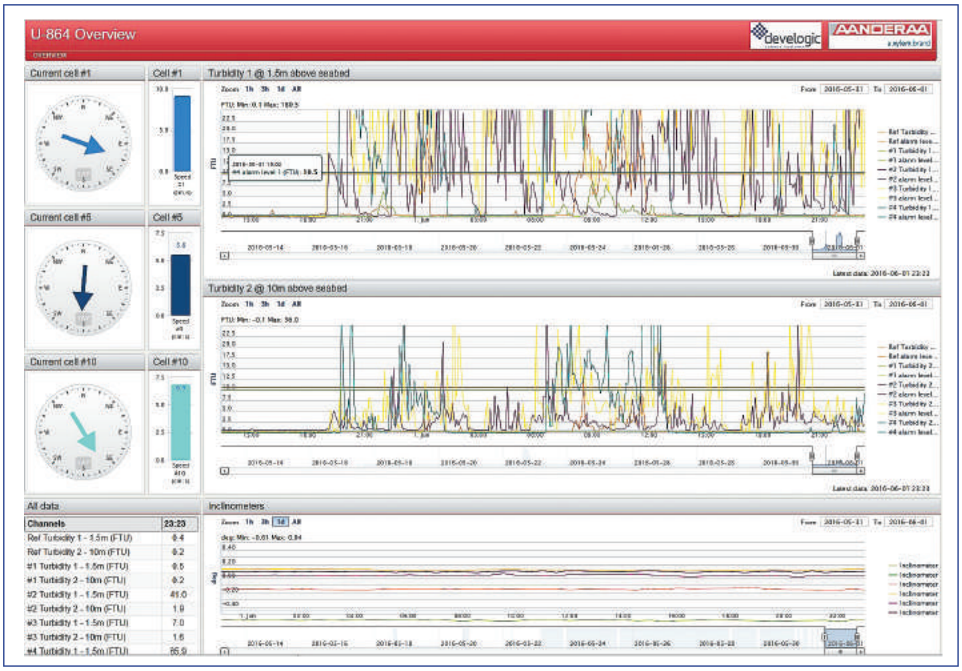
Measurement Platforms

The subsea part of the monitoring system was designed around develogic CSL.1000 compact seafloor landers equipped with inductive and acoustic telemetry integrated into a network together with the surface buoy. These landers are a fully integrated instrument platform with all subsystems necessary for deployment, operation, data transmission and recovery. The key lander systems—data logger and processor, release actuator, satellite beacon, smart power supply, acoustic and inductive modems—are all linked to the communication network with individual addresses. This provides maximum flexibility in system configuration and operation. It is possible, for example, to switch data transmission on the fly from the acoustic to the inductive telemetry, reroute data in case of component dropout or diagnose and reconfigure all systems via the available communication interfaces. This feature is especially useful by enabling the possibility of remote support from the manufacturer via Iridium satellite transponder integrated into the GPS/Iridium beacon.

This platform provides extensive support for sensor integration: Up to eight sensors can be interfaced in the basic version via RS232/422/485 and Ethernet. The power supply voltage to the attached sensors is programmable. High energy capacity of up to 4,400 Wh paired with the low power consumption of the core system allows for extensive deployments up to several years.

As part of the U-864 counterfill monitoring project, acoustic Doppler current profilers for monitoring ocean currents and turbidity sensors were installed on a short mooring at 1.5 and 10 m above the seafloor to measure sediment load at these levels. Multiple inclinometers and shock sensors were attached to the wreck hull. The landers re-





(Top) CSL.1000 seafloor lander prior to linking to the inductive network underwater. (Middle) Laying of the steel wire inductive communication cable by ROV, involving cable reel with contactless connection spike. (Bottom) Web portal with visualization of turbidity, inclinometer and ocean current data.

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layed data via inductive and acoustic communication to the surface telemetry buoy.

Telemetry Gateway Buoy

For relaying the subsea data via satellite, a develogic SB.600 sensor-and-telemetry buoy was selected. This buoy features a spar-type design with 600-mm diameter and an overall length (including mast) of 12 m. Due to the lack of external antennas and cabling and the hermetically sealed design with a pressure rating of 10 bar, it provides maximum robustness under severe conditions. Due to a small buoyancy cross-section, it is very stable in rough seas, minimizing mooring load. The buoy is equipped with multiple communication interfaces, as well as extensive monitoring and safety subsystems.

To address the possibility of damage to external cabling, the subsea acoustic modem is directly integrated into the lower bulkhead. The steel mooring wire acts as a carrier for the inductive telemetry.

An AIS aids-to-navigation (AtoN) transponder, active X/S-band radar reflector, high-intensity navigation light and backup GPS/Iridium beacon provide maximum safety with regard to collision avoidance.

The integrated solar power system with a rechargeable battery capacity of 7,200 Wh, supplemented with redundant hydrogen monitoring and a catalytic conversion safety system, together with the optimized power consumption of the entire setup, is able to support continuous long-term deployments, even in regions with low insolation.

Telemetry Network

The challenge of this project was to design a robust multinode subsea communication network around the operation area that takes minimal installation effort. As counterfilling installation work had to be stopped in case no real-time monitoring data were available and sampling periods were as short as 2 min., the highest communication reliability was mandatory to minimize idle time of the two on-site vessels, *"The challenge of this project was to design a robust multinode subsea communication network around the operation area that takes minimal installation effort."*

one of which contained the materials for the counterfill and the flexible fallpipe to distribute them. With the available expertise in acoustic communication and the ease of deployment of systems with a wireless subsea data link, the choice of acoustic modems was natural. But as it was clear from the beginning that the disturbance resulting from the counterfill rock and sediment dumping would cause high wideband noise levels of unpredictable sound pressure, inductive communication through steel wire was selected as a second means of communication to minimize the risk of downtime.

All seafloor landers and the surface buoy were equipped with develogic HAM.Base acoustic modems, allowing onsite baseline measurements immediately after lander deployment, prior to the start of counterfilling.

During the baseline measurement period, the ring-type inductive network interconnection was made by ROV. Every lander was equipped with an additional inductive modem and an ROV-transportable reel with a capacity of up to 1,300 m of 2-mm coated steel wire cable. The ROV picked up the reel from one lander, laid out the cable while traveling to the next lander's position and made the connection there via a contactless interface. To make an ROV operation for recovery obsolete, the inductive connector was designed so that the reels together with the cable were to be ejected upon triggering the ballast release of the landers.

During the active counterfill installation, data from the seafloor landers connected to the inductive network were relayed via the mooring to the surface gateway buoy. Data from a remote seafloor lander responsible for collecting reference data were transmitted via the acoustic link. Additional landers sampling backup data were installed at a later time, relying solely on acoustic communication with the surface buoy.

Data from the surface buoy was relayed via Iridium satellite communication to servers, with one system located at the NIVA office in Oslo and the other one on board the offshore support vessel.

Measurement data violating the threshold limits caused the transmission of SMS messages to key personnel. In addition, a visible and audible alert was provided, triggering additional water sampling at the location of the threshold violation and later analysis of the mercury load of the collected samples.

Data were visualized and made accessible via a Web portal hosted on the server at NIVA in Oslo.

Results

At the end of June 2016 the project was successfully and safely completed ahead of schedule. The monitoring system reliably provided data throughout the entire counterfill installation. Monitoring and data analysis showed that mercury-contaminated sediment did not spread during the work done to stabilize the wreck.

With this project, develogic has set new standards for large-scale and highly complex underwater communication systems with integrated measuring platforms. The counterfill work reduced the risk of future wreck and sediment movement, including materials contaminated with mercury.

This enables the responsible Norwegian authorities to evaluate and prepare the next steps toward final elimination of contamination risk in the environment. **ST**

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