AUV Operations in Marine Mining

DBM GEOSURVEY is the marine survey arm of De Beers Marine, the worldâ€™s largest marine precious mineral mining company. DBM GEOSURVEY has pioneered the development of geophysical survey systems over the past 20 years to improve mineral resource development and support DBMâ€™s mining activities. Core to this development was the decision to adopt autonomous underwater vehicles (AUVs) as the primary survey platform. We look back on the challenges and successes of 7 years of AUV operations.<P>

One of the key factors crucial to the success in offshore diamond mining and exploration operations is the ability to improve geological understanding of the mineralisation process and to cost-effectively identify mineralised targets. Geophysical imaging constitutes the fundamental framework upon which the entire exploration and resource development process is based. The distribution of diamondiferous sediments on the sea floor is complex and highly variable, and the ability to map these deposits is linked to efficiency and profitability of the mining operation. Geophysical data are also acquired pre-mining for mine planning and optimisation, and post-mining to enable auditing mining-tool effectiveness and environmental impact assessment of mining activities. The majority of offshore diamond mining activity occurs off the west coast of Namibia and South Africa in the middle shelf region (an area 5 to 150km from the coast in water depths from 70 to 200m), and hence this is the area where the majority of geosurvey work is carried out.

Conventional Geophysical Systems

The primary tools for mapping diamond deposits had been side-scan sonar and chirp sub-bottom profiling. Up to 1999, conventional towed systems were used for these surveys; a MacArtney Focus 400 remotely operated towed vehicle, equipped with Klein 5000 side-scan sonar and chirp sub-bottom profiler positioned by long-baseline and ultra-short-baseline acoustic systems was the primary survey tool. It was shown at this point in time that the resolution achievable with these systems was not good enough to accomplish the task required and that a major change was required as the geophysical imagery was not keeping pace with developments in mining and sampling improvements.

Why Use an AUV

A new system was required to take the business forward. Autonomous underwater vehicles (AUVs) were identified as a critical technology. The unique potential of AUVs as survey platforms offered the possibility of higher resolution and higher precision survey and the capability to host new and enhanced geophysical sensors. Improved weather performance and reduced end-of-line manoeuvring would reduce the unit cost of a survey, making higher resolution sea floor mapping economically viable at the level of scale and accuracy required. Critically, the AUV’s ability to fly with tighter line spacing would support the development of higher resolution sub-bottom profiling and the accuracy and stability of flight would make possible high-resolution bathymetry independent of water depth.

Project Goals

In 1999, approval was given to purchase the Maridan 600 AUV. The year 2000 was spent procuring the AUV and equipping the vehicle with customised geophysical systems. The survey vessel was sold and all future operations would take place on charter vessels. The immediate goal of the project was to replicate the survey capability of the conventional towed system using an AUV and to develop the operational ability to support this new approach to survey with the longer-term goal of delivering new sensors and mapping systems.

Payload Systems

The project team responsible for the acquisition of the AUV was split into an operations team and a research and development team. The R&D team was tasked with specifying and acquiring the geophysical payload of sensors and improving the resolution of data from the AUV, specifically with the development of an AUV-based 3D chirp sub-bottom profiler system. The initial payload was comprised of a dual-frequency Klein side-scan sonar, SRD seafloor visualisation system (SVS) swath bathymetry and chirp sub-bottom profiling system. Key challenges included the selection of low power consumption and level of complexity, and integration risk. From the first days of operations, the benefits of AUV survey could be seen in the quality of data acquired and the ease of processing to produce high-resolution maps. Today, the 3D sub-bottom profiling system and video systems deliver unprecedented resolution mapping of the sea floor with continuous 3D volumes of seismic data and full coverage video mosaics whilst high-resolution flawless bathymetry charts are routinely acquired using both RESON and SRD SVS sonars.

Operations and Control Systems

Meanwhile, the operations team worked together with the AUV manufacturer Maridan to ensure that the AUV was equipped with safety systems to minimise operational risk. The launch and recovery system was designed and implemented to be capable of operating in the storm-dominated Namibian and South African waters up to sea state 5. Operations containers were designed and fitted out to our specifications. The operations team worked on process and procedure to minimise risk during all phases of the operation cycle from mobilisation onto a vessel through pre-launch mission planning and tests to deployment of the AUV and safe recovery.

Positioning Systems

The requirement for high-resolution site investigations and anticipation of the need for tight line spacing survey and very accurate control led to the development of the world’s first synthetic long-baseline navigation system for the vehicles. This capability saw the fusion of high-resolution inertial systems with the use of a single long-baseline acoustic positioning transponder to build repeatable, high absolute resolution, high rate positioning control.

The Survey Model

The AUVs are operated in fully autonomous mode, meaning that they are pre-programmed with a survey plan detailing all working parameters, flight path, survey altitude and sensor settings. The AUV is launched and is controlled on the surface by remote control and once the instruction to execute the plan is given the AUV assumes control and the mission commences. During the mission, the AUV transmits basic diagnostic information regarding its status via the acoustic modem link or via radio if on the surface but bandwidth limits the quantity of data. Each payload and component system is responsible for its own health monitoring and reporting. The AUV responds to status information provided automatically. The AUV has a sophisticated error-monitoring capability and is programmed to respond to various circumstances dependent on severity. Limited interaction with the AUV is possible; for example, it is possible to stop the current survey plan and send a new survey plan to the AUV whilst underwater via an acoustic modem link and then run this new plan. In the case of an emergency, the AUV can drop a ballast weight making the vehicle very positively buoyant and forcing it to the surface. Once on the surface, the AUV makes use of its flashing lights, a long-range very-high-frequency radio direction finder, ARGOS satellite monitoring, data radio and an acoustic pinger to ensure safe and fast location and recovery.

The Development of AUV Operations

In the early days of AUV operations, the reliability of the AUV was poor and over a year period only achieved approximately 40% availability. Because of the reliability of the AUV, operations were limited to daylight hours only. As availability moved past the 65% mark, operations were expanded to night-time deployments. Recoveries were still considered too risky to do at night. In 2002, the AUV underwent a major overhaul. The major shortcomings of the AUV and supporting systems that had been identified based on operational experience were addressed in a joint project with Maridan. The launch and recovery system (LARS), which had been purpose-built for this application to support operations from a low-spec vessel of opportunity, was also upgraded to improve the level of articulation and control giving improved weather performance and improved operational flexibility.

24-Hour Operations

After this intervention, the sustained availability improved to over 90%, and reliable and robust operations with the AUV were the order of the day. For the first time, the operation of an AUV could be analysed for efficiency and improvements could be introduced based on consistent performance. The improved reliability of the AUV coupled with the improved control of the LARS enabled operations to be fully extended to 24 hours. A survey cycle was 10 hours (6 hours dive time and a 4-hour recharge time). Line kilometres per dive were approximately 30km and an area of 0.8 by 0.8km could be mapped per dive. The team size was six (a party chief, two surveyors, two engineers and a data processor). All data were processed and verified directly after the dive so that any bad data could be re-run.

Dual AUV Operations

In 2006, the 3D chirp sub-bottom profiler system came online and, due to the need for closer line spacing, the work programme demanded more resource and efficiency. A second Maridan AUV was purchased to double the production. At almost the same time, the AUV cycle time was increased to 17 hours (13.5 hours dive time and a 3.5-hour recharge time) with the introduction of polymer lithium batteries and upgrades to the power control and propulsion systems. Due to the fully autonomous capability of the Maridan AUVs, the two submarines are deployed simultaneously, so production from one survey vessel is doubled. Only one launch and recovery system is required and the team is enlarged to nine (a party chief, two surveyors, four engineers and two processors).

AUV Capabilities Today

In 2D mode at 25-m line spacing, an area of 1.5 square kilometres can be mapped per cycle. In 3D mode at 2.5-m line spacing, an area of 0.16 square kilometres can be mapped per dive (0.4 by 0.4km). Each submarine completes approximately 65 line kilometres per dive. As our efficiency improves, total line kilometres per day of production are fast approaching 200km. The processing team of two produces a bathymetric digital terrain model, side-scan sonar mosaic and a seismic project with processed SegY data within 8 hours of the dive data being received by them. The bathymetry data have a resolution of 30 by 30 by 2cm in Z. The side-scan has a resolution of 20cm along and across track, and the 3D chirp sub-bottom resolution is 30 by 30 by 4cm in Z.

For the first time, production from an AUV operation has exceeded that from a conventionally deployed system. This same production rate has allowed us to complete the work programme in a much shorter period, allowing us to look at the international market to evaluate if the spare capacity can be taken up by another market sector.

Containerised AUV Operations

The survey equipment is containerised. Mobilisation of the charter vessel is undertaken in one day while demobilisation is completed in 6 hours. The AUVs and systems including the launch and recovery system have been flown to England for a survey campaign. Depending on the host vessel and facilities, it is possible to be mobilised in a foreign port within 48 hours.

As a result of the continued improvement in the AUVs and the growth of our operations experience coupled with the newly developed payload systems, we now have robust reliable survey systems capable of very high rates of survey routinely delivering very-high-resolution geophysical maps of the sea floor with quality and resolution independent of weather and water depth. This steep change in data resolution and quality has delivered major benefits to diamond mining operations, improving both the development of mineral resources and mining efficiency.