With the rich prize of offshore minerals and hydrocarbons, maritime nations are increasingly seeking to accurately define their boundaries under the 1983 UN Convention on the Law of the Sea. The techniques call for a multidisciplinary team with a range of sensors and systems at their disposal the authors argue.

UNCLOS Surveys: an expert team with integrated specialised tools

By Dr Jerry C Wilson, Edward Saade and Prof C. D. Green

Definition of seaward national boundaries under UNCLOS requires a team including marine geodesists, surveyors, geologists/-geophysicists and supporting technical specialists. Boundary determination has always been the provenance of surveyors, and national- or global-scale definitions require experienced geodesists. Geologists are called upon under UNCLOS to interpret and define seafloor conditions such as geomorphology, crustal types and limits, and sedimentary prisms. For this the geologist utilises geophysical measurements of seismic reflection/refraction and velocities, magnetics and gravity, as well as high-resolution bathymetry.

In order for the expert team to provide the client country with the best results and most advantageous outcome, the team must utilise a suite of state-of-the-art tools. These tools are best integrated on a single specialised vessel dedicated to UNCLOS surveying. An example of such a vessel is the *R/V Thales Venturer*.

The vessel was originally designed for seismic survey – an important part of UNCLOS surveying – an excellent starting platform from which to build an integrated survey vessel. The additional essential capabilities include full ocean-depth swath bathymetric systems, gravity and magnetics, plus onboard charting and interpretive facilities. The latter provide for survey adjustments as discoveries are made.

The importance of marine surveyors is directly linked to the fact that none of these data types are of value unless precisely positioned. Thales' SkyFix system is a proven worldwide open-ocean navigation service which is ideal for UNCLOS applications.

Technical Requirements

By its very definition the Law of the Sea rules for determining jurisdiction beyond 200 nautical miles calls for integrated procedures. All aspects depend upon surveying principles of both the land (e.g. metes & bounds) and hydrographic surveyors' practices. The basis of all UNCLOS references is the coast baseline. Since coastlines change with landmass movement (earthquakes, isostatic rebound, continental drift, etc), erosion, deposition, and other geological processes, it is possible that the fundamental basis for UNCLOS surveying may need to be verified or re-established. These baselines are a direct function of a tidal datum such as Lowest Astronomical Tide, which may also be updated with a new series of tidal records. But the more significant differences in states' seaward boundaries will depend upon deepwater seafloor conditions. In terms of the Law of the Sea these conditions are defined by two categories of seafloor survey data:

1. Bathymetry and geomorphology

a. Bathymetric data are required first to define the 2500m isobath. This contour provides the reference for an offshore baseline, which contributes to the definition of the outermost "cut-off" line, or maximum possible extension of states' seaward jurisdiction. Adding an offset line 100nm seaward of the 2500m isobath develops this component of the "cut-off" line. The other component is a line 350nm from the coastal baseline; it is notable that bathymetry may allow jurisdiction even beyond the 350nm maximum.

b. Geomorphology interpreted from the bathymetric database is used to define the location of the foot of the continental slope. To this offshore reference line is added a 60nm offset line, which defines an extension of jurisdiction based on geomorphology.

2. Geology, including sediment thickness, seismic data and crustal conditions

a. Seismic data can be used for definition of offshore points beyond the foot of the continental slope that mark the extent of the continental sedimentary wedge over oceanic crust where its

From the UN Convention on the Law of the Sea, UNCLOS:

"For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either: (i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope; or (ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope. . ."

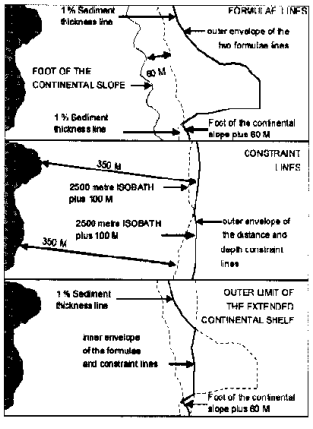

Figure 1. UNCLOS boundary definitions and data types/requirements (isobath/bathymetry, sediment thickness/seismic)

thickness is 1% of the distance from the foot of the slope.

b. These interpreted data points must be separated by no more than 60nm.

Key UNCLOS data requirements include geodesy, geophysical, hydrography and geology. These are merged with knowledge of Law of Sea and geomorphology and structural geology and geophysics, to determine whether an extended boundary claim is justifiable. Other data types include seismic refraction using sonobuoys or OBS units, magnetics and gravity. The relationships of these UNCLOS boundary definitions and the data required are illustrated in Figure 1.

Equipment and Processes

From these UNCLOS requirements the importance of detailed deepwater bathymetry and subsurface geological information is evident. These parameters interact to provide definition of the maximum jurisdiction for coastal states. While the 2500m contour and foot of slope may be derived from a single bathymetric profile, it is clear that multibeam echosounding offers powerful benefits to the applicant state. The deep sea terrain can be as complex as the land and this knowledge provides a better basis for definition of these two important offshore baselines.

Seismic data are the most reliable means for a country to assure itself that the best definition of the extent of its continental geology has been achieved. For UNCLOS, the style of marine seismic data acquisition is more similar to global crustal studies than to the more common exploration seismic configurations. The UNCLOS definitions do not require full 3D seismic techniques, however short-offset 3D may prove economically beneficial in some geological settings. In addition to 2D seismic reflection, other seismic and geophysical data which are used include long offset reflection, refraction using sonobuoys or OBS, marine magnetics and gravity data acquisition.

A dedicated UNCLOS vessel

Thales Venturer was built in Norway in 1986, where she enjoyed an excellent reputation in her previous role as a seismic survey vessel. At 89 metres in length the vessel, seen in Figure 2, offers greater sea-keeping ability, thus reducing weather risks. The Thales Venturer is maintained to DNV classification at the highest standards. Accommodation onboard is of a very high standard and there are 40 single cabins with ensuite facilities.

The vessel is powered by 3 × 2255 hp Rolls-Royce engines, which enable it to reach a top speed of 15 knots. Propulsion is via dual-pitch propellers driven directly, or by diesel electric motors. All the vessel's main equipment is flexibly mounted, reducing vibration and noise generation.

Navigation signals are from Thales GeoSolutions' SkyFix Premier service, which has been introduced to mitigate the effects of ionospheric disturbances on DGPS performance brought about by the increased activity of the ionosphere. It offers a performance improvement by using dual-frequency DGPS systems at both the reference station and the user end. This allows for 'iono-free' DGPS positions to be derived, which are consistent and unbiased around the clock.

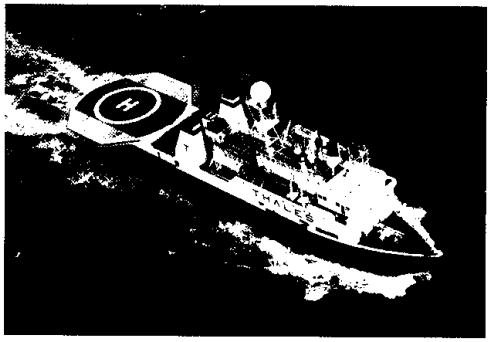

Figure 2. Thales Venturer

At the heart of the bathymetric survey instrumentation is SeaFalcon 11, a new generation multibeam echo sounder, which provides accurate mapping and unequalled coverage of the seabed at depths to 11,000m. The SeaFalcon 11 operates at a central frequency of 12 kHz and features simultaneous transmission of five fore-aft multibeams (see Figure 3) comprising 400 cross-track measurements each for a total of 2000 per pulse. This unique technology results in higher data densities, which can allow faster survey speeds. The SeaFalcon system includes a hull-mounted narrow beam sub-bottom profiler, which is fully heave compensated.

The five simultaneous multibeams analyse, at the same time, distinct adjacent ensonified areas. Each acoustic beam is steered in specific directions separated by adequate intervals. The sector covered by this principle is five times the conventional sector. This suppresses seabed gaps due to the ship's motion and provides higher operating speeds. Importantly for UNCLOS applications in deep water, this compensates for the longer time-of-flight through the water column.

The SeaFalcon also produces imagery of the sea floor. The reflected energy from the seabed depends on morphology and sea bottom type. The five sets of acoustic returns are used to create an image mosaic where redundancy due to over-sampling provides improvement of image quality by speckle reduction and full seabed coverage.

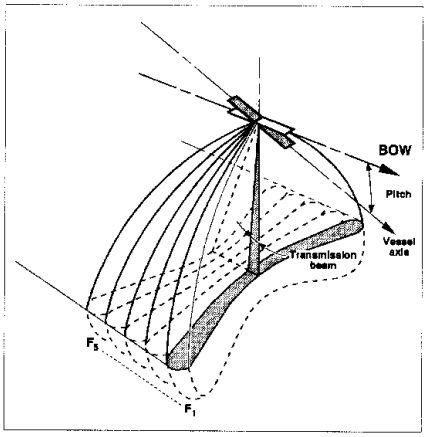

Figure 3. SeaFalcon's simultaneous transmission of five fore-aft multibeams for deepwater data density.

Another major quality of the SeaFalcon is the high-resolution, narrow beam width of the acoustic beams for sub-bottom profiling. This is based on the use of the crossbeam technique providing a narrow footprint. Classical sub-bottom profilers generate a 30° beam width that needs high ping rates for integration. Narrow beams improve the sub-bottom

Figure 4. Components of Thales Venturer's specialised array for crustal investigations.

analysis by suppressing artefacts or interference between seabed backscattered first layer signals and the sub-bottom layers. This valuable additional data provides augmentation for the interpretation of seafloor imagery by adding information in the vertical.

While generally not indicated for UNCLOS surveying, Thales Venturer also offers towfish positioning using Posidonia, an Ultra Short Base Line (USBL) hydro-acoustic positioning system capable of providing positioning over a wide area down to 6,000 metres in noisy environments.

Thales Venturer is rigged with a full 2D multichannel seismic acquisition package, specifically designed with the optimal source and receiver configuration to maximise the collection of deep-seismic data. The system is designed to provide penetration to the base of the continental crust for academic and territorial boundary investigations. The specialised array for deep-crust investigations is configured as two subarrays, each with two strings. This 5,200 cubic inch high-energy array provides a very broad frequency seismic energy source, rich in low frequencies. The array was designed with a number of requirements:

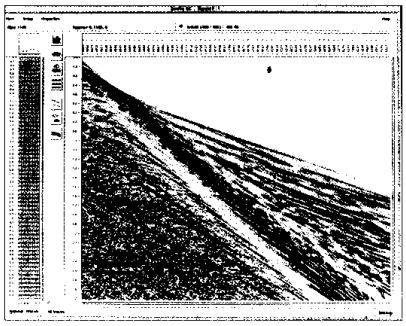

Figure 5. Sercel seismic data quality control screen

- proven and industry accepted Bolt Air Guns,
- >5000 cu.in to achieve >100 b/m (128Hz/70db filter) or >150b/m (256Hz /70db/octave filter).
- Broad spectrum, rich in low frequencies with significant energy below 10Hz.
- Re-configurable to provide a high quality source for exploration 2D and 3D seismology to cope with varying targets and differing geology.

Figure 6. Thales Venturer data processing and charting room.

The deep-penetration array components on the gun deck are shown in Figure 4. The system is supported by eight Hamworthy air compressors providing in excess of 3200 cfm at 2000psi.

Thales Venturer's marine seismic acquisition system is the Sercel Seal system, one of the very latest and most advanced available. The Seal System is the result of 30 years of streamer manufacturing experience and 40 years of development of acquisition systems, gaining improvements through flexibility in their architecture, higher integration of electronics, lower power consumption and higher reliability. An example of the data quality screen is shown in Figure 5.

With ever-compressed delivery schedules and the benefit of in-field adjustments to survey plans and coverage, it is essential that survey reports and charting be created offshore in near real-time. To facilitate efficient processing of this data, the vessel boasts a 180 square-metre instrument room, as seen in Figure 6. In addition to the real-time Quality Control of the acquisition data stream from Sercel, the Thales Venturer is equipped with a ProMax seismic data-processing workstation. ProMax operators are part of the crew and can undertake a QC processing sequence, including brute stacks, as directed by the state representatives on board.

With a high-speed data link to enable transmission of key tests and data examples to shore, the vessel uses Seispact compression software (enabling compression ratios of up to 20:1) to facilitate transmission of QC data samples to shore.

Conclusions

A specialist UNCLOS team includes hydrographers, geodesists, geophysicists and geologists. Each specialist has a task inter-linked with the others. Each requires a different data acquisition plan, which may change during the course of a survey campaign. Further, the various specialist tasks must be integrated with the others' into a result that yields a solid submittal for the State.

A survey vessel with the facilities of the Thales Venturer provides the means for the whole UNCLOS team – specialists and state representatives – to work comfortably together on data products with results in near real time. Further, this favourable arrangement allows for modification to the survey plan as discoveries are made. GW

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