

Simulation Training for Replenishment at Sea (RAS) Operations: Addressing the Unique Problems of 'Close-Alongside' and 'In-line' Support for Multi-Streamer Seismic Survey Vessels Underway

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ABSTRACT: Modern seismic survey vessels in 'production', may tow twelve or more streamers, each of which can be six to eight kilometres long. Together with associated paravanes, tail-buoys and acoustic 'guns', the streamer spread width of such wide-tow configurations can extend to 1200 metres. The physical deployment and recovery of such an extensive array is time-consuming and expensive. The entire survey operation requires the constant attendance of a suitable offshore support vessel (OSV) to act in the role of 'chase vessel', but more critically, to provide close replenishment support underway and, when required, rapid emergency towing assistance.

While naval crews rightly claim a near monopoly on the skills-set necessary for underway replenishment, the naval RAS exercise almost never involves the supply and receiving vessels engaging 'close-alongside'. The seismic/OSV replenishment operation, on the other hand, frequently necessitates such a demanding and stressful manoeuvre. This paper presents a training solution involving the use of a 360° full-mission bridge simulator.

1 SUPPORTING A 3D MULTI-STREAMER SEISMIC SURVEY OPERATION

1.1 *Seismic Vessel Capabilities*

Modern seismic survey operations are a far cry from the days of relatively small modified vessels towing a lone streamer or two that could be set and recovered in a few hours. Today, the seismic fleet is dominated by larger purpose-built vessels, though there are still many vessels in service, converted from other roles and designations. Modern seismic arrays typically comprise 12 streamers, possibly extending up to 8000 meters astern of the mother vessel, and measuring a swept path of 1200 meters across the ship's track. The very latest vessels now leaving the building yards have towing points for up to twenty such streamers. Such extensive equipment is capable of yielding a 3D seismic picture of great fidelity.

1.2 *The Seismic Survey Concept*

Seismic surveys are carried out extensively in ocean and offshore areas with a known potential for reserves of oil and gas in the sub-sea rock formations. The seismic survey vessel tows the steamer array suspended below the surface, carrying hydrophones. Sound waves are transmitted from the vessel using compressed air guns which travel down through the seabed and reflect back from the different layers of rock (Figure 1). These reflected sound waves are received by the hydrophones located along the seismic streamers which, when processed, gives a three dimensional picture of the substrata.

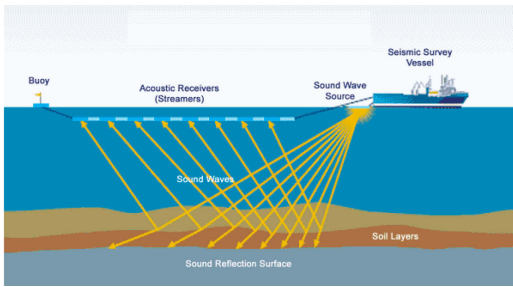


Fig. 1. Marine Seismic Survey

Seismic survey vessels ‘in production’ show the shapes and lights for a vessel restricted in its ability to manoeuvre. The streamer cables are spread by divers/paravanes, similar in function to that of mid-water trawl doors, and can extend to 1200 metres in width. The end of each streamer is marked by a tail-buoy carrying radar reflector and flashing lights.

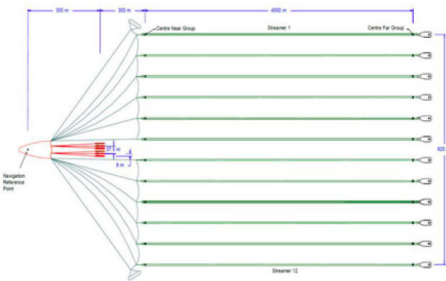


Fig. 2. A 12-streamer 3D Seismic Array

Seismic survey vessels tow at a speed of 4 to 5 knots and need to be on a straight line whilst surveying and are almost invariably accompanied by a ‘Chase Boat’ to police the immediate task vicinity and to assist in notifying other vessels of the seismic operation. Survey areas vary greatly in size and may cover extensive areas of the sea surface.

1.3 The need for a support vessel

It will be readily appreciated that the 3D multi-streamer seismic array described above is not something that could be deployed or recovered in a few hours: it is typically a two-day task, and perhaps longer. This means that once the survey operation has started and reached full production, significant interruption or suspension of the work is unlikely except for very pressing circumstances. A further consequence of that imperative is that the seismic ship must be supported and replenished under way, as the operational situation demands. An offshore supply vessel (OSV), suitably modified for the purpose, is the solution of choice for most seismic operators. And when not directly engaged on support and replenishment duties, the same OSV serves in the ‘chase boat’ capacity.

1.4 The support vessel ‘close alongside’

The support vessel must replenish the seismic ‘mother’ ship with fuel and machinery consumables, primarily, but also with victuals and catering stores, and all other general and technical stores necessary for uninterrupted seismic production. And from time to time the support vessel will be required to ferry and transfer personnel to and from the mother vessel, as when crew rotation is scheduled. These transfer operations (fuel, stores, personnel) are most often effected with the support vessel ‘close alongside’ the mother ship.

1.5 The support vessel ‘in-line’

In other circumstances, and for various reasons, the support vessel may not be able to transfer fuel from a ‘close alongside’ position, in which case she will have to take station ‘in-line’ ahead of the mother ship. This demanding manoeuvre requires the support vessel to make a close approach ‘in-line’ ahead and bringing her transom to about 40 metres from the mother ship’s bow, passing a shot line and messenger, then opening the distance between the two ships to 90 metres — a separation maintained by a heavy distance line — before passing the fuel line. The support vessel will now have the challenging task of maintaining her station for perhaps the coming six hours, until refueling is completed.

1.6 Readiness to offer an emergency tow

The support vessel will have one other major assignment in executing her close support role: to provide an emergency towing capability to the seismic vessel in the event of her suffering a serious propulsion failure. The consequences of such a power failure on the mother ship mean a very rapid loss of speed, caused by the drag of the paravane/streamer array. However, the inertia of this same array will ensure that its loss of speed is not as rapid as that of the mother ship.

1.7 Short time window

If forward motion is not restored to the mother ship she is in danger of becoming entangled and ensnared in her own gear — an expensive ‘seismic spaghetti’ of streamers, buoys, paravanes and towing lines. In such an emergency, the support vessel has a time window of perhaps 15 minutes (maximum) in which to make a close approach and connect up the emergency towline.

1.8 Immediate priority

The immediate priority for the support vessel is to get the stricken mother ship moving again, along the

original path and away from the entanglement danger of her gear. Even one knot, or less, will achieve this and buy the time necessary to restore power on the seismic vessel.

2 SIMULATOR REQUIREMENTS

2.1 *The needs of the industry*

The initial request to develop a suitable simulation training programme for such unusual and unique replenishment-at-sea (RAS) manoeuvres came from a local offshore operator, Mainport Group, Cork. In late 2005, they won a contract from the French seismic operator, CGG (now CGGVeritas), to provide a seismic support vessel for operations in the Indian Ocean — and they needed simulator-based training for their crews. For the project, the 360° main bridge (full-mission) simulator at the National Maritime College of Ireland (NMCI) was utilized.

Subsequently, Mainport added four similar vessels (OSVs) to their seismic support division, working for CGGVeritas and other seismic operators. Then in late 2009, CGGVeritas agreed with NMCI, a similar bespoke training programme for their seismic ship masters and mates, paired with their matching support vessel counterparts.

2.2 *Kongsberg full-mission simulators at NMCI*

The Kongsberg full-mission bridge simulators at NMCI are specifically designed for complex ship-handling manoeuvres and advanced navigation exercises. All important navigation and manoeuvring data are presented to the conning officer on the bridge via a comprehensive array of statutory (SOLAS) instruments and displays.

By configuring the 360° simulator with an accurately compiled ship model having realistic hydrodynamic characteristics, the high-end simulator generates a ship-manoeuving environment of impressive fidelity. In this respect, the NMCI full-mission simulators are rated world-class, and the entire simulation centre is ranked amongst the best such facilities anywhere.

2.3 *Realistic ‘ownship’ behaviour*

In the simulated environment, the behaviour and response of the visual ‘ownship’ model to the engine, rudder and interaction forces and to the environmental conditions, is governed by a matching mathematical ship manoeuvring model. The model must behave in such a way that the position, heading, velocity and swept path of the ‘ownship’ are always representative of real ship behaviour.

2.4 *The necessity for a 360° simulator*

The panoramic visuals of a 360° simulator are an essential feature of any training exercise attempting to simulate the fidelity of a replenishment-at-sea operation. This constraint is self-evident for towing and ‘in-line’ RAS evolutions, where the support vessel master needs to have an unrestricted view astern. But it is equally valid in the ‘close aboard’ approach (support vessel approaching the mother ship beam-on) where the full broadside view is just as necessary.

2.5 *‘Ownship’ and ‘target’ models*

The ‘ownship’ model used as the simulated support vessel was the Kongsberg supply vessel SUPPLY02L, fully dynamic in six degrees of freedom (heave, sway, surge, roll, pitch and yaw), representing all horizontal and vertical motions of the ship. For all RAS exercises the seismic mother ship may be simulated by a generic ‘target’ model, though a dedicated seismic ship ‘target’ model (CGG ALIZE, Figure 3) has recently been developed.



Fig. 3. Seismic Survey Ship CGG ALIZE

3 RAS PREPARATIONS

3.1 *Matrix of permitted operations*

A RAS evolution ‘close alongside’ the seismic ship requires planning, preparation, careful attention to procedure and skilful ship-handling. It is a daylight manoeuvre only, constrained by agreed limits on visibility, wind speed and direction, and sea/swell state — a maximum wind speed of 20 knots and significant wave height of 1.5 metres are the usual upper limits of acceptable conditions. Weather limitations and other restrictions for RAS and the wide variety of seismic operations should be promulgated in company manuals — CGGVeritas meets the requirement by publishing a tabulated *Matrix of Permitted Operations*, abbreviated to *MOPO* in their fleet guidelines and procedures. Tool-box meetings on both vessels are essential. Day, time and scope for the RAS transfer having been mutually agreed, either master must have complete discretion to abort

the operation at any time during the approach phase or throughout the transfer.

3.2 RAS speed of 4.5 knots

Before any closing approach manoeuvre is initiated the mother ship must confirm her track, heading and speed, and throughout the RAS approach she must advise the support vessel of any small changes in those parameters — it is a given that any substantial changes should not be contemplated. The necessity of maintaining the operational speed for the streamer array dictates a typical RAS speed of about 4.5 knots.

3.3 Why the beam-to-beam approach?

In the most common type of RAS operation, involving naval formations, the re-supplying fleet tanker becomes the designated formation 'guide' and seeks to maintain her heading within 1° of the signalled replenishment course. And whereas naval vessels positioning for their RAS station will approach the 'guide' from astern or fine on her quarter, such aspect is never an option for a seismic/support RAS; the wide towline controlling the diverter/paravane is angled 45° outwards from the quarters of the seismic ship, which constrains the support vessel's approach to a narrow sector on the mother ship's beam.

3.4 Choice of steering control

The support vessel is likely to assume a standby station about 1000 metres abeam of the seismic ship, on the agreed side. A closer standby station is acceptable, but not if that station is inside the paravane path. There is much debate in the industry on the choice of auto-pilot or manual steering for the support vessel's RAS approach, especially in the latter phase of the manoeuvre when bringing the vessel from the 'close aboard' station (about 30–50 metres abeam) to the 'close alongside' position.

3.5 The case for auto-pilot control

The reality of small crews means that a skilled helmsman is unlikely to be available, particularly at a time of peak demand when all available crew are needed on deck. Also, given the widespread lack of opportunity for manual steering in commercial shipping there is deep concern within the industry that the manual steering skills of seamen, generally, are inadequate. Neither is it acceptable that the master should manually steer his ship in the final approach; he already has sufficient demands on his judgement, watching his speed, avoiding the wide tow wires and other overhangs and obstructions on the mother ship, controlling inter-ship and intra-ship communications, and, most critically, the ever-constant eye for

interaction effects. In the circumstances, the case for using the auto-pilot is compelling, and no less compelling is the need to ensure that such equipment is fully serviced and totally reliable.

4 APPROACH AND DISENGAGEMENT

4.1 Safe convergence

In commencing her approach from the stand-by station, the support vessel must steer an inward convergent course (towards the mother ship) by about 20°, and increase speed so as to avoid increasing the aspect angle with the attendant risk of fouling the paravane tow wire. For instance, if the base course and speed (survey track) is 120° x 4.5 kn, a starboard-side approach will require the support vessel to steer 100° and set her speed at 4.8 kn. If the convergent angle were 30°, an approach speed of 5.2 kn would be necessary to maintain the same 90° aspect. A useful visual guide for the support vessel master is to keep the seismic ship's bridge-front in view: if, during the approach, an increased aspect angle leads to the loss of that view the support vessel has fallen abaft the optimum approach line, and runs the risk of fouling the wide tow wire.

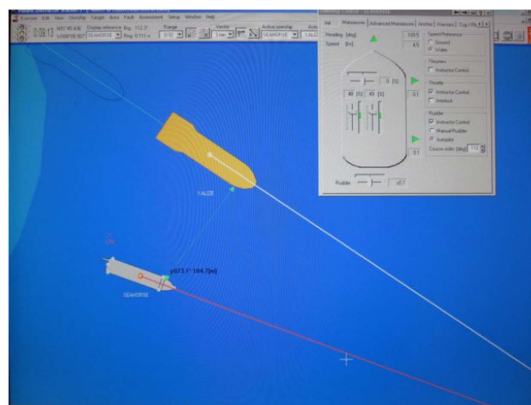


Fig. 4. Support vessel converging on mother ship

4.2 Reducing the convergent angle

As the support vessel closes the mother ship the convergent angle must be reduced (Figure 4). When the lateral distance between the ships is down to 100 metres the convergent angle should not exceed 10°, and at the same time the support vessel will need to trim back her speed; as the courses approach coincidence so too should the speeds of both ships.

4.3 Suspend and reappraise

The 100 metre mark is a good position at which the support vessel should temporarily suspend the convergent manoeuvre. This will allow the masters of both vessel the opportunity to reappraise the situation and to reassure each other that all checklist parameters for a safe RAS operation remain valid.



Fig. 5. Both vessels confirm willingness to proceed

4.4 Coming into position 'close alongside'

If there is no reason to abort the evolution the support vessel should resume the convergent course (Figure 5). Ten degrees convergence is still acceptable, but this should be gradually reduced so that as the support vessel arrives in the 'close aboard' station, 50 metres from the mother vessel, the convergence should not exceed 5°. In the final phase of the manoeuvre, from 'close aboard' to 'close alongside' the convergent angle must be reduced further so that when contact is made on the yokohama-fenders the convergence is 2° or less. In reality, when the ships are 10–15 metres apart there is usually little need for any convergent angle because the dominant interactive force between the ships at this stage is most likely to be that of attraction.



Fig. 6. 'Close alongside' replenishment station

4.5 Avoiding simulation 'freeze'

In the normal course of simulation exercises the intuitive simulator response to the 'ownship' model making contact with a 'target' vessel at close quarters is to signal a collision condition, at which point the exercise functions freeze and the simulator must be reset. In the RAS simulation the same outcome is evident when the support vessel (as the ownship) makes heavy contact with the mother ship, such as when the convergent angle is too large or when her position alongside is so far aft that she strikes the protruding sponson structure. On the other hand, if the contact force between the ships is gentle and correctly positioned, as when there is little or no con-

vergent angle, the simulation exercise will continue without interruption (Figure 6).

4.6 Critical securing lines only

Once the support vessel, properly fendered, is safely alongside the mother ship the agreed securing/mooring lines must be rigged. These usually consist of a for'd breast-line and two fore-springs – lines connected from the forepart of the support vessel only. Bearing in mind the formation speed of 4-5 knots, it is never acceptable to have any securing lines connected to the after-part of the vessel.

4.7 Favourable disengagement

When fuel and stores transfer is completed the support vessel must prepare to disengage and clear away from the seismic vessel — all before the onset of darkness. On some seismic/support vessel combinations the vessels will separate and diverge under the favourable effect of hydro-dynamic interaction, as soon as the securing lines are released. But in many cases, this will not happen.

4.8 Adverse interaction effects

Where the adverse interaction effects are dominant, the force of attraction between the ships will restrain the support vessel in the 'close alongside' position. Any attempt by the support vessel to clear the side of the mother ship by increasing speed and using outward helm will fail because it is not possible to steer away in these circumstances. If the attempted manoeuvre is allowed to continue, the outcome illustrated in Figures 7 and 8 is inevitable; the support vessel will move forward, all the while restrained against the side of the seismic ship, until the critically adverse interaction effect becomes manifest. This is the 'bow-in' turning moment that will cause the support vessel, despite carrying outward helm, to turn across the bow of the mother ship. Averting disaster at this point is in the hands of the seismic master, who must take all way off the vessel instantly.

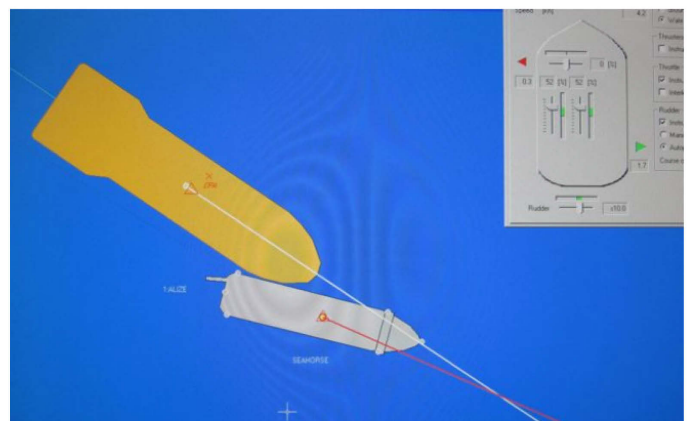


Fig. 7. Critical interaction effect



Fig. 8. Imminent risk of capsizing

4.9 Using thruster and inboard helm to overcome adverse interaction effects

Where, as described above, interaction effects prevent the support vessel from steering directly on a divergent course from the 'close alongside' position she must first use her bow thruster to open out a divergent angle. As this angle increases the master will need to increase speed and apply 5° inboard helm (to keep the transom clear of the side of the seismic vessel). How long to keep the inboard helm applied is a judgment call, but it should not be maintained if its turning force threatens to overcome the outward rate-of-turn from the bow thruster. Once the support vessel is 10–15 metres clear of the mother ship and has a divergent heading of about 10° she has the manoeuvring freedom to steam clear away with little risk of exposure to any further adverse interaction effect.

5 TOWING

5.1 'In-line' RAS station

In the circumstances where the support vessel is unable to transfer fuel from the 'close alongside' position, she will have to take station 'in-line' ahead of the seismic ship. This manoeuvre requires the support vessel to make a similar approach to the 'close aboard' station, as described above, and then increase speed while holding a convergent course. The objective is to pass within 50 metres of the mother ship so as to take temporary station 'in-line' ahead of her, with about 40 metres separation between her transom and the mother ship's bow. This close proximity facilitates the exchange of a shot line, messenger and 'distance line'. The distance line is of hawser-like quality and is used to maintain a near-constant distance of about 90 metres between the two ships. Once the heavy distance line is established and lightly tensioned, the fuel transfer line is then rigged between the ships. The support vessel must now settle into the stressful role of constant vigilance in seeking to maintain her station for perhaps the coming six hours, until refueling is completed.

5.2 Towing exercise requires second simulator

The simulation of an emergency tow scenario requires a different arrangement of simulators and models. While a tow-line may be assigned and controlled from the support vessel 'ownship' it is only possible to connect it to another 'ownship', which, in turn, must be assigned to another simulator. A further problem arises in the simulation exercise when attempting to achieve towing fidelity. An actual support vessel confronted with an emergency tow scenario will need to use substantial power to get the seismic vessel moving at just 3 knots, because of the enormous drag created by the streamer array and associated gear (approximately 80t). A simulator 'ownship' assigned as the seismic ship will generate only the drag appropriate to the particular model dynamics. However, if the simulator ownship control includes the optional External Forces menu it is possible to apply a range of such forces to the seismic ship model so as to achieve realistic fidelity in simulating seismic streamer drag.

6 CONCLUSIONS

The modern multi-streamer 3D seismic survey operation is enormously challenging, in the financial and technical resources required to mount and maintain the venture at sea. Downtime in seismic production carries significant penalties, hence the need for the unique OSV support described in this paper — support activity for which few mariners are likely to have prior knowledge or experience. A properly resourced full-mission 360° simulator centre is able to meet that specific training need.

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