The Nautical Institute

DP Operator's Handbook

Third edition

by

Captain David Bray FNI

Captain John Daniels, Captain Glenn Fiander,
Captain Dane Foster

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This book has been prepared to address the subject of dynamic positioning. This should not, however, be taken to mean that this document deals comprehensively with all of the concerns that will need to be addressed, or even, when a particular need is addressed, that this document sets out the only definitive view for all situations. The opinions expressed are those of the authors only and are not necessarily to be taken as the policies or view of any organisation with which they have any connection.

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In addition, Captain Noel Leith MNI AFRIN made a considerable contribution to the review for the third edition. We also had input from Tidewater's DP team.

The collective wealth of experience represented by these seafarers is immense, and I am privileged to have been able to work with them in the production of this new edition.

For information supplied over the years I am indebted to the various manufacturers of DP and peripheral systems, in particular Kongsberg Maritime, Converteam, Nautronix, Sonardyne, Guidance Limited, MDL, Fugro and others.

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David Bray
January 2020

Foreword to the third edition

By Captain John Lloyd RD MBA FNI

CEO The Nautical Institute

The success of dynamic positioning (DP) as an effective tool in the control of vessels is shown through the continued growth in its use across an increasing range of vessels. Once the preserve of the oil and gas sector, DP is now ubiquitous across the whole of the energy sector including renewable energy activities and developments such as walk-to-work arrangements. Increasingly, the provision of DP is also seen in cruise vessels and the superyacht sector.

DP is growing as a specialist subject in maritime colleges that recognise the importance of preparing their students for all developments at sea. It is rare to see a new simulation installation without a dynamic positioning capability and the industry should be grateful to the systems manufacturers who ensure contemporary solutions for shiphandling challenges.

With such widespread use, it is important to have a 'go-to' source of information that delivers both basic information and more detailed technical guidance for the mariner. I am delighted that Captain Bray FNI has continued to provide The Nautical Institute with his support and direction in this updated edition.

The Nautical Institute is recognised by industry as the leading provider of certification services to the DP community. With the introduction of a revalidation requirement for certificates, we have helped ensure that DPOs have recent experience relevant to their role at sea.

We are pleased that many training centres, ships and individuals use the *DP Operator's Handbook* as a valuable source of reference, both for new operators under training and as a valuable source of reference for more experienced operators.

The work of Captain Bray and the review team has delivered this updated and refreshed guide to ensure the book remains as relevant today as when it was first published. The chapter sequence supports the professional development of the mariner and the technical content addresses contemporary use of DP. The book remains the flagship text for our DP scheme and I am delighted to commend it to the reader.

Contents

Chapter 1

Introduction

Dynamic positioning has become an established technique for offshore-related and specialised shipping. The earliest, very rudimentary DP systems were introduced in the 1960s in deepwater drillships, but the technology did not come of age until the early 1970s when Honeywell developed a DP system for a CIA-funded vessel, the *Glomar Explorer*, that then became a production product. From these beginnings there are now thousands of DP-capable vessels in service, with more being built.

It is more than 50 years since the first fully automatic dynamically positioned vessel entered service. The first DP-capable vessel started operating only 34 years after the launching of the last ocean-going cargo-carrying square riggers.

One individual more than any other deserves to be called the father of DP: Howard Shatto. Responsible for the systems on board drillship *Eureka*, Shatto effectively enabled the first fully automatic positioning of a vessel using thrusters in 1961. At that time, the system was called APE, but fortunately the acronym was changed to DP! Shatto was Chairman (Emeritus) of the Dynamic Positioning Committee of the Marine Technology Society of the USA until his death in 2018.

It may be thought that DP is now a fully mature technology, but a visit to any of the conferences regularly held on the subject will soon dispel that myth. The technology is rapidly changing in every area – propulsion, control systems, position reference, operations etc – and it can be hard to keep on top of all these developments. For vessel operators and DPOs the challenge is even greater, and DP operators may find themselves on a limited range of vessels lacking the most up-to-date equipment.

The one that started it all: *Eureka* designed by Howard Shatto
Credit: Howard Shatto

The technology related to DP has changed and developed very fast, and the learning curve has been steep. As the number of personnel involved in DP operations has increased, a huge base of expertise and experience has built up. Nevertheless, a large number of personnel are new to DP techniques, and training is a major requirement within the DP vessel industry.

The Nautical Institute has been involved with DPO training and qualification from the beginning. The Nautical Institute scheme for the training of DPOs is accepted worldwide. Shore-based training centres all over the world provide elements of training approved and accredited to a common high standard.

This handbook is not intended to be a comprehensive treatise on the subject of DP. It is aimed at those who may be entering the DP scenario from more conventional vessels, and it highlights some of the pitfalls and problems that may be experienced. It does not attempt to replace the handbooks supplied by system manufacturers, nor does it go into great detail on individual manufacturers’ systems. In providing an overview of the topic, the aim is to lead the reader into further study and discussion, supplemented by references to further reading.

This book is recommended to be used as the student guide to the NI Induction and Simulator Courses.

Chapter 2

Dynamic positioning principles and systems

2.1 Basic principles

Dynamic positioning ability can be defined as: *A system that automatically controls a vessel's position and heading exclusively by means of active thrust.*

Dynamic positioning is a vessel capability provided through the integration of a variety of individual systems and functions.

The DP system comprises a computer with an interface for operator commands and a display. When the vessel control is switched to DP, the computer takes control of the propulsion devices, rudders, main engines and thrusters.

In reality, the hearts and brains of DP systems are the computers, usually referred to as *controllers*. They receive feedback data from a great variety of sources to generate propulsion commands by which the vessel is controlled and manoeuvred. In any control engineering scenario there is a *set-point* value, which is the desired value. In DP operation there is set-point position and set-point heading, both input by the watchkeeping officer or DP operator (DPO). Measured values of position and heading are continually fed back into the controllers, while the difference between set point and feedback is termed *error* or *deviation*. The controller computers continually adjust thrust commands to reduce these errors to – or maintain them at – zero. The variables under the control of the DP system are the position of the vessel in both longitudinal (surge) and athwartships (sway) directions, and the vessel heading (yaw).

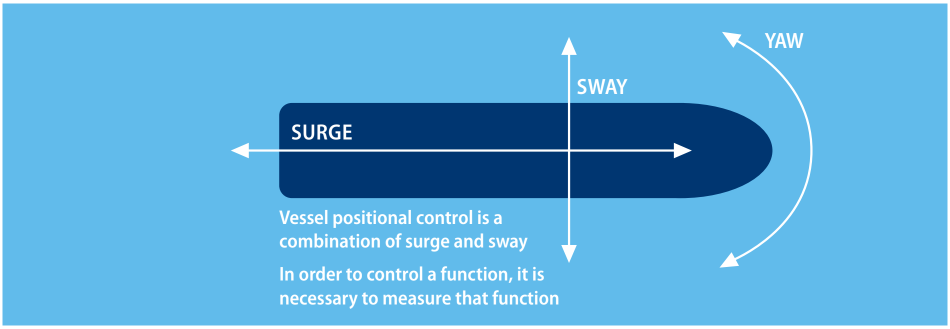

Diagram 1 – Vessel movements controlled by dynamic positioning

DP control station in offshore construction barge *Balder*

All modern complex control systems, such as DP, use mathematical modelling (Kalman filtering and PID control loop) techniques as part of their control functionality. The system contains a mathematical model, or description, of the vessel's dynamics. This includes dimensions, hydrodynamic and aerodynamic data, thruster characteristics and location, vessel reference point and mass. These are used for continuous prediction of future vessel positions, headings and velocities. Data are continually compared with the corresponding measured values, allowing the computation of corrective thrust commands. A DP system is an example of an automatic closed-loop (PID) controlled function.

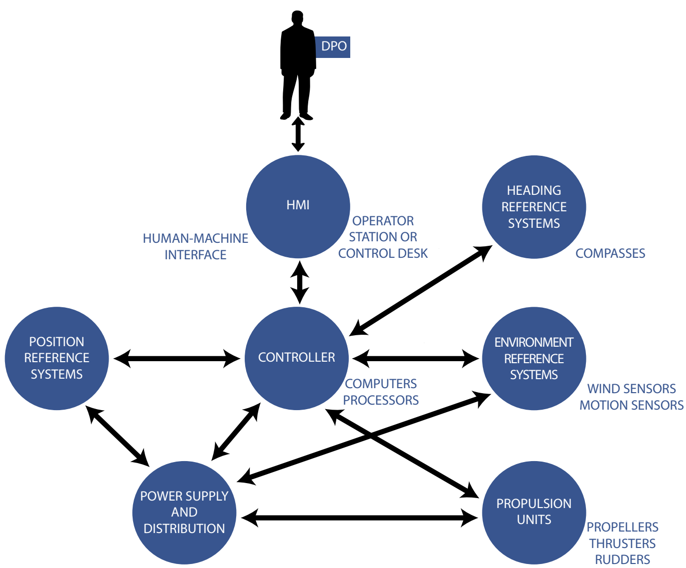

Diagram 2 – Elements of a DP system

The DP software contains static data on the vessel parameters, but it is also an adaptive feature. The analogy is that of steering a vessel by hand. Although skilled at steering, a helmsman will take five minutes or so to get the feel of the vessel after taking the wheel. The DP system does the same: the control takes up to 30 minutes to adapt fully to the vessel configuration and the present environment. Subsequently, the system adapts to changes in the vessel or environment, just as helmsmen will adapt their steering to changing sea states. It is normal to allow 30 minutes as a model-building period, or settling time, to reduce oscillations in position and/or heading. In recent years some system manufacturers have shortened the modelling period to 10–20 minutes. In safety-critical operations 30 minutes is still recognised as a standard settling period.

In modern vessels, controllers are often configured as part of a fully integrated local area network covering all vessel control and monitoring functions and facilities. The controller facility may be provided either by one processor operating alone or, to provide a level of redundancy, by an array of two, three or more. When two or more processors are provided, then one is online while the others act as synchronised hot backups. If three are installed, then there exists the possibility of 'voting' or triple-modular redundancy, with one unit online and two backups. All critical computations are thus triplicated and compared; any discrepancy allows automatic indication and rejection of the errant unit.

2.2 DP system components and layout

As mentioned in 2.1, DP is best described as the integration of a number of functions. Central to it are the controlling computers or processors, which communicate with all other parts of the system via the vessel network.

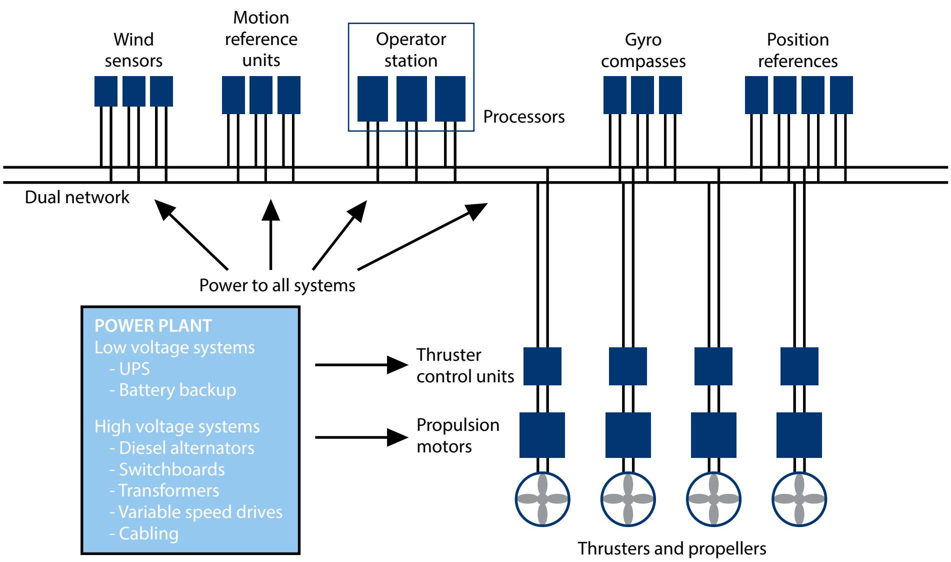

Diagram 3 – DP system components

The system is controlled and operated using the DP console, or desk, containing operational controls, buttons, screens and manual joystick. This console should be located in a position affording a good view of the surrounding sea area, and is usually on the bridge or pilot house. Most modern systems function under a version of Windows so will be a familiar environment to the PC-literate DPO. DPOs are a vitally important part of the DP system. It is, of course, necessary that they be fully competent to conduct DP operations. Discussion of human factors is included in Chapter 9.

For any variable function to be controlled, the variable needs to be accurately measured. The controllers therefore require accurate and reliable data on vessel position and heading, so DP systems are interfaced with gyro compasses and a variety of position reference systems (PRS).

Gyro compasses are standard pieces of ships' equipment, and in DP vessels are fitted in duplicate or triplicate according to the DP equipment class. It is normal to find three compasses installed to fulfil the requirements of Equipment Classes 2 and 3 (see Chapter 3 on system redundancy).

A more recent development is the fibre-optic compass. This device provides a full compass facility from a solid-state unit (ie one with no moving parts). Solid-state units are often configured to provide other vessel attitude data such as roll and pitch (see also Section 2.4).

Position reference systems provide feedback data on vessel position. For DP, there needs to be a greater level of precision than is required for conventional navigation. Accuracy of vessel positioning is limited by the precision of the PRS, and typical positioning accuracy of a DP vessel is within 1–2 metres. Position reference is therefore required to be in the area of 1 metre or better.

A PRS is an independent system interfaced into the DP controllers. It can be satellite-based (GNSS, DGPS, GLONASS, Galileo); optical laser (Fanbeam, CyScan, Spot Track and SceneScan); microwave-based (Artemis, RADius and RadaScan); underwater hydroacoustic (HPR) or mechanical (taut wire). DP systems are enabled to receive and pool data from two or more PRS to determine a 'best-fix' position from all monitored data. The more PRS that are in use at any one time, the greater is the precision of this best fix and the impact of the loss of any one is minimised. A detailed consideration of the topic of position reference systems is given in Chapter 6.

The DP system is interfaced to various sensors and other peripheral equipment. This is detailed further in Section 2.4.

The vessel is ultimately under the control of the propulsion units – propellers, rudders and thrusters – so all these need to be interfaced into the DP system. Propulsion commands are sent in respect of pitch, rpm, azimuth and rudder angle, while feedback from all units is continually monitored. The DPO must continually monitor the set-point and feedback values for each propulsion unit, because although a discrepancy ought to generate the appropriate warnings and alarms, a failed thruster does not necessarily trigger an alarm. This is because in stable conditions the commands may not vary by much. A thruster might have failed as set, ie it is outputting a constant fixed thrust value and not reacting to commands. No alarms are generated if the value does not change, because the failure thrust value is very close to the command. This failure mode will only be picked up by the diligent DPO. More details on propulsion systems can be found in Chapter 7.

Every vessel needs power, and the power supply is very much part of the DP system. A power problem will have an immediate knock-on effect to the DP system and vessel capability. Most DP-capable vessels are diesel-electric or hybrids of this, thus the diesels, alternators, switchboards, cabling, propulsion motors and power-management system all form part of the DP system. Diesel upstream systems – cooling, lube, control and fuel – must also be regarded as part of the DP system. Water contamination of a fuel day tank may cause one or more diesels to stop, resulting in an immediate power shortage. The vessel may not have sufficient power for all the thrusters and propellers, which is likely to lead to a loss of position. Further notes on power plant are contained in Chapter 8.

2.3 DP system functions

This book does not describe in detail the operation of any particular make or model of DP system, facility or function. DPOs will need to familiarise themselves fully with all functions, facilities and procedures of the system they are using and study carefully all operational handbooks and manuals. What follows is an outline of some common functions available. Bear in mind that terminology of functions and facilities varies between DP system manufacturers.

The main function of DP is to enable the vessel to maintain a fixed position and heading, and to make changes to that position and/or heading in a controlled manner. To that end, facilities are provided to allow the DPO to select a new position. This may be defined as a range/bearing from the present position, or in global coordinates such as UTM eastings and northings, or lat/long. Alternatively, a simple input of metres ahead/ astern/port/starboard may be utilised. The vessel may then be moved to that new position at a specific speed. Likewise, the heading of the vessel can be adjusted to a new value at the desired rate of turn.

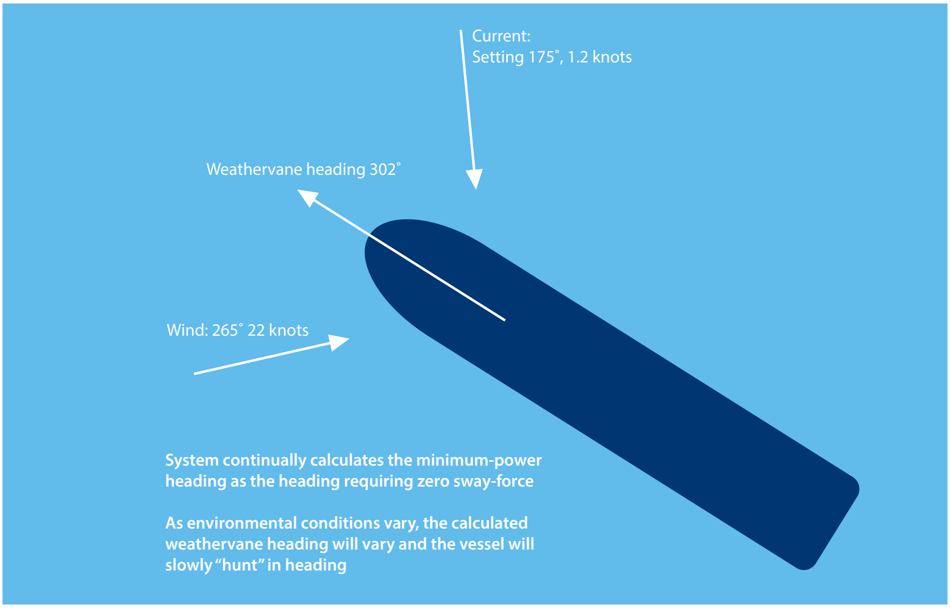

Diagram 4 – Weathervane or optimum heading facility

The above relates to the *auto positioning* function of the DP.

2.3.1 Joystick

The system also allows the vessel to be controlled by means of a joystick. This facility enables automatic integration of propulsion units, letting the DPO use a single joystick to control vessel position and/or heading manually. This facility is sometimes referred to as 'DP joystick', 'manual DP' or 'semi-automatic'. The joystick gives the operator manual control over any combination of surge, sway and yaw while the DP system controls the other axes.

Additionally, a requirement for Equipment Classes 2 and 3 is an independent joystick (IJS) facility separate from the DP system and controllers. The IJS is an emergency control for the vessel.

2.3.2 System gain

Gain, sometimes referred to as *position sensitivity*, is the relationship between the vessel's positioning situation and the power used. Many DP systems have low, medium and high gain settings, thereby providing a choice of response times. In general, low gain is employed in calm weather or where positional precision is not a prime concern. Low gain settings may reduce fuel consumption. In a high gain setting, decreased response time with more power is used in order to maintain a tighter position, for example in position-critical operations or in more severe weather conditions. Another function is known as 'relaxed gain' in which the vessel's set-point position is expanded into a disc of specific radius (selected by the operator). Within this area the vessel is allowed greater freedom of movement, power being increased only when the vessel approaches or passes the limit of the area.

In modern DP systems, further adjustment may be made to the positioning ability in order to conserve power and fuel. Kongsberg's latest-generation system offers a green DP function, in which complex predictive calculations allow the damping of positioning with the minimum of fuel expenditure.

With any of the facilities mentioned above, it is essential that DPOs thoroughly familiarise themselves with the function in order to avoid unwanted surprises. A gain setting can also be applied to the joystick control, with a variety of alternative control selections.

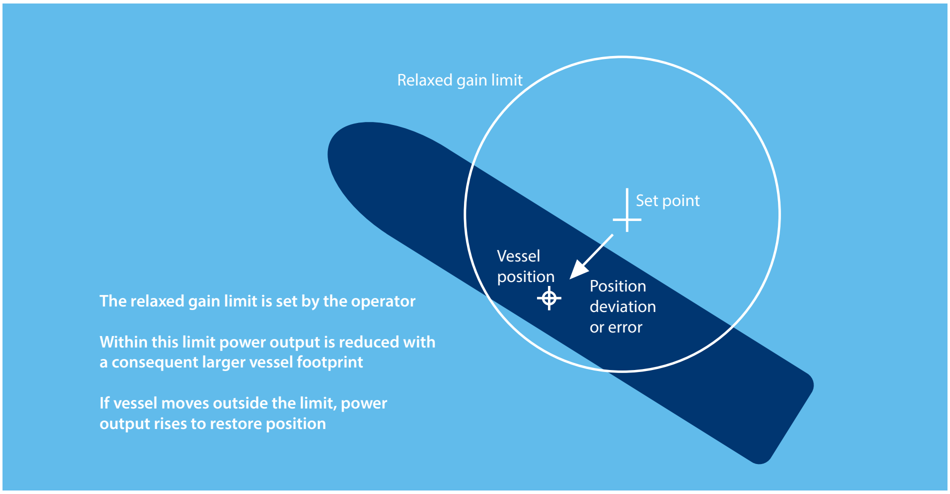

Diagram 5 – The relaxed-gain facility

2.3.3 Follow-target and follow-sub modes

Follow-target mode can refer to operations above surface or below, although typically the follow-sub mode is used for sub-surface operations. These facilities can be found on many systems. They are often employed by vessels that need to maintain position relative to a moving target – an ROV support vessel or a vessel operating a pipe-trencher unit, for example – rather than to a geographical location.

A method of conducting such operations is known as 'dog on a lead.' With this method, the DP system is configured to use a single PRS, which is an acoustic beacon located on the ROV or trencher. This method puts control of the vessel's movements into the hands of the ROV pilot rather than the DPO and should be treated with caution.

To the DP system, the vessel is stationary, as the beacon is a fixed entity, whereas the vessel is actually trying to maintain position relative to a moving target. However, because problems can arise from this procedure, it is not recommended. Often, the agility of the vehicle is greater than that of the vessel, which struggles to keep up.

In follow-target mode the ROV/diver acoustic beacon is designated 'mobile', so the DP system does not include it in the PRS pool. Instead, that beacon is designated the 'follow/mobile' beacon. The DP system must be configured with other PRS (eg DGPS) in the normal manner. The DGPS will still hold the vessel in position while the HPR beacon is inside the geographically fixed circle (radius defined by the DPO) placed around the ROV and this becomes the ROV's operational area. The ROV (with beacon) can move freely with the vessel on a fixed location. If the ROV breaks out of the circle, the DP reacts by adjusting the vessel position by an amount equal to the radius in the appropriate direction and generating a new circle. This continues as many times as necessary.

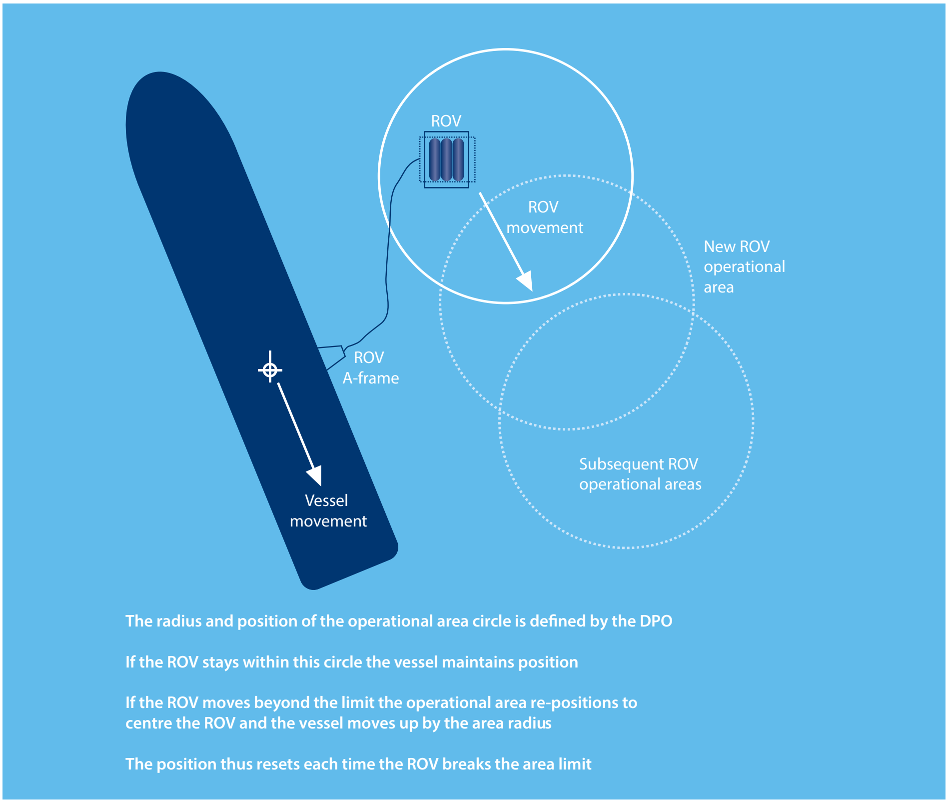

Diagram 6 – The follow-target facility

Another way in which the follow-target facility may be used is where the vessel has to be positioned relative to a slow-moving target such as a DP offtake tanker loading from an FPSO. Variations on this theme may be referred to as 'follow-rig' or 'follow-ship'. Because the FPSO is anchored and weathervaning, the offtake tanker loading in tandem must match this movement. In this case, the operational area consists of a target box located on the FPSO's stern reference point. The tanker carries an imaginary bowsprit, the end of which must be maintained within the target box. Provided the bowsprit end point remains within the box, the tanker maintains a fixed position. This position is adjusted when the bowsprit end breaks out of the box as the FPSO moves. A similar facility may be used by a DP supply vessel working the FPSO.

2.3.4 The autotrack or track-follow mode

The autotrack mode allows a vessel to track slowly along a predefined line, itself defined by waypoints. This facility may be useful in vessels conducting cable-laying or pipelay operations, dredging, rock dumping or surveying. Whatever the type of operation, a comprehensive plan of the track will be compiled, with full details of vessel speed and heading on each leg of the track and points where the tracking may need to be temporarily suspended. A numbered listing of the track waypoints and their coordinates is compiled, with attention paid to such details as chart datum and coordinate frame in use. The track file may be compiled by the surveyor, away from the bridge, and imported into the DP system. If this is the case, then all parameters of the imported file will need to be carefully checked.

The DP system autotrack function is accessed via a complex menu system. The DPO can enter data manually from the track table or plan using a facility called 'track table' or 'track editor'. This facility allows entry or deletion of waypoints, insertion of new waypoints at any point and entry of values of vessel heading and speed on each leg. Once a track has been compiled (often considerably in advance of the operation), it can be saved and recalled later.

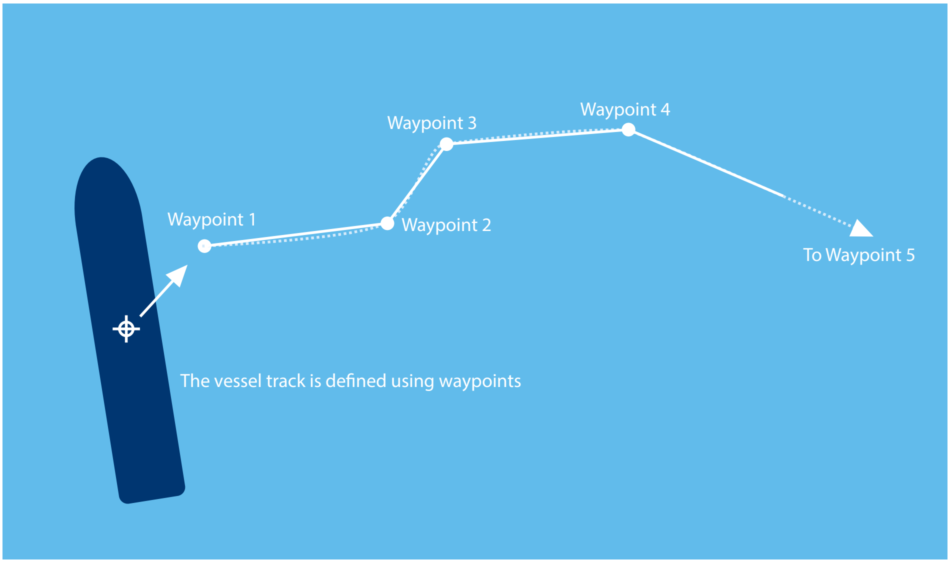

Diagram 7 – The autotrack facility

DPOs will need to familiarise themselves with all the permutations of autotrack settings and configurations available. They should know the exact reaction of the vessel to each of the menu choices. The DPO specifies how the vessel will handle a waypoint passing – whether it stops on the waypoint or proceeds around a radiused turn, and whether it slows down on the turn – and any track offset. Offset facilities may be useful for making small adjustments to the track placement while the tracking is in progress. Several alternative offset strategies are available.

A further variation on the autotrack theme is the 'move-up' function. If operating a pipelay vessel, it may be necessary to move the vessel forward a distance equal to one or two pipe-joints (12m or 24m) at frequent intervals. Having compiled the autotrack, the vessel can be operated in the move-up mode, with a single move of the required distance initiated by a button-push.

The commonest mode of autotrack operation is the low-speed option. Here, vessel heading is under the full control of the operator – the vessel does not necessarily sail along the track in a conventional bow-first manner. The vessel heading may be adjusted to give a lee for the operational elements, or the vessel may maintain a weathervane or minimum-power heading during the tracking. Vessel speed is limited to 3 or 4 knots in this configuration. An alternative option is high-speed autotrack, or 'auto-sail', in which the full cruising speed of the vessel is available. In this configuration, vessel heading is dictated by the system, the vessel navigating in a more conventional bow-first manner on main propulsion only. Low- and high-speed mode may also be determined by the thruster configuration because of the limitations of tunnel thrusters.

It is important that DPOs and all concerned are familiar and practised with the operation of the autotrack function. The start of an operation using autotrack is not the time to investigate and practise the facility. In the past, problems have arisen during a long east–west track that spans more than one UTM zone. Matters of this kind should be resolved well in advance. In modern systems, provided the hemisphere, zone and position have all been entered into the DP system correctly, the changes will be accounted for by the controller without additional input. The autotrack function requires position reference from DGPS only.

2.3.5 Riser angle or riser-follow mode

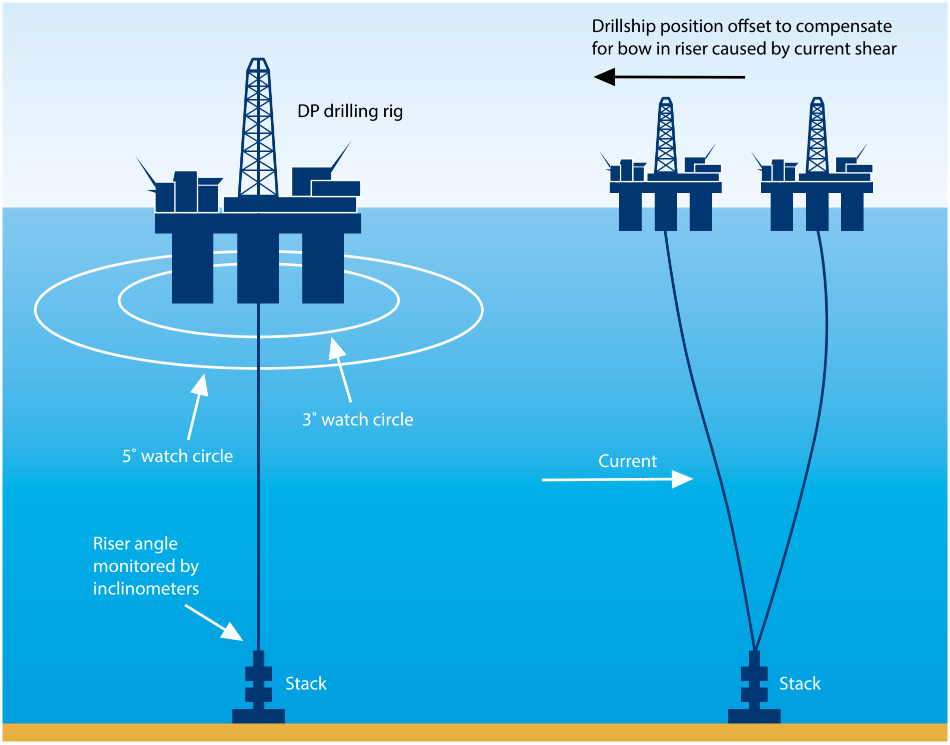

Diagram 8 – Riser angle mode of operation for drillships

This function is of great importance in deepwater drilling operations in which the critical factor is the management of riser angle. The riser is the pipe containing the drillstring, supported from the drillship and connected to the seafloor wellhead or stack assembly. This connection is known as the lower flex joint (LFJ) and conducts the rotating drillstring through to the well. It is vital that the riser be perpendicular to the stack, otherwise damage will occur to the drillstring and wellhead components. Riser difference angle is monitored via sensors located above and below the LFJ, and fed back to the pilothouse and the DP system. Typical angular criteria are 2° (amber) and 3° (red), although these values will vary from ship to ship because of the clearance between the riser and the drillstring or the size of a tool being passed through the blow-out preventer (BOP). Up to 2° riser difference angle, drilling proceeds normally. If the riser difference angle reaches 3°, drilling stops and preparations are made for a riser disconnect operation, and this must be initiated if the riser angle reaches 5°.

Riser difference angle is affected by tidal flow, as the riser bows down-tide. The DPO compensates for this by moving the vessel. In deep water there may be a complex tidal shear pattern, resulting in an irregular riser profile. In 'riser angle' mode, the DP system receives feedback from the riser management system, and displays the 3° and 5° watch circles on screen. These circles will drift on screen as tidal conditions change, and the DPO will adjust the vessel position and heading to maintain angles within limits. In this type of operation, therefore, the DPO is less concerned with the vessel's actual position than with the riser feedback.

2.3.6 Shuttle tanker functions

Some general information on shuttle tanker operations is given in Chapter 4. This is a specialist DP configuration not found in, or required for, other types of vessel, and many of the DP functions are specialised too. A shuttle tanker will almost always work in a weathervane mode, as the power-to-weight ratio of these vessels precludes adopting any other heading. The tanker will be configured to load from one or more specific offshore loading terminals (OLTs), which may be fixed tower structures, floating towers, submerged turrets or FPSOs. The position and other characteristics of the OLT are contained within a file in the DP system, accessed from a 'select OLT' menu.

The vessel will approach from a downwind or down-tide direction, keeping the OLT ahead, transferring into DP control at an appropriate point (usually outside the 500m zone). The DP system will have an 'auto-approach' function, allowing the DPO progressively to reduce the distance from the OLT. All the time the vessel is maintaining a weathervane or minimum-power heading. Once on the defined position circle, at the correct distance from the OLT for the loading phase, the DP is selected into the 'loading' function. With the loading hose connected, the vessel is maintaining a fixed distance from the OLT, while weathervaning around that point. Position is continually adjusted to keep the OLT ahead and the vessel on the minimum-power heading.

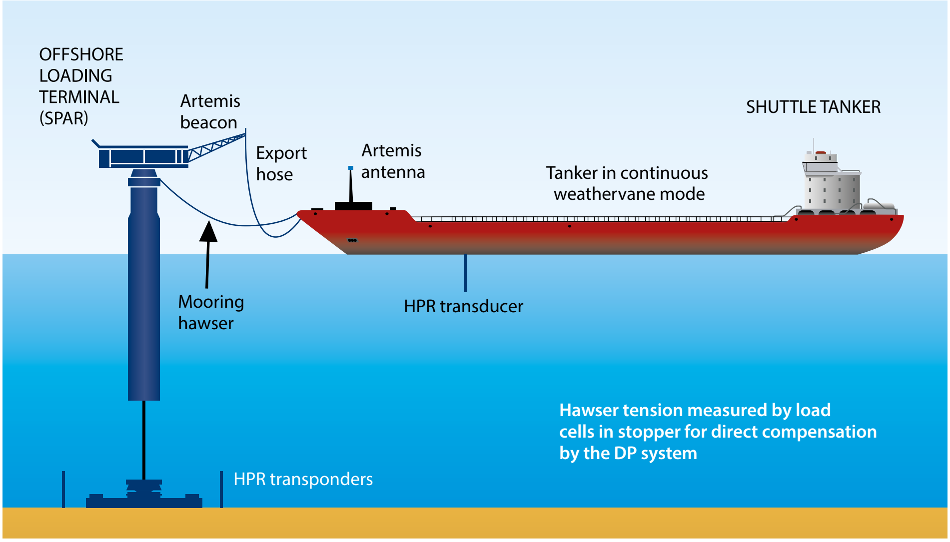

Diagram 9 – OLT loading

If loading is from a submerged turret, the position of the turret is monitored by underwater acoustic methods as part of the vessel's hydroacoustic position reference (HPR). Special displays show the position relationship between the turret and the vessel. The vessel's reference point will be the docking cone in the forepart of the vessel's bottom. Once the turret is recovered and locked into the cone, the vessel may simply stop all thrusters and propellers, and weathervane naturally, anchored to the cone. This is possible only if weather and tidal conditions are light to moderate. If more severe conditions are experienced, the DP system may be brought into use in a 'damping' mode.

Many offshore offtake operations are from FPSO installations. Here, the tanker maintains a position in tandem with the anchored FPSO and must match her movements and heading. The FPSO is not normally DP-capable, but may have thruster control of heading, within environmental limits. The approaching tanker may request the FPSO adopt a specific heading for the approach phase. The auto-approach facility will be used (see Diagram 9) until the vessel is at the desired location relative to the FPSO stern reference point. The tanker's loading function will then allow a follow-target facility using a position box as described in Section 2.3.3 above. DARPS (the Seatex Differential Absolute and Relative Positioning System) is one common positioning system used for this. Set-point heading for the tanker is the FPSO heading, which must be monitored via telemetry in the tanker.

2.3.7 Auto-area mode

A further variation on the automatic control of positioning is 'auto-area'. In this function, the DPO is able to specify a geographical area of any desired size. The area is usually circular, though it may also be elliptical. This becomes a 'loiter' area, in which the vessel drifts with no thruster commands. When the vessel crosses the area boundary, power is gently applied, and the vessel is slowly restored to the centre of the area.

2.3.8 Other DP functions and facilities

It is not the intention here to provide a comprehensive description of all available DP functions, but an overview of common facilities follows.

2.3.9 External force compensation

Some vessels under DP control experience a variety of external forces that need to be compensated for. An example of this is the pipe construction vessel, laying pipe using a stinger assembly at the stern. The stinger is a rigid support ramp taking the pipe from the pipe deck into the water. From the end of the stinger to the pipe touchdown point on the sea floor the pipe is unsupported and must be kept under tension to maintain the correct catenary profile. To enable pipe tension to be maintained, the pipelay engine is programmed to feed pipe tension values back to the DP system. Thus the DP system and DPO are able to manage the thrust requirements for compensation. Similar external force compensation facilities may be provided for cable-plough operations or on fire monitors. If this compensation facility were not enabled, the external forces would be treated as false current.

2.3.10 Quick-current or fast learn

This facility provides a partial solution to the problem arising during rapid turn of tide. The tide or current value is deduced by the system, rather than being measured directly. The accuracy of the current value is dependent upon the quality of the mathematical model. If the tide turns quickly, the model will lag behind, because time is required for a new model data to build. This results in a deterioration of positioning ability. Modern DP systems incorporate a facility that allows a temporary acceleration of the model-build process, which may improve the positioning ability during this time. It must be emphasised that this facility is not perfect or foolproof, and there may still be some positional instability during such slack-water periods.

2.3.11 DP capability plot

DP operational handbooks provide capability diagrams that give calculated indication of the capability of the vessel in a variety of weather conditions. This software has two modes, Live and Theoretical. Live uses the present environment while Theoretical allows the operator to input thruster and environmental conditions for scenario testing.

Note: Capability plots always assume full power is available, therefore the plotted diagram will not change if, for example, generators are offline. To determine whether capability plots are accurate, the DPO should compare the thrust loadings from the capability plot with the actual thrust loads.

The operator must be aware of the limitations of this display, as it is still only a theoretical simulation of the vessel's capability and has not been obtained from real observation.

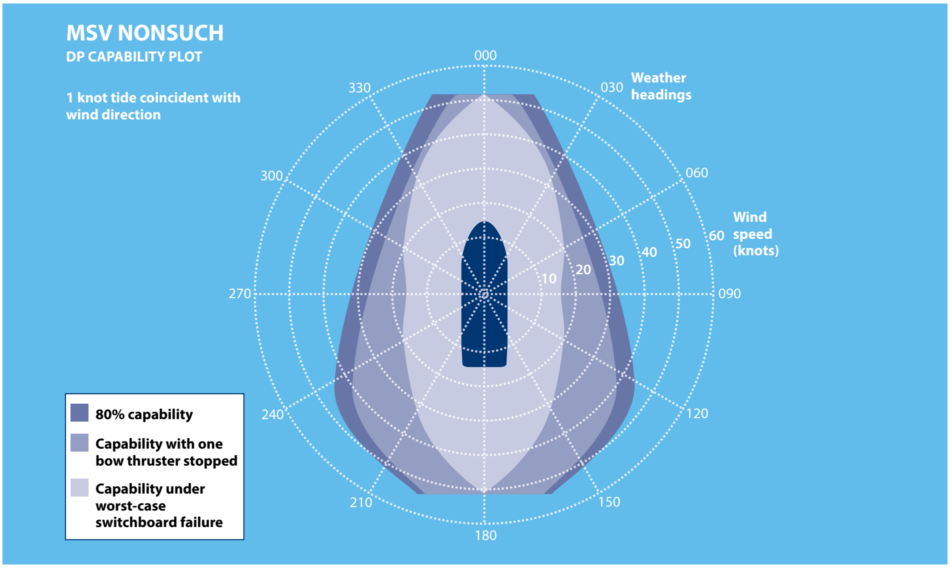

Diagram 10 – DP capability diagram

2.3.11 Footprint plots

Footprints are realistic presentations of the vessel's station-keeping ability. These records are initiated by the DPO and show how accurately a vessel can maintain position in the prevailing environmental conditions. This is normally done manually on a polar plotting sheet. All the variables – power, thrusters, ship's heading, wind speed and direction, current rate and direction, and position reference systems on line – are recorded on the sheet. There are several ways of doing this. The primary purpose is to provide the DPO with performance records demonstrating the vessel's station-keeping properties in different conditions. It is not unusual to print a screen shot of the plot from the DP screen showing the trace line for the same period. If there is a survey team on board their records can be used for a printed verification of the footprint. Footprint plots may also help in evaluating the accuracy of computer-generated capability plots.

2.3.13 Environmental regularity numbers (ERNs)

A further indication of station-keeping capability is given by ERNs. Classification society DNV GL provides four percentage values as a statistical indication of the amount of operational time that the vessel is able to maintain position under four thruster configurations: all thrusters running; the minimum effect of a single-thruster failure; the maximum effect of a single thruster failure; worst-case single failure. The statistics relate to year-round conditions in a stated geographical area, eg North Sea. Typical ERNs for a particular vessel might be 99, 99, 98, 68. These values will be tabulated within the vessel classification document.

Lloyd's Register provides a similar service, known as Performance Capability Ratings (PCRs) for redundant-capability vessels in just two groups. Bureau Veritas has its own measure of rating a vessel's DP position-keeping ability called Environmental Station Keeping Index (ESKI).

2.3.14 Drift-off calculation

This optional software feature, when set up correctly, will show the drift-off profile related to an operator-specified failure mode. If, for example, a total blackout situation is selected, the display will show the predicted positions and headings of the vessel at specific time intervals (eg every minute) following the blackout. If the DP system does not have a drift-off calculation feature, the operator can observe the thruster allocation logic (TAL) vector as a guide to expected drift direction. The drift direction will be diametrically opposite to the TAL vector.

2.3.15 Autopilot and transit mode

The DP system often incorporates autopilot functions. When the vessel is in transit, there will be a dedicated thruster configuration. As an example, a vessel having three azimuth thrusters aft may, in autopilot mode, have the two wing thrusters locked for forward thrust, while the centre thruster is enabled to steer with azimuth angle limited to 35°.

2.4 Sensors and peripheral equipment

The DP controllers need feedback about the environment in which the vessel is operating, especially continuous and accurate data on vessel roll and pitch angular values. The data is provided by an inertial motion sensor called a motion reference unit (MRU). This device outputs not only roll and pitch data, but also heave values, together with rate (velocity) data on each of the three measured values. Alternatively, roll and pitch data may be provided by a device called a vertical reference sensor or unit (VRS or VRU). The processors need instantaneous roll and pitch data in order to correct data input from PRS that measure vessel position as an analogue of a vertical angle (taut-wire systems and underwater acoustic systems). In these PRS, vertical angle is measured by a sensor that rolls and pitches with the ship; if no correction were applied, the processor would interpret this as a moving vessel. Roll and pitch data input allows these angles to be corrected or reduced to the true vertical.

Wind sensor

The other element of the environment requiring measurement is the wind, and a number of transmitting anemometers are installed. Usually fitted in (at least) duplicate, wind sensors may be of the traditional rotating cup type or of the more modern ultrasonic variety. It is not unusual to find three wind sensors installed, using two different principles. These wind sensors input data into the model, allowing wind loads on vessel hull and superstructure to be computed and compensated for. However, wind conditions can change rapidly and radically, and gusting conditions will adversely affect the DP performance of the vessel.

The system needs to be able to react rapidly to large changes in wind speed and direction. The mathematical model does not serve to best effect in these conditions, because of the delay between changes and system reaction – it takes from five to 30 minutes to update. With most variable elements within the vessel model environment, such as vessel displacement or tide, the changes take place slowly, so this speed of reaction is appropriate. However, gusting wind conditions can play havoc.

The DP system compensates for this problem with a function known as 'wind feed-forward', in which radical changes in wind speed and/or direction bypass the mathematical model and generate compensating thrust directly. This is achieved by looking up the aerodynamic data in the vessel model, including checking the draught to determine how much thrust to apply. In some DP systems this is known as 'gust-thruster compensation'. For this compensation to give satisfactory results, the wind sensors must be reading representative values for the wind. The DPO must ensure that the wind sensor selected from the array available is reading clear wind, unobstructed by any wind shadow from structure. For more on wind sensors, see Section 2.5.2.

A further environmental value needed is current. It is not possible to obtain representative values for the current from any vessel-mounted sensor. In effect, the current value shown on screen is what forces remain when all known measured forces are accounted for. A continuous discrepancy between predicted position within the mathematical model and measured position derived from the PRS indicates a current. The DPO should be aware that this 'current' value is only a *deduced* value and not a real measurement, so it is subject to error. In fact, any error within the DP system will be incorporated into the displayed current value. One DP system manufacturer does not call this vector 'current' at all – it is referred to as 'sea force' and displayed in tonnes. Errors within the system that may affect the accuracy of current display include erroneous thruster pitch feedback and erroneous wind sensor data, perhaps from a jammed wind-vane unit. Other interfering factors may include waves and swell conditions or thruster wash from a nearby vessel.

In specialist vessels, other external sensors provide the processors with feedback data including measurement of external forces and of riser angle (in a drillship). External forces may take a variety of forms. In a pipelay vessel, pipe tension needs to be maintained at pre-set values as the lay progresses. Pipe tension is monitored at the pipe tensioners and fed directly into the DP system, allowing direct and immediate thrust compensation for tension and changes in tension. Similarly, in a cable-lay vessel towing a cable plough, hawser tension is monitored and fed back. A shuttle tanker tandem-loading from an FPSO unit ahead will monitor hawser tension and make similar compensation.

2.5 Some DP problem areas

As with any system, DP has its limitations. The DPO must be familiar with these limitations and problem areas, some of which are described here.

2.5.1 Operations in shallow water and strong tidal conditions

DP vessels may not perform well in shallow water or strong tidal conditions. One reason is the lack of efficiency of some position reference systems in shallow waters. The PRS affected are taut-wire systems and hydroacoustic systems.

Taut-wire systems are problematic in shallow water because of limited horizontal scope or range. The maximum allowable wire angle is typically 28° to the vertical, so if there are only a few metres under the keel, horizontal range is also only a few metres. Ray-path angle considerations mean that hydroacoustic systems are reduced in accuracy. This is due to the flatter ray-path causing greater distortion and losses due to refraction of the signal.

In shallow water, acoustic systems suffer proportionately higher levels of thruster noise interference. In general, it is wise to avoid the use of underwater PRS in shallow water.

Where there are strong currents or tides – often the case in shallow water – the vessel has to employ larger amounts of power and thrust in order to maintain position and heading. Consequently, this leaves smaller amounts of both in reserve, affecting the redundancy considerations. If the vessel is working harder to maintain position, it will undoubtedly be creating greater levels of noise and water turbulence, with further detrimental effects on the performance of hydroacoustic position reference.

As mentioned in Section 2.3.10 above, DP systems perform badly during periods of rapid turn of tide, and this is often a feature of areas where depths are limited and tidal conditions are severe.

Many underwater activities are adversely affected by strong tidal conditions and shallow water, particularly diving and ROV operations. Work of this kind must undergo a full risk-assessment process, with all hazards identified and assessed.

2.5.2 Operations close to a fixed structure

Offshore support vessels of all types routinely work close to fixed platform structures. The main and immediate danger is making contact with the structure. DPOs must ensure that they have a direct view of the structure. It is an axiom of DP work that before instruments and alarms start to react, a positioning problem will usually be apparent visually to an observant DPO.

The presence nearby of a large fixed structure will have a detrimental effect on the DGPS position reference. The structure may block satellite signals and thereby reduce satellite availability. Reflection of satellite signals from the structure will create multipath reception. Signal blocking and multipath reception will both adversely affect station-keeping performance. In addition, the differential correction signal may be lost due to shadow from the platform structure. All of this adds up to a simple truth: DGPS cannot be regarded as a fully reliable PRS close to platform structures.

Other position reference systems may become unreliable when working close alongside fixed structures. It is not unknown for platform personnel to move laser targets while they are in use. Even the reflective clothing worn by platform personnel may seduce optical laser-based systems from their designated targets, particularly during platform safety drills.

A further concern when working in such close proximity is the interference caused to wind sensor readings. If a vessel is working close-in on the downwind side of a platform, the wind sensor may be severely wind-shadowed and therefore unable to deliver representative wind data, even though the vessel herself is being affected by the wind blowing through the legs of the platform. This may lead to deterioration of positioning efficiency, and there is no real cure for this problem. Another potential problem is interference to wind sensors from downdrafts from helicopter rotors, either on nearby structures or own vessel. Under these conditions it is essential that wind sensor input is temporarily disabled.

2.5.3 Operations in close proximity to other vessels

By their nature, DP vessels are restricted in their ability to manoeuvre and must always display the appropriate signals. In the offshore theatre, several vessels may be working close to each other which can give rise to a number of hazards, chief among them being collision. DPOs should always bear in mind that any vessel in the area, including their own, may suffer total power loss or blackout. Do you have a contingency plan for this?

What will happen if the supply boat working the platform crane suffers blackout? Will it drift down on own ship and is there any action we can take? If own vessel is position-constrained in a safety-critical task, operations may have to be suspended until the situation becomes safer.

Two DP vessels near to each other may also generate problems. Thruster wash from one vessel may disturb the positioning of the other, which could lead to thruster-thruster interference and positional loss by one or both vessels. A nearby vessel may cause line-of-sight loss on laser- or microwave-based PRS. If one vessel is using underwater acoustics, the thruster noise or aeration of the other vessel may block acoustic returns. All of these problems should be considered in the risk assessment for the task.

Offshore construction vessel *Balder* positioned for a topside installation