Operating The DP Vessel.

A Dynamic Positioning Overview by Capt. R.P. Morris. AFNI.

Who is talking to you? A brief introduction…..

I left school and went to sea as Deck Boy, after 3 months at Gravesend Sea School.

Served up to A.B. with Palm Line, Buries Marks and Blue Star Line.

With the demise of British crews, armed with a grant from Trinity House in Hull, I went to the marine college in Plymouth and passed for 2nd Mate.

Sailed as 3rd Mate with Blue Star. After further redundancy joined Maersk in their tanker fleet.

I transferred to Maersk Offshore sailing as 2nd Mate aboard AHTS vessels before being transferred to my first DP ship.

I then then joined Swire Pacific as Chief Officer. gaining further DP experience on a MPSV and ROV vessel.

My next move took me on to drilling and workover DP vessels, both semi-submersible and mono-hull, and was promoted to Master in 2009.

2019 to 2021 saw me serve aboard smaller DP vessels involved in geotechnical seabed survey work before returning to larger drilling vessels with Saipem, where I continue to serve as Master.

*DP Log book shows approx.'**55,000** hours of DP time*

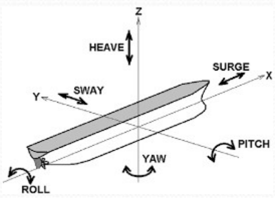
1st Ship

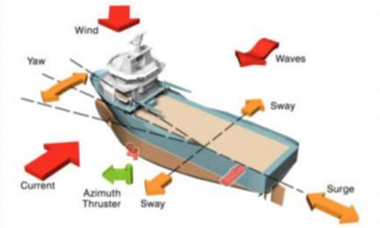
1st DP Ship

Current Vessel: *Saipem Santorini*

How does the ship move, and what is Dynamic Positioning?

- We are familiar with the 6 degrees of freedom a vessel has; surge, sway, yaw, pitch, roll, and heave.
- It is obvious then that even on that calmest of days a vessel will always being moving in seaway; she is in a constant dynamic state.
- A Dynamic Positioning system will be aware of the last 3 degrees of movement, but will not compensate for them. It will only act on the vessels movement in the horizontal plane i.e. *surge, sway* and *yaw*. By recognising that dynamic, DP will use both the hard and soft-ware components within its make-up to position the vessel as per the DP Operators request.





- What this means is that the DP system will react to *disturbances* in these 3 axis, or the dynamic movement of the vessel, when comparing them to the desired position set-point, which is determined by the DP Operator.
- Therefore it is quite apparent that at early design stages of any DP vessel thrust capability of the chosen propulsion, and manoeuvring system, is key. It must be sufficient, with redundancy, to maintain the required position in the most extreme weather conditions likely to force the vessel to move around these 3 axis, that may be expected in the vessels chosen operating area.

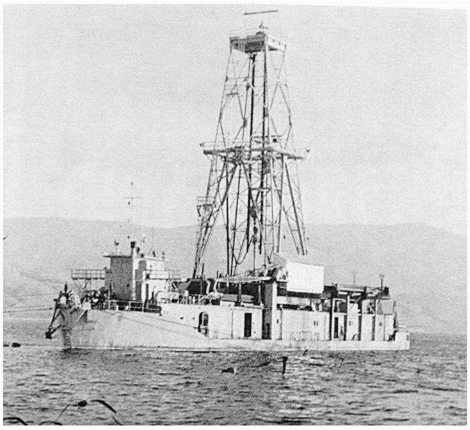
What is Dynamic Positioning?

- Essentially a computer/operator controlled ability for a vessel to maintain her position in a seaway.
- As the vessel moves in a seaway, and is affected by the other environmental forces impacting upon her, so the positioning system counteracts these forces dynamically, to maintain the operator settings i.e. position and heading.
- DP can be set-up for 3 main conditions;

1. to remain static, holding the vessel position when engaged in operations such as diving and drilling.
2. dynamic in relation to a moving object, such as *follow* mode, for pipe-lay, rock dumping or ROV survey operations.
3. dynamic in relation to a waypoint, or series of waypoints, such as auto-track mode, for the above or short in-field voyages.

- For Operator, you can assume Watch-keeper, as we are required to maintain not only the DP Watch but also a full Navigational Watch; even when the vessel is sat on DP, she is still considered *under way.*
- The first DP vessel is subject to some debate. In the early 60's a drill-ship "*Cuss 1*" had 4 azimuth propellers fitted, and drilled a well in 900+ meters of water, with the thrusters controlled manually. However a Shell vessel "*Eureka*" came out in 1961 fitted with a basic analogue computer interfaced with a taut wire reference system to maintain position automatically.

What is Dynamic Positioning?



Cuss-1

The Eureka

DP Class: as per IMO Circ. 645/1580, Class Societies issue DP Class Notation to a vessel.

- **Class 1**: No part of the DP system offers any redundancy i.e. a single component failure could lead to a loss of position. Risk due to failure; MINOR
- **Class 2**: Equipment does have redundancy so no single fault in any active system will lead to failure and position loss i.e. thrusters, generators, switchboards, position references, sensors. However loss of static equipment could lead to position loss i.e. cables, pipelines, valves. Risk due to failure: MAJOR
- **Class 3**: Essentially a step up from Class 2 with regards compartmentalisation. Some equipment will have further redundancy such as additional gyro's, reference systems (extra DGPS say) or additional L/O pump, SWC pump, steering motors for an individual thruster. The main requirement for Class 3 is to ensure that any one compartment – Engine Room, switchboard room, DP control station (main bridge) – can be lost due to fire or flood, and the vessel still maintain station. Risk due to failure: FATAL

DP class notation

IMO equipment class	BV	DNV		ABS	GL	LR	NK		RINA		RS	IRS		CCS	NMD	KR
	Bureau Veritas	Det Norske Veritas		American Bureau of Shipping	Germanischer Lloyd	Lloyds Register of Shipping	Nippon Kaiji Kyokai		Registro Italiano Navale		Russian Register of Shipping	Indian Register of Shipping		China Classification Society	Norwegian Maritime Directorate	Korean Register of Shipping (Korea)
	DYNAPOS SAM	DYNAPOS AUTS	DPS 0	DPS-0		DP (CM)			DYNAPOS SAM						DPS 0	
Class 1	DYNAPOS AM/AT	DYNAPOS AUT	DPS 1	DPS-1	DP 1	DP (AM)	Class A DP	DPS A	DYNAPOS AM/AT	IPD-1	DYNPOS-1	DP-1	GS (KK)	DP-1	DPS 1	DPS (1)
Class 2	DYNAPOS AM/AT R	DYNAPOS AUTR	DPS 2	DPS-2	DP 2	DP (AA)	Class B DP	DPS B	DYNAPOS AM/AT R	IPD-2	DYNPOS-2	DP-2	GS (SK)	DP-2	DPS 2	DPS (2)
Class 3	DYNAPOS AM/AT RS	DYNAPOS AUTRO	DPS 3	DPS-3	DP 3	DP (AAA)	Class C DP	DPS C	DYNAPOS AM/AT RS	IPD-3	DYNPOS-3	DP-3	GS(SS)	DP-3	DPS 3	DPS (3)

Types of DP Vessels

Platform Supply Vessel (PSV)

Offshore Construction Vessel (CSV)

Types of DP Vessel

Dive Support Vessel
(DSV)

Pipe Laying Vessel
(PLV)

Types of DP Vessel

Accommodation/W2W Vessel

Well Stimulation/Frac Vessel

Types of DP Vessel

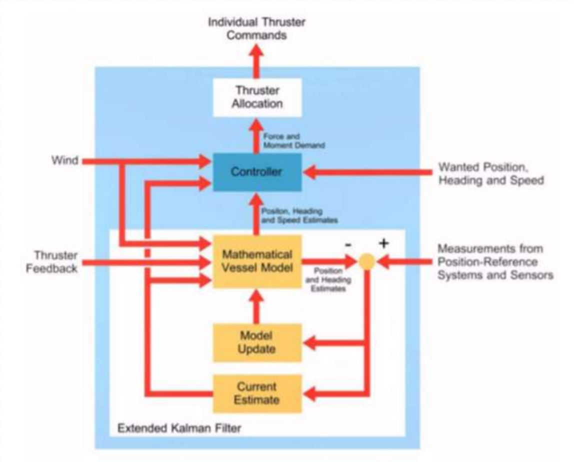
Rock Dumper

Shuttle Tanker.

How is the position dynamically controlled?

- Like any vessel, the DP ship is fitted with main engines, propulsion and steering systems. Combinations vary from vessel to vessel with CPP's and high lift rudders, tunnel thrusters, full azimuth thrusters, drop-down thrusters, etc. My current vessel, for example has 6 x full azimuth thrusters; 3 fwd' and 3 aft in a triangular formation each end.
- So the engines are running, with all propulsion and steering systems fully available to the DP Operator. What else does the DP vessel require to maintain station?
- **Heading.** DP requires heading information input, and this is provided by means of a standard gyro compass. Nothing different to that of a tanker or bulker, but in DP vessels of Class 2 and 3 design we have more than one for redundancy purposes.
- **Motion.** For DP to be aware of how the vessel is moving in a seaway information is provided in the form of MRU's or VRU's (Motion/Vertical Reference Sensors). Built with solid-state gyros and accelerometers, todays MRUs provide real-time motion measurements with high dynamic accuracy. These are vital for DP model accuracy. Draft sensors, or manual draft values can be used; again this is important DP information due to the effect on current and wind on the hull.
- **Environmental data; wind**. Every ship is affected by wind; you will be familiar with leeway. Accurate wind direction and speed is vital for a DP system. This is provided in the form of data transmitted to the controlling computer from a selected anemometer. Again depending on class of DP vessel there may be a single anemometer or multiple. Two main types are available, cup and ultra sonic.
- **Environmental data; current.** There are two choices for the Operator 1. Raw data input or computer based Quick Current.
- All of this information is fed to DP simultaneously, to the selected controller computer. Here a process called the *Kalman* filter is applied. This is essentially a series of mathematical equations which are constantly being performed, the result of which will determine what , where ,and how much thrust is to be applied by the propulsion system to maintain position.

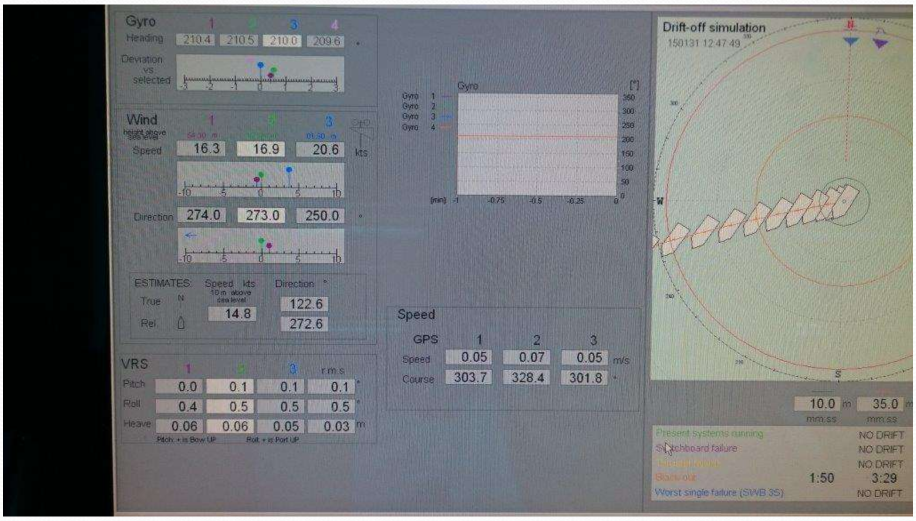
Extended Kalman Filtering



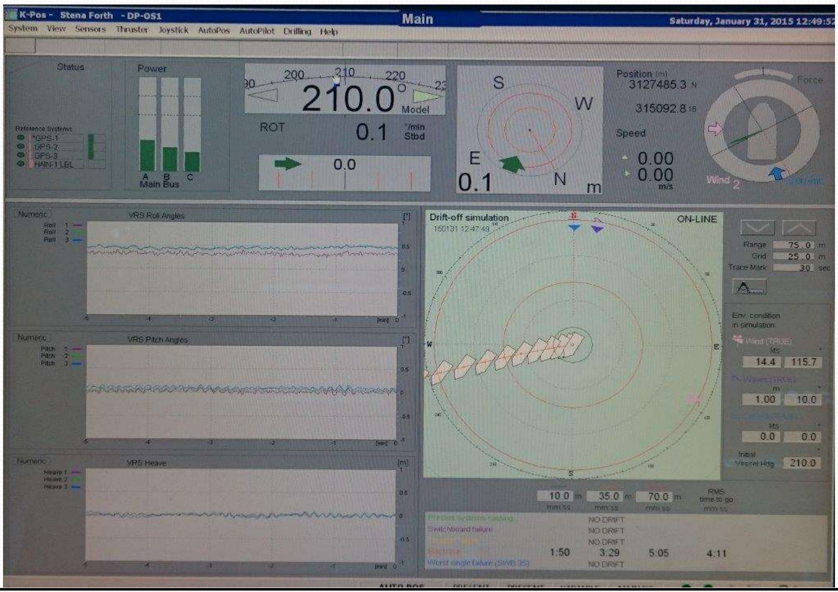
The Extended Kalman Filter provides the following advantages:

- Optimum self-adaptive noise filtering of heading and position measurements according to noise level and measurement-update rate.
- Optimum combination of data from the different position-reference systems. The system calculates a variance for each position-reference system in use, and places different weighting on their measurements according to each system's individual quality
- In the absence of position measurements, the model provides a "dead-reckoning" mode. This means that the system can perform positioning for some time without position measurement updates from any position-reference systems

Operator screen showing gyro, wind and motion info.



Operator screen showing MRU info; pitch, roll, heave.



Cup & Ultra-Sonic Anemometer.

Anemometer Issues.

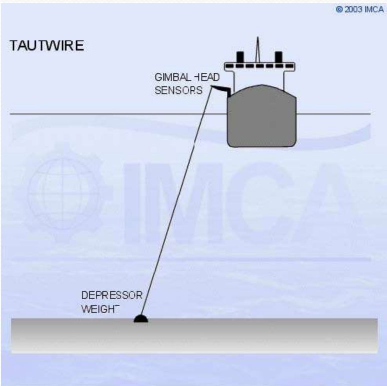
Swirling wind (eddying), helicopter down-draft, pipe-line venting, line squalls, water-spouts, etc can all produce errant readings on the anemometer that can have major detrimental effects on DP. A simple, but bold, solution once the Operator has recognised the issue, is to simply de-select the anemometer from DP. No wind information is better than wrong information in this case.

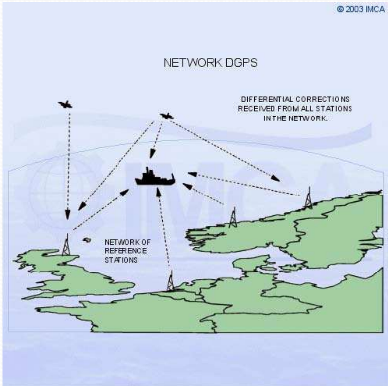
Where am I? DP Position References.

- We have looked at propulsion, compasses, motion and wind sensors. So how does DP know where it is?
- On initial set up DP will be given a position set-point by the Operator to maintain. This set-point is either in standard Lat/Long, but more commonly in Northings/Eastings from a datum point.
- DP then must be given references to maintain this position. These are known as Position Reference Systems (PRS)

- **DGPS (Differential GPS)** A standard GPS signal that is intercepted, has a differential correction applied thereby increasing its accuracy to 10cm. This correction is based on distance of the GPS signal to a known position of the diff signal station. This correction is provided to the subscribers receiver by private companies such as Fugro, Veripos, IALA, InMarsat, Spotbeam. Cost is per annum of approx' $100,000.
- **Acoustic Referencing** can be used by placing transponders on the seabed either singular or in groups depending on water depth. These transponders are sending and receiving a signal to/from a transducer head below the vessels hull. Single transponder use (SSBL – Super Short Base Line) is suitable to maximum 1000m water depth. For greater depths groups of 3, 4 or 5 are set out in arrays (LBL – Long Base Line). Here the transponders transmit and receive between each other, and the transducer head on pre-set frequencies.
- **Taut Wire** is a reference used in shallower waters up to 450m. A weight is set on the seabed connected to a wire that is spooled on to a tension winch. As the vessel moves so the offset angle and distance is measured by a head mounted gimbal sensor.
- **Radius/Radascan** are microwave based signals sent from the unit on the DP vessel to a target receiver mounted on the structure it wishes to DP from. It is a relative motion based system.
- **Fan Beam/Cy-Scan** use a laser pulse that is sent from a unit fitted to the DP vessel, and rebounded by way of a reflector system mounted on the structure the vessel is alongside. Like the microwave system, this is relative motion based.

LTW & DGPS



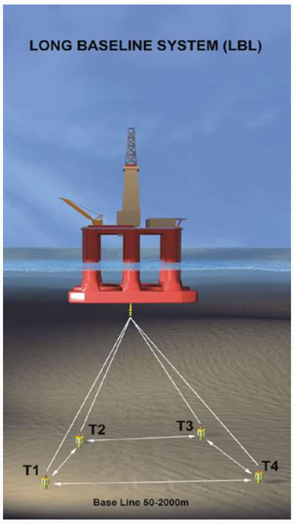


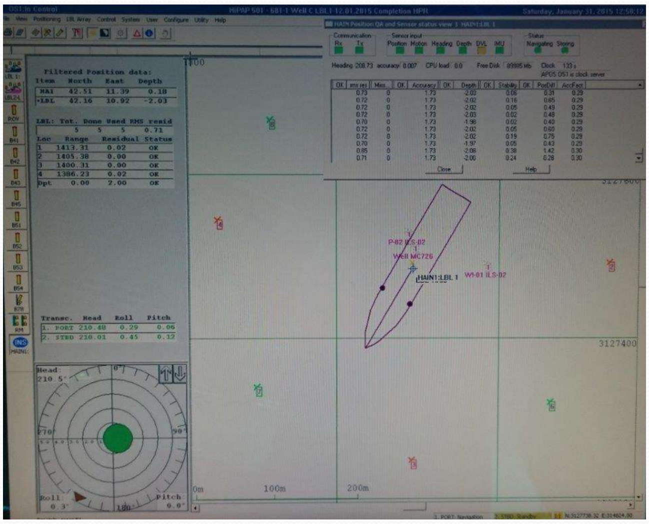
DGPS Receiver & Operator Display Screen.

Microwave PRS

Kongsberg C-Node type transponder & transducer head.

Typical seabed array and LBL screen





Taut Wire

Gimbal Sensor

Clump Weight

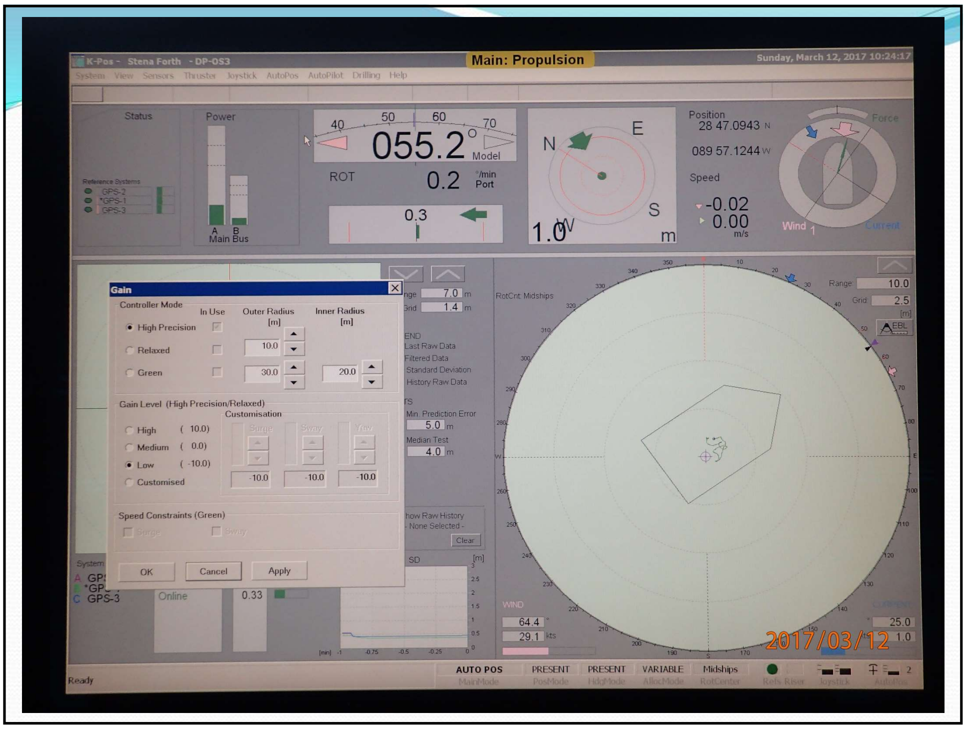
Fan Beam Unit & Reflector.

Position References Issues.

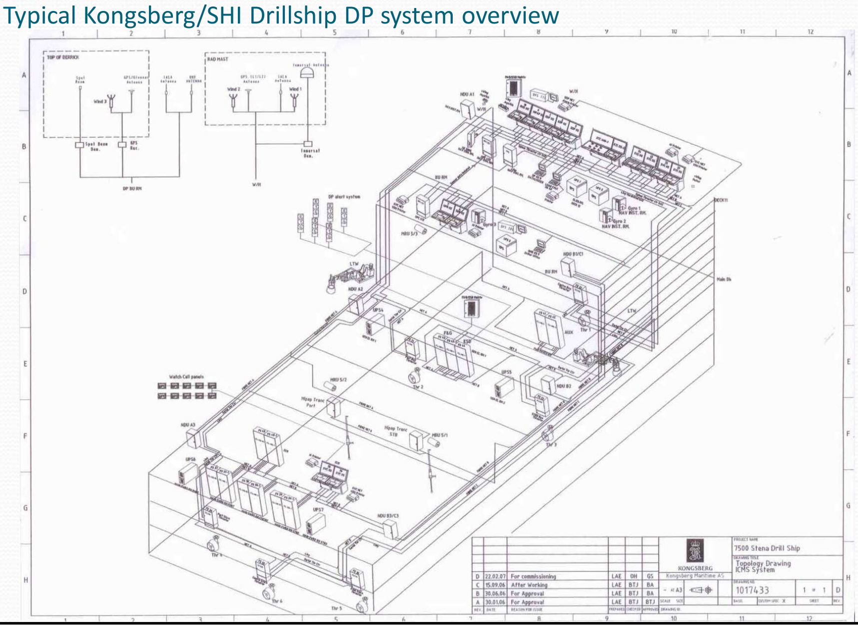
- DGPS. Masking, scintillation, solar flaring, multipath, latitude/time- lack of visible satellites, correction station issues, HDOP/VDOP (Horizontal/Vertical Dilution Of Position).
- ACCOUSTICS. Software issues, incorrect sound profile set-up, noise – thruster/propeller wash, overboard discharge, cetacean, loss of transponder.
- LINE OF SIGHT. Fanbeam lens/reflector dirt, sun, flaring, fog/heavy rain, excessive vessel movement, false target.
- POSITION DROP-OUT. Term used for loss of all references. DP will continue to position vessel based on the model built up; it is the DP equivalent of Dead Reckoning. Length of time the vessel will remain on station is dependant on the strength/quality of model.
- VOTING. DP will determine the most suitable reference to use as the main for positioning, depending on strength. For example where a vessel is sitting on 3 x independent reference systems such as 1 x DGPS, 1 x HiPAP, and 1 x Fanbeam, DP will select the most accurate and make that the lead, or preference reference – normally it would be DGPS. The DPO must remain aware that in the event he is using, for example, 2 x DGPS, and 1 x HiPAP then the DP voting will again chose DGPS, due to numbers, but if an error occurs to DGPS then DP will not reject it as it is likely that the error will occur on both DGPS receivers. In this case the Operator must recognise the issue, de-select DGPS, and leaving him with only 1 x reliable reference the vessel is out of class and must suspend DP operations.

How much power? Gain setting.

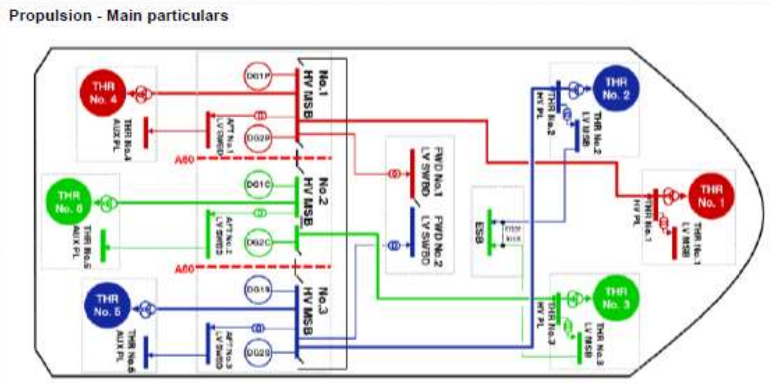
- A very important setting within the DP system is known as Gain. This can also be called sensitivity. Quite simply this can be described as the relationship, in setting terms, between vessel positioning and the resultant power used to maintain that position.
- There are 3 main settings, Low, Medium and High. Each setting will determine DP response time and power applied to a position offset.
- There is also a High Precision setting that can be applied to each of the 3 main settings; i.e. Medium Gain, with High Precision.
- We can also see a Relaxed Gain setting, and, in Kongsberg systems, a Green DP mode. Here you can set a specific radius for the vessel to move within before DP will react to correct position. Fuel saving is the big advantage here, rather than accurate positioning.
- It is essential that any DPO is fully familiar with their vessel's gain settings -v- reaction, as incorrect setting can lead to problems. If for example the DPO select High Gain, in HP mode , thinking that it will improve the position accuracy then, conditions depending, we can see hunting, surging, and ramping up effect on thrusters and engines, which will result in less accurate positioning as well as excessive fuel use. Likewise if conditions are marginal and we become too relaxed then a Low Gain setting can lead to obvious problems of positioning in that the vessel reacts too slow to a drift off situation, which can impact on the operation greatly.



Typical Kongsberg/SHI Drillship DP system overview



Vessel Power Management System.



Setting Up on DP

- Con the vessel manually to known co-ordinates.
- Stop her, settle her down, then take control in joy-stick mode.

Set Up cont'

- Once you have chosen the desired heading, with vessel nicely stabilized you start to give control to DP. There is no specific order, it depends on the environmental forces you are facing and the work-scope. You must ensure gyro, MRU, and anemometers are selected accordingly, and your position reference is steady.
- My own preference is to select *auto heading* first, so DP will now maintain heading that you have set, while you remain in control of fore/aft and athwartships movement. Next I will keep fore/aft control allowing DP to take care of any athwartship movement by selecting *auto sway*. Finally I give DP full control by selecting *auto surge*; at this time the auto position button will illuminate. One can stop and settle vessel and select *auto position* straight away i.e. going directly into DP.

First Hour

- Now that the vessel is set up on DP in your desired position, with all necessary tools assigned, the first hour is vital. This is when the watch-keeper must ensure all controllers, sensors, references, thrusters and power management systems are performing as required. During this time DP will form the station keeping *model*.
- This is basically a memory bank of data that DP will store of everything effecting the vessel, and react accordingly using the tools above. The longer the vessel remains on station and conditions remain stable then the better the model. Minimum model time required is 30 minutes. A simple sailor-type analogy for what is meant by the model is to liken it to a helmsman taking the wheel of a conventionally conned vessel; it takes him time to get the "feel of her" before he can improve the accuracy of the course required. The importance of the DP model is redundancy; in the event of some form of sensor, or reference loss (known as position drop-out) DP will maintain station from the model, giving the operator some time before the vessel will gradually drift off set-point.
- We now carry out our pre-operational trial, with assistance from the ECR. During this time we test DP proving the sensors, references, thrusters and power management through a series of heading changes fore/aft moves athwartship moves, boxes, etc. Basically assuring the bridge watch that DP is set up as desired and 100% reliable.
- Once trials are complete and system is set up as required the model continues to build increasing the system accuracy by fine tuning itself continuously. We now set our watch system of hour on/hour off the desk with a Senior DPO and Junior DPO on watch at any one time, who continually monitor DP and instruct the system to move the vessel or alter heading as operations require.

Stena Drilling

Periodical DP Checklist
DrillMax Vessels Only

CLIENT			
Date	12 MAR 2012	Time	07⁰⁰
Location	GRAND ISLE 70	Well	N/A
Northing	3187721.4	Depth	44 m.
Easting	211805.4	Heading	055°
Wind	054 / 37 kt	Current	027 / 1.2 kt

SYSTEM		Remark	HPR
Backup Status	SDP OS ☑		APOS OS_OK ☐ APOS OS_OK ☑
DP Analysis	ON ☑ OFF ☐		☐ LBL in use / LBL NO / HPR
Redundancy	A ☑ B ☑ C ☑	Master: A	☐ SSBL in use / CHAN — N/A
Time/date OK	OS ☑ OS ☑ OS ☑ APOS OS ☑		Date of last Ping cont.
Panel Light test	OS ☑ OS ☑ OS ☑ APOS OS ☑		Date of last sound profile
DP event printer	ON ☑ Off ☐		
Rotation Center	Main DC ☐ Aux DC ☐ Other MID ☑		

SENSOR		1	2	3	4	Diff
Gyro	Enabled	☑	☐	☑	☑	0.7°
	Preference	☑	☐	☐	☐	—
Wind	Enabled	☑	☑	☑		10°
	Preference	☑	☐	☐		4'
VRS	Enabled	☐	☑	☑		0.1°
	Preference	☐	☑	☐		0.1 m

TAUTWIRE	LTW 1	LTW 2
Along ships	N/A m	m
Athwart ships	m	m
Wire length	m	m
Depth		

Draught	12,00 m	Sensor ☐		Manual ☑	
Limits position	3 m	3 m		5 m	
Limits heading	3 °			5 °	
Limit VRS	Pitch 2 °	Roll 2 °		Heave 2 °	
Riser monitoring	UFJ N/A °	LFJ N/A °			

DGPS										Northings	Eastings
#1	☑	☐	☐	☐	☐	☐	☐	☐	8	3187731	211805
#2	☑	☐	☐	☐	☐	☐	☐	☐	8	3187732	211805
#3	☑	☐	☐	☐	☐	☐	☐	☐	8	3187731	211805
#4	☐	☐	☐	☐	☐	☐	☐	☐			

Reference systems in use (✓ for on-line, M for monitored)			
DGPS 1	☑	DGPS 2	☑
DGPS 3	☑	DGPS 4	☐
HPR 1	☐	HPR 2	☐
LTW 1	☐	LTW 2	☐
RPR	☐	HAIN	☐

IAS	Remark
Check all main systems (power, propulsion, cooling, ballast, bilge, fire and gas etc.) Is their status sufficient for current operation? YES ☑ NO ☐	DHT: 46 m³ TSDT: 10 m³ DDT: 23 m³

CONTROLLER			
R.O.T.	5 °/min	Speed	0,05 m/s
Controller mode	HP ☑	Relaxed ☐	Green ☐
Gain	High ☐	Medium ☐ Low ☑	Custom ☐
Joystick	Thrust: REDUCED	Precision: GENERAL	

DP BACKUP ROOM & EQUIPMENT ROOM		
Back-up DP: set up as Main DP, clear alarms	OK	☑
Switch printer on, clear alarms, load the paper	OK	☑
Are all available UPS units in normal status?	Yes	No
Are all available Gyros in normal status?	Yes	No

THRUSTER						
Allocation: Variable ☑	Manual Fix ☐ HPR Zone ☐			Force Bias: On ☐ Off ☑		
	1	2	3	4	5	6
Available	☑	☑	☑	☑	☑	☑
Enabled	☑	☑	☑	☑	☑	☑
Set point and feedback				OK ☑		

POWER MANAGEMENT SYSTEM						
Board	1		2		3	
Generators	1	2	3	4	5	6
Gen. available	☐	☐	☐	☐	☐	☐
Gen. online	☐	☐	☐	☐	☐	☐
Power available	kW		kW		kW	
Power consumed	kW		kW		kW	

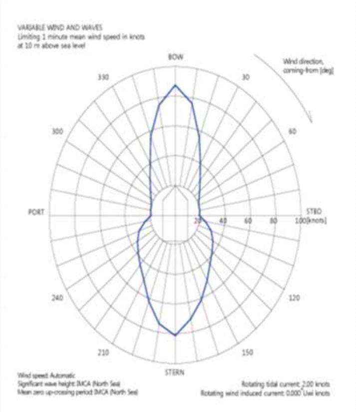
RMS readings	UFJ N/A °	LFJ N/A °	TJ Stroke N/A m
Communication with Drill Control	Intercom OK N/A	Normal Telephone OK ☑	DP Alert Lights (test daily) OK N/A

Remarks: V/L ON DP WORKING SUPPLY VESSEL TERREL TIDE STBD FWDD SPLIT FROM CENTRE AND PORT

Completed by: HENDRIK EZVELIN	Position: DPO	Signature:	
In charge of watch: HENRIK EZVELIN	Position: SDPO	Signature:	

DP Capability Plot.

- These come with the vessels DP Operator handbook. They will be set out for a range of weather and current conditions, giving a diagrammatic view of what performance the Operator can expect from the vessel in these conditions. A Far more effective and accurate tool for the DP Operator is the on-line capability plot. This is a visual display, calculated by DP with Operator input required for sea state and raw current, that provides a live indication of the vessels capabilities.

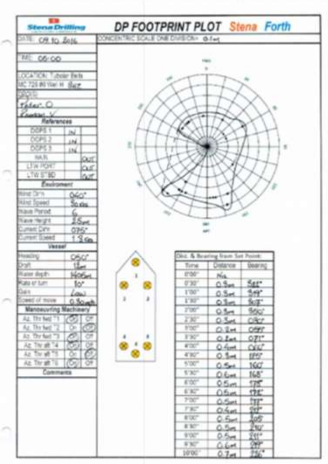


DP Drift-Off Display.

- This is another very useful diagrammatic display that is available to the DPO. This facility - which must be set-up correctly for accurate imagery - will provide the DPO the vessel’s predicted drift-off profile given an operator specified failure mode. For example, if the DPO choses total black-out mode, then the display will show the predicted position, and heading of the ship, at specific time intervals following the black-out.

DP Footprint

- These are a realistic presentation of a vessels station-keeping ability, and differ from the handbook capability plot in that they are real time data based. They are compiled by the DPO, with the purpose of building up a performance log of the vessel in given conditions for reference purposes.



DP Consequence Analysis

- With regard propulsion and power configuration, DP can provide the Operator with an online *consequence analysis*, of a worst case single-point failure. This software must be running continuously when a vessel is operating in DP Class 2 or 3. The software will re-calculate every minute using 3 criteria; power available/ in use, propulsion in use, and environmental forces acting on the ship.
- Initially the software will determine where, or what the worst case is.
- It will then simulate this failure, providing information on the potential outcome.
- If the failure is likely to cause any issue on the ability of the vessel to hold position or heading, this will be presented to the Operator in the form of an alarm "*consequence analysis drift-off alarm*"
- This will then prompt the Operator to fully assess the situation, and take effective corrective action.

DP Problems & Tests.

- Drift-Off; When the vessel loses position, due to forces acting upon her, following a failure.
- Drive-Off; When the vessel loses position due to forces acting within her.
- Software error; screen freeze, black screen of death, virus, reference systems.
- Hardware error; cable break, component failure, thruster issue, engine/switchboard black-out.
- Human error; incompetence, poor hazard perception, inadequate planning, fatigue.
- Failure Mode Effect Analysis; FMEA trials are carried out at building, or conversion, stage of the vessel then at 5 yearly interval. The purpose of this extensive testing program is to identify single point failures that could cause issues with the vessels station keeping ability. Every component of the system is tested for failure, with the results noted. Conditions at the time of tests, alarms, expected/non-expected system reactions, etc, are all used as a reference for when operating the vessel.
- Annual DP Trials; As the term states, this is an intense set of tests to determine the health of the ships DP system conducted on an annual basis. It is not to be confused with the FMEA, but is rather modelled from it.
- Pre-Operational Trial; A set of test procedures carried out on DP once vessel is set-up to ensure she is responding to the conditions. A series of steps to adjust heading and position to the operators satisfaction is carried out using all reference systems as a group and independently, using various thruster configurations. Model and position drop-out test are carried out. It also acts as a check list for the operator that he has the DP system set-up in good order. Trial will test switching to back-up DP control in the event vessel loses its main DP station. An ECR version will also be carried out.